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LIST OF ABBREVIATIONS

ABI	Ankle Brachial Pressure Index
ACR	Urinary Albumin Creatine Ratio
ALT	Alanine Aminotransferase
AST	Aspartate Aminotransferase
BMI	Body Mass Index
CA	Cluster Analysis
CAD	Coronary Artery Disease
CASP	Critical Appraisal Skill Programme
CKD	Chronic kidney disease
CMNN	Communicable Maternal, Neonatal and Nutrition
CVDs	Cardiovascular Diseases
DPs	Dietary Patterns
EFPQ	European Food Propensity Questionnaire
eGFR	estimated Glomerular Filtration Rate
FPQ	Food Propensity Questionnaire
GDP	Gross Domestic Product
GGT	γ-glutamyl Transferase
GI	Glycaemic Index
HBA1C	Glycated Haemoglobin
HDL	High density lipoprotein
HOMA	Homeostatic Model Assessment
IDF	International diabetes federation
IPAQ	International physical Questionnaire
IR	Insulin Resistance
LCD	Low-carb Diet

LDL	Low Density Lipoprotein
LMICs	Low and Middle-Income Countries
MCAR	Missing Completely at Random.
NAFLD	Non-Alcoholic Fatty Liver Diseases
NCDs	Non-Communicable Diseases
PCA	Principal Component Analysis
RODAM	Research on Obesity and Diabetes among African Migrants
RRR	Reduced Rank Regression.
SES	Socio-Economic Status
SSA	sub-Sahara Africa
T2DM	Type 2 Diabetes Mellitus.
TCFL2	Transcription Factor 7-Like 2 Gene
TG	Triglycerides
WHO	World Health Organisation

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1. INTRODUCTION

While migration has increased significantly in recent times because of increase in worldwide commercial and technological prospects as well as frequent international travel. It also offers a rare chance to research the effects of diverse lifestyle factors on long-term trends and risk factors for a variety of primarily environmental diseases, including non-communicable diseases (NCDs) such as type 2 diabetes mellitus (T2DM) (Misra and Ganda 2007). This is because the rise of NCDs particularly T2DM among migrants' groups and their compatriots have prompted several hypotheses and the most prominent is environmental influence in which lifestyle and dietary changes are embedded (Choukem et al. 2014).

T2DM, which is a major form of diabetes mellitus is often referred to as non-insulin-dependent diabetes mellitus or adult-onset diabetes. It is mostly characterized by increased blood glucose levels because of insulin resistance and relative insulin deficiency. People with this condition may not need insulin therapy to survive, at initial stages or frequently throughout the rest of their lives since there is mostly no autoimmune destruction of cells. Thus, the major influence on the development of T2DM is the synergies of genetic and environmental factors such as dietary intake which is a major contributor (Association 2010; Ginter and Simko 2013).

It is evident that the gradual shift of traditional dietary practise characterised by plant-based and fibre-rich diet to modernised or westernised diet high in saturated fats and refined carbohydrates may contribute to the development of T2DM and other diseases such as non-alcoholic fatty liver diseases (NAFLD) among transitioned populations especially in sub-Sahara Africa (SSA) (Osei et al. 2021).

NAFLD which is mostly known as a Western disease (Treviño and Katz 2018) is gradually penetrating into many regions in Africa. It is one of the major causes of chronic liver disease globally, affecting approximately 25% of the populace, and the second highest cause of hepatic cancer (Perdomo et al. 2019b; Spearman et al. 2021). Again, it is predicted to have an impact on about 42-93% of patient with metabolic syndrome (Tutunchi et al. 2021). In SSA, although the prevalence and incidence are rare, it is predicted that about 13.5% of the general population are affected (Spearman et al. 2021). However, this may be underestimated considering the prevalence of NAFLD is rising along aside with incident of metabolic syndrome and T2DM (Kalafati et al. 2019b; Tian et al. 2023).

Previous research on NAFLD has shown that consuming too much energy is a significant contributor to the progression of the condition (Kalafati et al. 2019). Other, research have discovered that people with confirmed NAFLD are two times at risk of developing T2DM (Tanase et al. 2020). The association between T2DM, insulin resistance (IR), and NAFLD are expected given that, insulin is supplied straight to the portal vein after secretion, following the same path as the absorbed glucose, and the liver clears out a significant amount of portal insulin at the first pass (Firneisz 2014). Since NAFLD and T2DM tend to coexist in subjects and may even share many risk factors, we proposed that dietary patterns (DPs), which are linked to NAFLD may be associated with T2DM.

Again, with the management of T2DM, dietary recommendation for carbohydrates is one of the controversial areas (Jung and Choi 2017). Since T2DM reflects the disturbance in the glucose-insulin metabolism, carbohydrate restriction was the first point of attack before the availability of insulin (Nielsen and Joensson 2008). The rationale behind lowering carbohydrate diet in patient with T2DM is due to the fact that blood glucose rises as a result of carbohydrate consumption, hence a low-carbohydrate diet (LCD) lowers glycaemic and insulin levels, which boost the amount of circulating fatty acids that the body can use as energy by producing ketone bodies (Khazrai et al. 2014). As a result, there is a quick reduction of weight and an increase in satiety. In fact, studies done over a short period of time mostly shows significant improvements in blood glucose even when there is no body weight loss (Dyson 2015). However, critics of this type of diet claim that cutting back on carbohydrates typically causes an increase in the percentage of saturated fatty acids in the diet, which has a bad impact on macrovascular disease (Khazrai et al. 2014). While other research has reported that long-term use of LCD may restrict the full complementary of micronutrients leading to potential vitamins and minerals deficiency (Feinman et al. 2015).

Clearly, dietary carbohydrate quality and quantity may contribute to the development of T2DM in African populations under nutritional transition, however the underlying mechanisms remain unclear.

1.1. Type 2 diabetes mellitus in sub-Saharan Africa

The rise of T2DM has posed a serious health and economic risks (Tuei et al. 2010). Globally, T2DM accounts for about 1.9% disability adjusted life years, and doubling since 1990 (Mobula et al. 2018). For the past decades, the prevalence of T2DM among adults have tremendously risen worldwide. In 1964, about 30 million people were predicted to have T2DM (Ogurtsova et al. 2017). And less than 40 years later, about 171 million individuals were projected by the world health organisation (WHO) to be living with T2DM (Wild et al. 2004). The International Diabetes Federation (IDF) found in 2021 that diabetes is one of the 21st century's fastest-growing worldwide health emergencies (**see figure 1**). The number of persons with diabetes worldwide is predicted to reach 537 million in 2021, 643 million in 2030, and 783 million in 2045 with the largest increase in Africa (134%). Additionally, it is anticipated that 541 million individuals would have reduced glucose tolerance by 2021. Over 6.7 million persons between the ages of 20 and 79 are anticipated to pass away in 2021 because of diabetes-related diseases (International Diabetes Federation 2021).

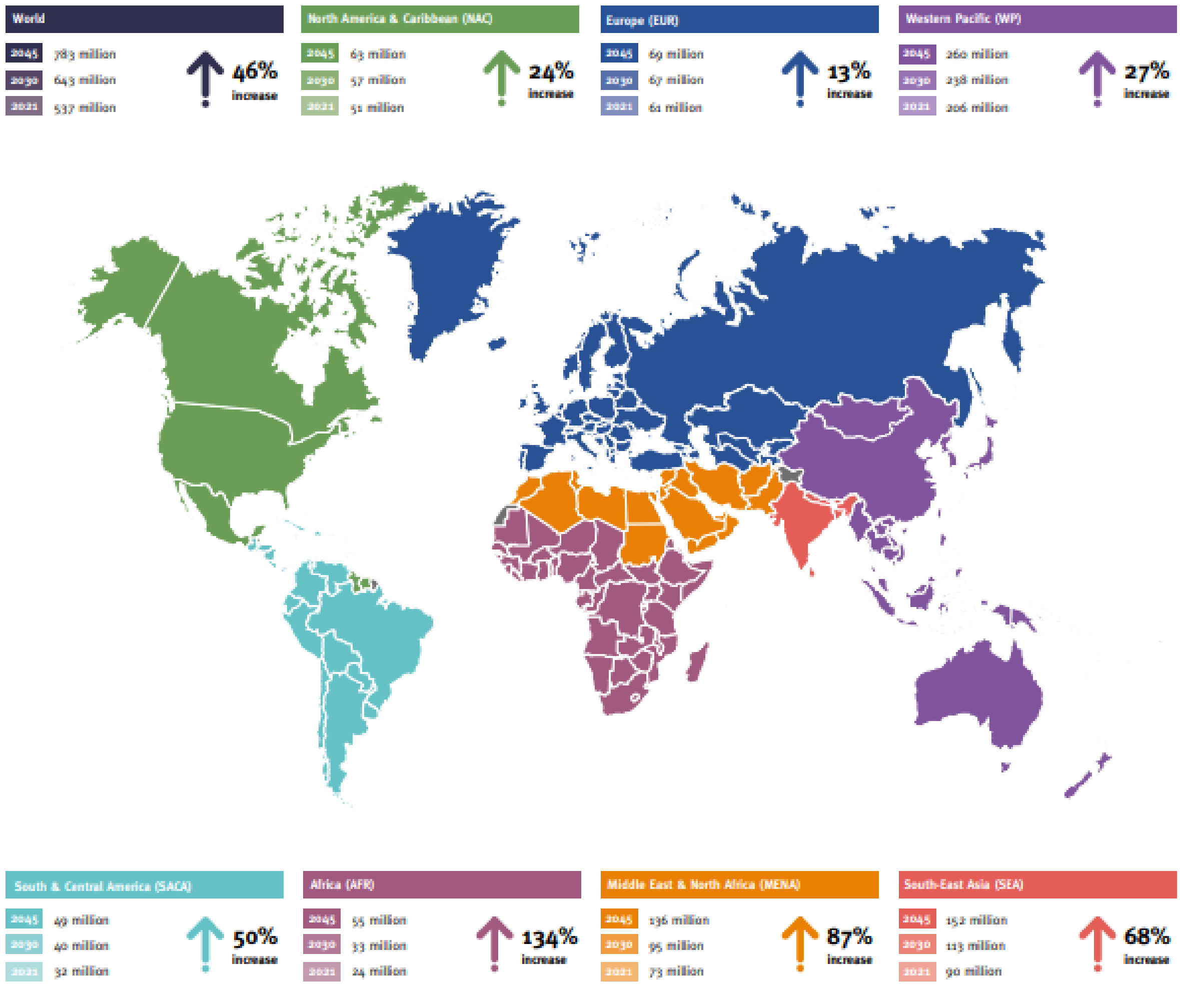

Figure 1: Estimated number of people with diabetes worldwide and per region from 2021- 2045 (29-79year). From IDF diabetes atlas 10th Edition 2021 (International Diabetes Federation 2021).

About fifty years ago, T2DM was considered a scarce disease in most of the African countries. Indeed, between the year 1960 and 1988 a prevalence of less than 1% was reported in African countries such as Lesotho, Uganda, Malawi, and Ghana (Ojuka and Goyaram 2014). Currently, T2DM remains one of the most common chronic diseases among population in Africa (Motala et al. 2022). And the prevalence of the disease and its risk factors are suggested to mirror figures in Western countries (Abubakari et al. 2011; Whittemore et al. 2004). In SSA, the prevalence rates of T2DM among the population in rural areas (0-0.5%) lower compared to those in the urban settings (1-6%) (Tuei et al. 2010). There is also major concern of about 90% of undiagnosed prevalent diabetes reported for some countries in SSA (Mbanya et al. 2014).

Presently, the impact of T2DM epidemic as a result of higher mortality and morbidity is devastating in Africa. Healthcare costs related to the disease alone are estimated to increase by 50 % between 2010 and 2030, reaching an estimation of UD$2 billion by 2030 (Audain et al. 2019a). In 2015, the total cost arising from diabetic expenditure was about 1 percent of the total gross domestic product (GDP) or US$19 (Mobula et al. 2018).

1.1.1. Type 2 diabetes in Ghana

The rise in T2DM prevalence is not different in Ghana (Doherty et al. 2014). In 1958 using urine analysis, Dodu (1958) reported a prevalence of 0.4% of people living with T2DM in Greater Accra, the capital city of Ghana. Also, another community study in Ho in 1964 reported a lower prevalence of 0.2% (Dodu and De Heer 1964). In fact, the earlier reports of prevalence for Ghana in 1990s was around 2% (Katey et al. 2022). Based on these findings, policymakers were given the notion that the disease was scarce. Subsequently, a rebirth of the knowledge on the threats of T2DM were brought by the United Nations Organization (UNO) at the national, regional and the district levels (Katey et al. 2022). Again, studies done by Amoah et al. (2002). indicated a rise of 0.4% in the prevalence of T2DM in the 1950s to 6.3% in the 2000s and this accounted for about 85–90% of diabetic cases in the Greater Accra region of Ghana The rise of T2DM in Ghana now exceeds any of its neighbouring countries in West African countries (Asante et al. 2020a).

In 2016, research done among 5659 Ghanaian adult aged 25-70 years reported that T2DM prevalence is about 10% in urban Ghana, 5% in rural Ghana and about 8-15% among Ghanaian migrant living in Europe have T2DM (Danquah et al. 2018). Again, they reported an estimate of 3.6% and 5.5% among men and women respectfully in the rural areas whereas in the urban areas, a higher prevalence of 10.3% and 9.2% was recorded for men and women respectfully.

Interestingly, similar pattern was observed for Ghanaian migrant living in the Europe (**see figure 2**) (Agyemang et al. 2016).

The trend of association with changing demographic profile i.e. rapid urbanization, cultural and social changes, sedentary lifestyle activities, obesity as well as poor diet in both rural and urban settings in Ghana has to be attributed with the increase in the prevalence of T2DM (Hushie 2019; Ojuka and Goyaram 2014; Sinclair 2019).

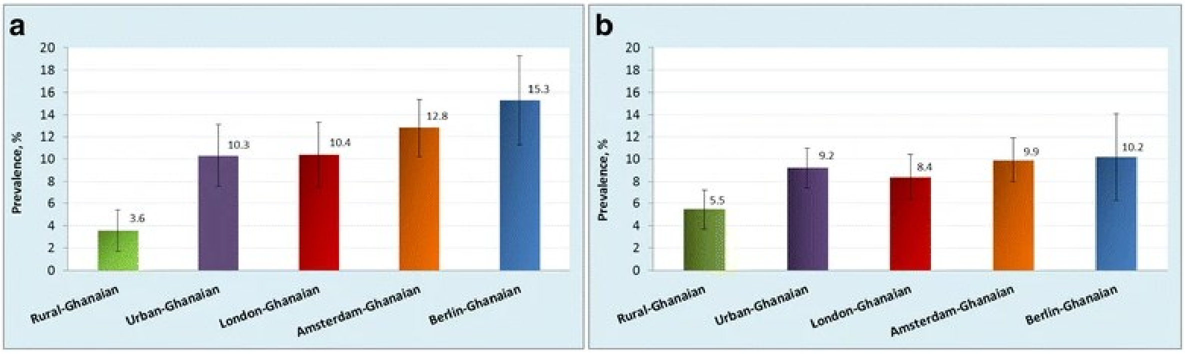

Figure 2: Prevalence of type 2 diabetes among men(a) and women(b) living in Ghana (rural and urban areas) and Europe (Amsterdam, Berlin and London) from Agyemang et al (2016).

It has long been noted that migration-related urbanization or westernization processes increase access to and consumption of calorie-dense, low-fibre meals as well as the adoption of sedentary lifestyles. As a result, there are now greater risks for morbidity and mortality from chronic diseases linked to nutrition and lifestyle (Rechel et al. 2013). This pattern has been observed in both affluent and low income nations during intra- and inter-country migration (Misra and Ganda 2007). It is therefore unexpected that migration has emerged as one of the most important factors affecting social and economic development worldwide (Abubakar et al. 2018; Carballo et al. 1998). Estimates indicates that most of global migration occurs within low-and middle-come countries (LMICs) (Abubakar et al. 2018). And while migration may be an asset to many (Holmes et al. 2021), migrants may also experience cultural and behavioural changes which may have impact on food patterns and their environment, thus leading to changes in health status (Kindarara et al. 2017). In fact, in high income countries, migrants from SSA origin tends to develop T2DM faster than in their host population with a higher prevalence compared to their host nation (Hayfron-Benjamin et al. 2019). Again, some studies have reported that people from the black race are 1.7 times likely to develop T2DM and experience disabilities from complications of T2DM than white race (Amankwah-Poku 2019). These high prevalence among migrants have been partly linked to lifestyle changes as migrants have become more affluent (Abubakar et al. 2018; Misra and Ganda 2007).

Intriguingly, the rate at which the worlds urban population is growing at 2.6% per year and this is also expected to increase to 70% of the total population by 2050 (Oyebode et al. 2015). As populations shift towards a more urban environment, increased rate of obesity and T2DM have been observed, likely as a result of the changing socioeconomic make-up of these new urban population (Gassasse et al. 2017). The ongoing rapid urbanisation is contributing to high non communicable diseases (NCDs) risk factors, such as unhealthy diet and sedentary lifestyle (Bertram et al. 2013).

For many SSA countries, the high incidence of T2DM has also been interpreted as a reflection of epidemiologic and nutritional transition occurring in the world (Audain et al. 2019). The fast growth of African economies is also bringing some environment and nutritional landscape that has embraced globalisation (Audain et al. 2019). And globalization has also been associated with the adoption of high calories such as "western diet," and decreased physical activity, all of which have detrimental effect on people's health (Tuei et al. 2010).

1.2. Complications of type 2 diabetes mellitus

Generally, individuals with T2DM are susceptible to complications driven by both modifiable and non-modifiable risk factors (Gudjinu and Sarfo 2017). In 2019, about four million adults died world wide of diabetes and its complications, and most of these death occurred among adults in the working class (younger than 60 years) (Saeedi et al. 2020). Again, it is also estimated that T2DM and its associated complications forms about 12% of health expenditure globally (Kengne et al. 2008).

In SSA, it has been reported that only 50% of people with T2DM are aware of their diagnosis and about 29% of them engage in diabetic health care, thus late diagnosis and poor treatment are leading to high mortality rate and prevalence of diabetic complications (Boateng et al. 2022; Firima et al. 2021; Hall et al. 2011). In 2013, T2DM accounted for 8.6% of total mortality in SSA. Generally, diabetic-related complications led by cardiovascular complications, contribute greatly to the high burden of the disease globally (Kengne et al. 2008). It is an empirical fact that the risk of developing cardiovascular disease (CVDs) is more than twice for those with diabetes (Aminde et al. 2016). Again, about 80% of mortality in patients with T2DM happens as a result of CVDs (Aminde et al. 2016). Data from the Diabcare Africa study indicated that hypertension is the most common T2DM complication in SSA, followed by signs of neuropathy which formed up to 48% and ocular complication which forms about 14-18% of the patient (Ekoru et al. 2019). Patients with T2DM tend to display high prevalence of hypertension which forms about 75% of most cases (Kengne et al. 2008). Furthermore, the duration of diabetes and glycaemic control are major determinants for retinopathy and it accounts for about 32% of all eye complication among patients with T2DM Africa (Tesfaye and Gill 2011). While, majority of foot ulcers (>80%) in Africa are mostly related to neuropathy and sometimes presented late with a poor outcome (Gill et al. 2009). This is mostly linked to disability and early death (Tesfaye and Gill 2011). In Ghana the prevalence of diabetic complications is rising exponentially (Afaya et al. 2020). In the urban regions, up to 58% of the people with T2DM have CVD (Abagre et al. 2022). In Kumasi, one of the urban cities in Ghana, the prevalence of macrovascular and microvascular complications of T2DM is 31.8% and 35.3% respectively (Annani-Akollor et al. 2019). Other common complications includes hypertension, retinopathy and neuropathy with a prevalence of 96.2%, 58.6% and 60.5% respectively (Afaya et al. 2020).

Patients with TDM may suffer significant long-term medical condition and psychologic impact which is usually due to poor management of prolonged hyperglycaemia which may lead to higher risk of developing both microvascular and macrovascular complications (Gudjinu and Sarfo 2017). Other risk factors may include negative attitude toward diabetes, poor treatment adherence, and a lack of illness awareness are the risk factors mostly associated with the development of T2DM complications (Bereda 2022). Examples of macrovascular complications may include coronary artery disease, cerebrovascular diseases, and peripheral artery disease, stroke, while the commonest microvascular complications may include neuropathy, retinopathy, and nephropathy (Abubakari et al. 2011; Atlas 2015; DeFronzo et al. 2015; Seid et al. 2021). Chronic hyperglycaemias compromise the metabolism of biological macromolecules such as proteins, lipids, carbohydrates, and nucleic acids as well as insulin, thus facilitating the development of major complications such as neuropathy, retinopathy, nephropathy, and cardiovascular diseases (CVDs). Other risk factors may include necrosis, inflammation or peripheral artery diseases which may contribute to macro-complications such as foot ulcers (Bereda 2022). Usually, the time for developing micro complications are faster compared to macro complication (Seid et al. 2021). Diabetes is the main cause of limb amputations, end-stage renal disease and blindness (Murea et al. 2012). Micro complications such as diabetic retinopathy is also one of the commonest causes of blindness in working class population in many countries (Thomas et al. 2019). Additionally, patients with T2DM are more vulnerable to infectious diseases such as pulmonary tuberculosis, urinary tract infections and skin and soft tissues infections (Berbudi et al. 2020).

1.3. Risk factors for type 2 diabetes mellitus and its complications

The risk of individuals developing T2DM is based on the interaction of both modifiable and non-modifiable risk factors. Another way of looking at the risk factors could be preventive, therapeutic or an interventional (Fletcher et al. 2002; Gudjinu and Sarfo 2017). Modifiable risk factors such as obesity, use of extreme alcohol, physical inactivity and diet can be changed to prevent the diseases while non-modifiable risk factors such as family history, age and ethnicity may serve as an alert for individual rate to contracting the diseases (Gudjinu and Sarfo 2017). T2DM in sub-Saharan Africa present multiple risk factors which may include report family history, ethnicity, poor diet, physical inactivity, obesity, age, urbanisation, social inequalities, cigarette smoking, alcohol intake etc. (Mbanya et al. 2014; Pastakia et al. 2017).

1.3.1. Non-modifiable risk factors

Non-modifiable risk factor such as genetic susceptibility have been regarded as and common important risk factor for T2DM (Murea et al. 2012). It is an established fact that T2DM is an inherited condition and this hypothesis has been supported by the high rate of T2DM in ethnic and racial populations (Fletcher et al. 2002). In fact, some studies have reported that the risk of developing T2DM among Asian, Blacks or Hispanic is significantly higher than those who identify themselves as White (Ardisson Korat et al. 2014). Also, chances of an offspring having diabetes when one of the parents is diabetic is about 40% and this even increases to 70% when both parents has the same conditions (Murea et al. 2012). However, some studies have shown that environmental factors have the probability of modulating phenotypic expression (Murea et al. 2012). Research done by the African American Diabetes Mellitus study found that a variants of the transcription factor 7-like 2 gene (*TCF7L2*) found in people in Europe has been replicated in West African population (Murea et al. 2012). This could be attributed to the fact that genetic effects are equal across the spectrum of environmental exposure**.**

Hence, the interaction between genes and environmental factors such as unhealthy diet, and physical activities may lead to obesity and insulin resistance and eventually T2DM. There is an ongoing effort to understand the interaction of gene and diet (Nutrigenetic and nutrigenomics). Nutrigenetic and nutrigenomics methods identify and discover the optimal diet for individuals by throwing light on how the genetic makeup of an individual coordinates response to diet (Dedoussis et al. 2007). Nutrient gene interaction can be regulated via the expression of genes through different mechanism (Ortega et al. 2017). For example, dietary polyphenols and phenolic compounds have been reported to modulate the expression of genes involved in insulin secretion because of their antioxidant properties to lessen the negative effects of oxidative stress in T2DM (Kang et al. 2019). A study that sought to examine genetic predisposition using a genetic risk score and dietary pattern in relation to diabetes risks, reported that westernised DPs is associated with high risk of T2DM among participants with high genetic risk score compared to those with low genetic risk scores. This observation was attributed to red meat, process meat, and their major components which may be the main food influencing how westernised DPs and genetic diversity combine to determine diabetes (Qi et al. 2009). Also, some studies have reported significant effect of the quality and quantity of carbohydrate on the association between TCF7L2 variants and risk of T2DM (Ardisson Korat et al. 2014).

Another important non-modifiable risk factor is age. T2DM is significantly more common as people age and until recently, it was known as a diseases for the adult (Steyn et al. 2004). Beyond the age of 30, muscle mass loss is anticipated to progress at a rate of 3-8% each decade, which occurs just before the rapid rise in the incidence of T2DM (Beaudry and Devries 2019). Although the mechanism surrounding the muscle loss is unclear in T2DM, changes in the skeletal muscle protein turn over can play an important role in the aetiology of the disease (Yakaryılmaz and Öztürk 2017). In recent decades, the age of onset has decreased, especially in nations where there is a significant disparity between energy consumption and expenditure. This is especially true for younger individuals and even teenagers (Alberti et al. 2007).

1.3.2. Modifiable risk factors

Obesity

Increase in the prevalence of obesity in SSA has been attributed to sedentary lifestyle, easy access to inexpensive processed foods and high fat and energy dense foods.

Indeed, some cross-sectional studies have also established a positive associations between high dietary fatty intake and body fatness (Astrup 2001). In Ghana, obesity rate has been increasing especially among women (Asamoah-Boaheng et al. 2019). This observation is mostly similar in many African countries where central obesity and physical inactivity are more prevalent in women compared to men (Asamoah-Boaheng et al. 2019; Goedecke et al. 2017). For instance obesity is about 10% among men and 36% among women who live in the urban area in most African countries (Goedecke et al. 2017). The differences could be attributed to gender related lifestyle. Also, social preference may partially account for the increasing rate of overweight and obesity especially among the Ghanaian population (Asamoah-Boaheng et al. 2019). This is because being overweight or obese is usually viewed as a sign of wealth, success, well-being, fertility, beauty and happiness rather than a health concern (Asante et al. 2020; Goedecke et al. 2017; Mbanya et al. 2014). Also, the burden of HIV/AIDs epidemic have led to many people having preference towards overweight or obesity to prevent being labelled as "thin" which is regarded as unhealthy and suggested as being HIV/AIDs positive patient, hence preventing stigmatization (Goedecke et al. 2017; Tuei et al. 2010). It is therefore not unexpected to see women put effort in gaining weight to look beautiful and prosperous. This may possibly account for the higher overnutrition among females (Amoah 2003).

Among Ghanaian populations, women show a higher prevalence of obesity than men, while males appear to be at a higher risk of getting T2DM than do females with equal BMIs (Agyemang et al. 2018). Some of these disparities may be explained by the fact that although BMI is a measure of general obesity, visceral adiposity also known as central obesity, is a stronger predictor of T2DM than BMI. According to a growing body of evidence, central obesity rather than BMI is a more important predictor of hyperinsulinemia, insulin resistance, metabolic abnormalities, and glucose intolerance. Given that men are more likely than women to have abdominal adiposity (central fat mass), also known as android adiposity rather than peripheral subcutaneous adipose tissues, they stand a higher risk for T2DM (Nordström et al. 2016). Also, gluteo-femoral fat distribution among African women has shown to be health beneficial as compared to abdominal or central fat accumulation (Nono Nankam et al. 2020). The development of T2DM is greatly impacted by rising obesity prevalence. Although, obesity emanates from the interactions of genetic and environmental factors, its root cause is an excess intake of calories over expenditure (Bäckhed et al. 2007). In terms of predicting obesity, epidemiological studies have demonstrated that excessive body weight, especially abdominal fat deposition is an important risk factor for T2DM (Schröder 2007). In comparison to body BMI, waist circumference or the waist-to-hip ratio, which reflect visceral (abdominal) fat, may be more accurate predictors of the risk of developing T2DM. These findings demonstrate that the distribution of fat, rather than just the total amount, is crucial (Alberti et al. 2007). Therefore, although obesity is defined as a BMI of ≥ 30 kg/m^2 , anthropometric parameters such as waist circumference and waist-to-hip ratio are very important to use (Tuei et al. 2010).

Primarily, the consumption of excessive fat and carbohydrate increases calories and postprandial oxidative stress. This may also lead to accumulation of body fat, which is associated with the progression of insulin resistance, one of the fundamental abnormalities involved in the pathogenies of T2DM (Pastakia et al. 2017; Schröder 2007; Tuei et al. 2010). Furthermore, the secretion of adipokines from the adipose tissues adversely affect the insulin-signalling cascade (Schröder 2007).

When lipids build up in non-adipose tissues as a result of over nutrition, fatty acids lead to the production of ceramide. And lipoapoptosis is most likely brought on by ceramide, a poisonous lipid. Alternatively, it has been proposed that elevated amounts of post-prandial and post-absorptive blood glucose (glucotoxicity) harm the pancreatic beta-cell (Joost 2008). Thus, obesity that persists interferes with metabolic functions that regulate lipids, blood pressure, and blood sugar (Tuei et al. 2010).

Lifestyle factors

One of the major independent risks factor for T2DM lifestyle are changes (Tuei et al. 2010). Many populations' levels of physical activity have dropped over the past few decades, which has greatly contributed to the current global rise in obesity and T2DM (Alberti et al. 2007). Previously, physical activities were high among African population due to traditional farming and long hours of walks to various occupation. However, there is a shift from energy-intense agriculture chores and walking to motorised vehicles, indoors entertainments, manufacturing and indoor services (Goedecke et al. 2017; Tuei et al. 2010). Also, global transportation is both cheaper and significantly faster and has facilitated easy links between people residing in different places (Davies et al. 2011). With regards to primary prevention of T2DM, physical activities have been found to reduce the cumulative incidence of T2M and has proven a long-lasting beneficial effect (Ojuka and Goyaram 2014). According to some surveys, the incidence of T2DM is 8 times lower in individuals who actively engage in lifestyle intervention such as physical activities (Ojuka and Goyaram 2014). Physical activity's protective mechanism and insulin seem to work in concert to safeguard the body. This is seen in skeletal muscular contraction during a single sustained physical exercise session where there is increase glucose uptake into the cells. This impact promotes glucose transfer into the muscle cell and increases blood flow within the muscle (Sami et al. 2017). Again, it has been discovered that exercise also lowers intra-abdominal fat, a known risk factor for insulin resistance.

With regards to alcohol consumption, moderate or low intake has been linked to increased sensitivity to insulin and improved insulin sensitivity and HOMA-IR (Neuenschwander et al. 2019). In fact, evidence from a meta-analysis study on the risk of T2DM and consumption of alcohol, reported a protective effect with moderate intake of alcohol among women (Baliunas et al. 2009). This protective mechanism may be supported by the findings that moderate alcohol counteracts the effect of obesity induced insulin resistance. However, high, or acute intake of alcohol has been associated with detrimental health such as liver cirrhosis which is a major influence of T2DM. Also, concomitant use of alcohol with anti-diabetic drug has been associated with hypoglycaemia (Pietraszek et al. 2010). Thus, many studies have described the association between alcohol and the incidence of T2DM as U- shape since high intake increases the diseases compared to moderate or light consumption of alcohol (Baliunas et al. 2009; Neuenschwander et al. 2019; Pietraszek et al. 2010; Wei et al. 2000).

Smoking has various effects on T2DM (Chang 2012). Although the exact mechanism of smoking and glucose homeostasis have not been fully understood, some studies have reported that smoking accelerate inflammation and oxidative stress, thus directly damaging β-cells function and thereby interfering with glucose uptake and glucose regulation (Chang 2012; Yuan and Larsson 2019). Also, further accumulating evidence have reported that chronic smoking may have a direct harmful effect on fat distribution, which is linked to insulin resistance and contribute to the development of T2DM (Wannamethee et al. 2001; Xie et al. 2009). In fact, it has been demonstrated in a sizable cohort that smoking is linked to higher HbA1c levels (Joost 2008). Despite a slight gain in weight, quitting smoking improves the lipoprotein profile and increases insulin sensitivity (Wannamethee et al. 2001).

Nutrition and composition of the diet

Diet plays a major role in T2DM, as unhealthy dietary habits can contribute to disease progression or pathogenesis (Zhang et al. 2018). The amount and quality of dietary energy intake may influence glucose tolerance and insulin sensitivity (Steyn et al. 2004). Over four decades ago, fried and fatty foods were not as popular or common as seen currently in most African countries. In fact, in Ghana, soft drinks were usually consumed during Christmas or festive seasons. However, nutrition transition is coupled with urbanization and rapid economic development. Nutritional transition characterised by a change in the prevalence of chronic diseases from undernutrition- to overnutrition-related (Amoah 2003; Ofori-Asenso et al. 2016). People are eating fried and fatty foods, soft drinks and more sauces than they did many decades ago (Amoah 2003). Moreover, energy condensed foods do not only promote weight gain and obesity but also contain glycated chemicals that augment insulin resistance (Sami et al. 2017).

Fat: quantity and quality

The quantity and nature of dietary fat can alter insulin sensitivity and glucose tolerance (Steyn et al. 2004). A high fat diet may worsen glucose tolerance through a number of processes, such as (i) decreasing insulin binding to its receptors, (ii) impair glucose transport, (iii) decrease amount of glycogen synthase, and (iv) promotes the accumulation of stored triglycerides in skeletal muscle (Steyn et al. 2004). Also, fatty acid contents of the food, in turn, influences tissue phospholipid composition, which may be related to insulin action. Most cohort studies that examined the effects of various triglycerides (saturated, unsaturated, and trans fatty acids in triglycerides) revealed increase in the risk of diabetes in people who consume more saturated and trans fats, and a corresponding decrease in those who consume more polyunsaturated fats (Joost 2008).

Carbohydrates: quantity and quality

There is contradictory data about total carbohydrate and T2DM however, other studies argued that any diet that encourages a decrease in postprandial glycemia and insulinemia will lower the risk of T2DM (Harrington and Phillips 2014). For carbohydrate quality, the best indicator is the glycaemic index which grades carbohydrate rich foods according to the effect on post prandial glycaemic response (Mattei et al. 2015). Consuming carbohydrate high in fibre and low in glycaemic index, which result in smaller post-prandial blood glucose excursions, is associated to a lower risk of developing T2DM (Joost 2008). While persistent consumption of refined or low glycaemic carbohydrate may stimulate prolong insulin secretion which can spike up age-related declination in insulin production and lead to premature development T2DM (Baliunas et al. 2009; Franz et al. 2010; Steyn et al. 2004).

Undernutrition

Some studies have also reported that intrauterine growth retardation and chronic undernutrition (stunting) predisposes an individual to T2DM. Thus, a person may be more susceptible to T2DM if they are obese as adults and have stunted growth as children (Tuei et al. 2010). This kind of risk is mostly seen among SSA populations in the rural areas where childhood undernutrition may be prevalent (Tuei et al. 2010). Also, it is predicted that there is going to be a shift towards earlier onset of T2DM among SSA populations, given the trend for early age consumption of sugar sweetened beverages (SSBs). For instance, children are weaned of breast milk with SSBs such as fruit juice and chocolate drinks (Audain et al. 2019). Furthermore, the younger generations have higher preference for processed, seasoned and highly sweetened foods compared to home-made or whole foods (Doherty et al. 2014). This may explain why the younger generations are also developing T2DM (Doherty et al. 2014).

1.4. Dietary patterns in the study of type 2 diabetes mellitus

It is widely acknowledged that healthy nutrition plays a fundamental role in the prevention and treatment of T2DM. Clinical trials and observational studies have shown evidence that certain foods and drinks, such as a high consumption of whole grains, nuts, and coffee, a moderate intake of alcoholic beverages, and a low intake of processed and unprocessed red meats and sugar-sweetened beverages, may reduce the risk of developing T2DM (Jannasch et al. 2017). People, however, consume a variety of foods rather than just one food type at a time and other micronutrients, food additives and even the physical properties of foods and nutrients interaction may contribute in glucose metabolism (van Dam et al. 2002). For instance, folate from beer may not be as healthy as the same quantity of folate from bread due to alcohol's effects on folate metabolism, urinary folate loss, and reduced intestinal folate uptake (Kant

2004). Mostly, food combinations reflect personal dietary choices that have been shaped by a wide range of economic, cultural, social, environmental, health, and lifestyle factors. Typically, eating more of some food items results in eating less of others and adjustments in one dietary component are typically accompanied by compensatory adjustments in other dietary components (Kant 2004). Therefore, the overall examination of effects of food consumption is important.

Studying Dietary patterns (DPs) has become a complementary approach to solving this problem (Jannasch et al. 2017). DP analysis is a useful method for dissecting the complexity of food intake and how it relates to health (Zhang et al. 2018). Furthermore, DPs mirrors or characterises dietary behaviour in real-life situations in which food or nutrients are eaten together (Schulz et al. 2021). Due to their capacity to account for the complexity of dietary intakes when frequently evaluated in relation to disease risks, they help to produce evidence for disease prevention (Schulz et al. 2021). Also, they make it possible to adopt a healthy diet in a variety of ways. Therefore, when described by the composite measure of diet quality included in dietary patterns, public health guidelines and recommendations may be most easily translated into eating behaviours (Cespedes and Hu 2015).

Traditionally, nutritional research focused on a single nutrients or a certain food and their relation to health (Cespedes and Hu 2015). Although, this traditional approach was quite important, it had many conceptual and methodological limitations. This is because people do not consume food in isolation instead they eat meals consisting of different food items and nutrient which are likely to interact or even build synergistic effect (Panagiotakos 2008). Again, it has also been proven to be incredibly challenging to distinguish the effects of different nutrients in observational dietary research due to multicollinearity between nutrients (Panagiotakos 2008). For example, the intercorrelation between specific nutrients like potassium and magnesium, makes it challenging to analyse their individual impacts because of their degree of independent fluctuation which is significantly diminished when they are included in a model at the same time (Hu 2002). Also, the effect of single nutrient in a diet is too small compared to a cumulative effects of multiple nutrients (Fahey et al. 2007).

There are three main approaches to dietary patterns (DPs) analysis. These may include exploratory methods, hypothesis-driven methods, and methods that combine the two (reduced rank regression method) (Schulz et al. 2021).

1.4.1. Dietary pattern methods

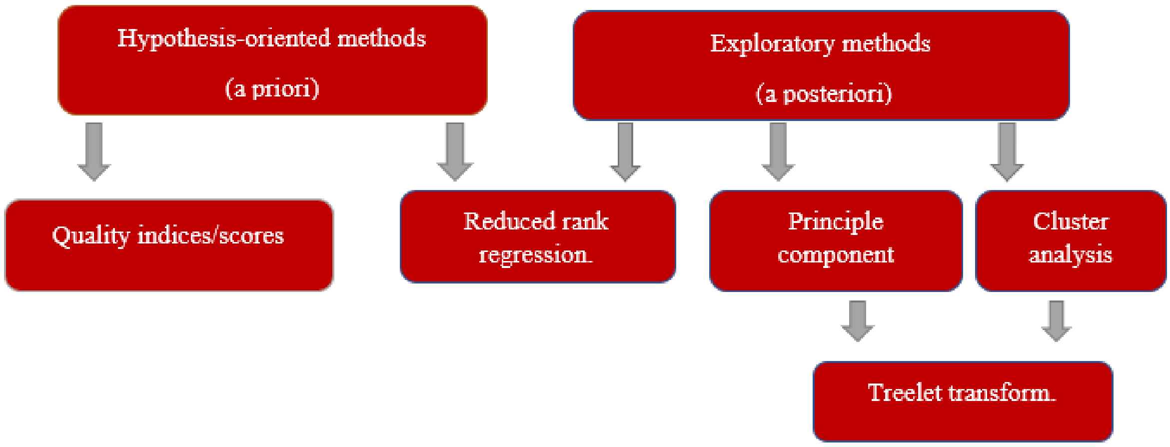

Figure 3: Methods for deriving dietary patterns.

(modified from Matthias B. Schulze and Kurt Hoffmann (2006).

Exploratory approaches

The exploratory approach is also known as the a-posterior analysis or data driven method. The approach create patterns based on correlation among food groups by compressing food data into a few underlying factors (principal component) and retaining as much of the food groups that contributes most to the variance (Panagiotakos 2008; Schulze and Hu 2002). Again, this is based on eating behaviour rather than on recognized dietary effects on health. The detected dietary trends are thus not always pertinent for illness risk (van Dam 2005). Results can, however, deepen understanding of potential dietary modifications and provide guidance for prioritizing dietary patterns in a population through public health programs (van Dam 2005). It is therefore very functional in the characterisation of population specific dietary patterns thus may have public health relevance (Batis et al. 2016). It has also shown good reproducibility across studies (Huybrechts et al. 2017).

Principal components analysis (PCA) is the most popularly used exploratory strategy for determining dietary patterns (van Dam 2005). According to Panagiotakos (2008), PCA is described as an orthogonal linear transformation of data in which the first principal component has the greatest variance when projected, the second largest variance when projected onto the second principal component, and so on. PCA is used to analyze dietary data with the goal of reducing the number of observed variables (such as food groups) into a smaller number of principle components (such as dietary patterns) that account for the most variation in predictors (such as food consumption) (Panagiotakos 2008). With dietary data, PCA aims to decrease the number of observed variables (i.e., food groups) into smaller number of principal components (i.e., dietary patterns) which explain maximal predictor variation (food intake) (Jannasch et al. 2017). Another multivariate techniques may include cluster analysis, and factor analysis (Panagiotakos 2008). Factor analysis mostly focuses on the underlying dependencies of explanatory variables (Liese et al. 2009; Schulze and Hu 2002). While cluster analysis (CA) is the method of choice when people need to be grouped into a certain dietary pattern. The cluster analysis do not aggregate observed food item but rather group individuals with homogeneous diet into distinct subgroups (Schulze and Hu 2002). CA groups people into clusters that are as far apart as possible (Wirfält et al. 2013). Again, CA can handle a high number of input variables effectively and has frequently been utilized in nutritional epidemiology investigations. New clusters are exclusive of one another (Wirfält et al. 2013).

A-priori analysis

The hypothesis-driven approach is also known as the a-priori analysis. It is possible to utilize a hypothesis-oriented method that creates dietary pattern scores using established criteria (van Dam 2005). Dietary indices or scores were the first techniques in epidemiology to evaluate how combination of foods or nutrients based on predetermined criteria was related to health outcome (Wirfält et al. 2013). The scores or indices of dietary quality are based on the existing knowledge about the relationship between foods, nutrient and diseases, which predict health status (Zhang et al. 2018). It quantitatively measures the quality of dietary habits that has already been recommended as healthy (Panagiotakos 2008). To fulfil a large portion of the dietary guidelines, a collection of components is identified. Individuals are graded on each component based on consumption level, and a summary score is produced for each person so that high scores represent dietary intakes that are in line with the advised diet (Wirfält et al. 2013). Suggestions are precisely done according to nutritional recommendations or food consumption models such as the Healthy Eating Index based on the USDA's food guidance system, the Dietary Approaches to Stop Hypertension diet, the Mediterranean diet score and the alternative Healthy Eating Index based on nutrients and foods predictive of chronic disease risk (Hu 2002; Jannasch et al. 2017). Choosing the distinct components of an a priori score, as well as the cut-off points and weights for each, may sometimes lie in subjective judgments (van Dam 2005). The main aim of many diet scores or indexes is to holistically assess the level of adherence to a specific dietary pattern or dietary guidelines recommendation. These diet scores are subsequently tested against a health outcome or investigate if the adherence of certain dietary guidelines are associated with reduced disease risk (Panagiotakos 2008). An advantage of dietary score is the simplicity to comprehend and the ability to be repeated or compared across different population (Zhao et al. 2021). However, this method lacks the benefits associated with examining past food patterns or discovering new dietary trends that might influence illness risk. To verify the accuracy of dietary recommendations, the technique can be utilized to capture the higher effects of the diet as a whole compared to the effects of its individual components (van Dam 2005). Again, the a-priori analysis may be limited to the current scientific findings regarding nutrition, health and disease (Kastorini et al. 2013). Finally, the capacity to compare relationships between various dietary indices is constrained by variations in modelling methodologies and scoring systems (e.g., median population intakes vs. predefined cut-offs) (Cespedes et al. 2016).

Hybrid methods (Reduced Rank Regression Analysis)

Comparable to the traditional principal component analysis but more flexible and potent, Hoffmann and colleagues have developed a new novel statistical technique called reduced rank regression (RRR) (Hoffmann et al. 2004). The RRR method has been designed to identify dietary habits associated with the risk of developing diseases (Joost 2008; van Dam 2005). It combines the strength of both a-posterior and a-priori analysis (Weikert and Schulze 2016). RRR focuses on identifying linear functions of food groups that explain as much variation in a set of intermediate response variables as feasible in order to achieve its primary goal of explaining the maximum amount of variance in predictor (food) variables (Weikert and Schulze 2016). Once more, the amount of response variables for the RRR approach restricts the number of dietary patterns that can be found. However, arbitrary choices like the selection of the initial food intake variables must still be made, and sensitivity analyses must be carried out (van Dam 2005). The use of dietary biomarkers that are important for the disease of interest as response variables is an alternate strategy that may be of interest (**see figure 4**). By using this application, one might avoid measurement errors associated with food composition data or a lack of knowledge on the bioavailability of various food combinations. Food combinations that best explain variance in biomarkers of dietary intake (van Dam 2005). Thus, the hybrid method best explains the relationship between diet and health through intermediate factors (Panagiotakos 2008). The RRR approach can shed light on the pathophysiological mechanism that connects dietary habits to disease, making it a helpful tool in nutritional epidemiology. It allows the comparison of findings from several study populations if the same set of response variables is used (van Dam 2005).

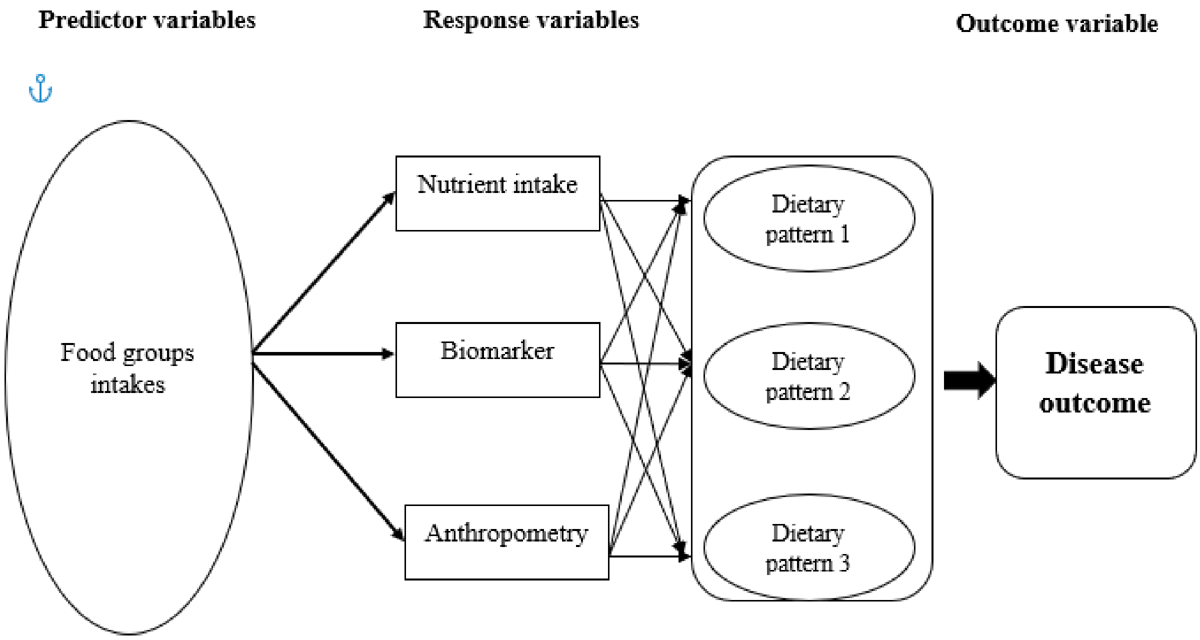

Figure 4:A model describing methods for deriving dietary patterns with reduced rank regression (modified from Zhao et al., 2021).

1.5. Study aims and objectives

The overall aim of this thesis was to gain insight into the relationships of dietary behaviour with T2DM among African populations under transition. The specific objectives were:

1. To synthesise population-based evidence on health exposure–outcome relationships among migrant groups in Germany.

2. To identify dietary patterns related with biomarkers of NAFLD and to evaluate the associations of these dietary patterns with T2DM among adults from Ghana.

3. To determine the associations of low-carb diets with glycaemic control and diabetic complications among adults from Ghana.

2. MATERIALS AND METHODS

The study employed two stages. The first stage was a thorough literature evaluation of published data from population-based studies that focused on the associations of modifiable and non-modifiable risk factors with health outcomes among immigrant groups in Germany. The recommended reporting for systematic reviews and meta-analyses (PRISMA) guidelines were followed for conducting a systematic literature review (Moher et al. 2009). Also, the protocol was registered under the International Prospective Register of Systematic Reviews (PROSPERO reference number: CRD42018085074).

The second part used quantitative analysis to find the associations between DPs and T2DM. To answer this question, RRR technique was applied to create sex-specific DPs associated with the proxy markers of NAFLD. Then, logistic regression was further used to ascertain the relationships between DPs associated NAFLD via RRR and T2DM.

In the third study, an LCD score was created and the associations of LCD with glycaemic control and diabetic complications in Ghanaian adults was assessed. It also determined the relationships between consumption of macronutrients and glycated haemoglobin (HbA1c) in the study participants with and without T2DM.

2.1. A systematic literature review and narrative synthesis

2.1.1. Inclusion and exclusion criteria

All peer-reviewed journals that have conducted studies on the aetiology of migrants' health in Germany were searched. Studies that reported the association between risk factors and health outcomes as determined by the WHO International Classification of Diseases, whether they were observational or experimental were included. Also, to provide adequate statistical power for risk factor-disease relationships in heterogeneous research and to prevent selection bias within the individual studies, studies with less than 100 participants were omitted. Review articles, research done outside of Germany, prevalence studies, and studies lacking an exposure-outcome analysis were also disregarded. We did not impose any limitations on the study participants' age range, gender distribution, or geographic location within Germany. Articles that were fully accessible and published in either German or English qualified. In **table 1,** the particular eligibility requirements are displayed in accordance with the population, intervention, comparator, outcome, and study design (PICOS) approach (Moher et al. 2009).

Table 1: Eligibility criteria according to the PICOS approach

Adopted from my published paper (Osei et al. 2022)

PICOS items	Inclusion criteria	Exclusion criteria
Population	• Migrants, asylum seekers, refugees, foreigners or guest workers; irrespective of the migration generation • Largest migrant groups in Germany (Microcensus 2018)	• Non-migrants • Migrants in other countries • Study population <100 participants
Intervention/Exposure	• Demographic factors • Environmental factors • Behavioral factors (including diet, physical activity, smoking) • Psychosocial factors • Socioeconomic factors • Biomedical, clinical and genetic factors	• Migration status as exposure
Comparator	• Non-exposed group in observational studies • Placebo or control group in intervention studies	• Comparison between migrants and non-migrants
Outcome	• infectious diseases • obstetric/gynecologic conditions • cardiovascular diseases, cancers • psychiatric disorders/mental diseases • health behaviors	
Study design	• Observational and intervention studies • Measure of association reported	• Qualitative studies • Non-empirical studies

2.1.2. Literature search and selection

A primary search was done in November 2019 and later updated on November 2020 in LIVIVO (an interdisciplinary search engine for the life sciences) and PubMed. Also, papers from featured articles' reference lists were added to the studies. Authors were also contacted for articles that were not available in full text.

Along with MeSH phrases that were pertinent to the search topic, keywords were connected in the search box using Boolean operators (AND, OR NOT) (**supplemental table1**). Articles included in the studies were imported into Endnote (V.X9.3.3, Clarivate Analytics, US), a reference management program. The process of selecting studies moved on in three stages: paper identification, title and abstract screening, and full-text screening, all in accordance with the predetermined eligibility criteria. The tittles of articles were vetted and chosen for inclusion by four authors. The titles' abstracts that had the potential to be included were then examined by two authors. For publications whose abstract were insufficient enough to either include or reject, the full manuscript was assessed. Conflicts between the writers were settled by consensus or by talking to a fifth author (OR).

2.1.3. Quality appraisal

The Critical Appraisal Skills Programme (CASP) checklists were used to evaluate the overall quality of the studies that were considered. These checklists include inquiries regarding the logical significance of epidemiological studies in three major areas: validity, scope and accuracy, and regional application of the findings ((CASP) 2018a; (CASP) 2018b; (CASP) 2018c). As a result, each study's evaluation of information bias and selection bias is guided by the checklists. For cross-sectional studies, CASP checklist for case-control studies was used ((CASP) 2018a). The rest of the publications were evaluated using the CASP checklists for randomised controlled trials (RCTs) ((CASP) 2018b) or cohort studies ((CASP) 2018c). We implemented the traffic light grading system: green means low bias risk, red denotes severe bias risk, and orange denotes uncertain bias risk. None of the articles were disqualified due to their quality. We were unable to generate Funnel plots or perform Egger's tests to identify publication bias because of the anticipated heterogeneous outcomes and effect measurements.

As an alternative, we looked for any patterns of larger studies predominating by plotting the log-transformed sample size of each study against the year it was published.

2.1.4 Data extraction and synthesis of findings

The health outcomes that were evaluated in the individual research were categorize under three classes namely, class I—communicable, maternal, perinatal, and nutritional disorders; class II—non-communicable diseases; and class III—injuries. Another category included health practices including smoking, going to the doctor, and sleeping. Exposures were grouped logically according to themes. In the case of migration-related characteristics, length of residence, migrant generation, German language ability, and legal residency status whereas socioeconomic factors consisted of educational attainment, employment status, and measures of wealth and income. Demographic factors also considered age and sex.

Associations were primarily grouped under (+) positive correlation when higher exposure to the risk factor was linked with higher odds, risk, or prevalence of the outcome; (−) negative correlation when higher exposure to the risk factor was associated with low odds; and (0) null findings where there was no correlation found between the risk factor's increased exposure and changes in the odds, risk, or prevalence of the outcome. A heat map was created for the observed relationships between common risk variables and major disease categories, showing positive relationships in red, null relationships in white, and negative relationships in blue.

2.2. The Research on Obesity and Diabetes among African Migrants (RODAM) Study

2.2.1 Study population and study design

Figure 5: RODAM study map showing 5 sites for data collection: London Amsterdam, Berlin, rural and urban Ghana.

Source: https://www.rod-am.eu/baseline/scientific-methodology/

The second and third objectives analysed data from the Research on Obesity and Diabetes among African Migrants (RODAM), a cross-sectional multicentre study, to respond to objectives on DPs and T2DM. The RODAM project aims to understand the causes of the widespread presence of obesity and T2DM among migrants African investigating the intricate relationships that exist between environmental exposures, genetics, and the high incidence of certain illnesses; and identifying specific risk factors within these general categories to help inform intervention programs.

The study covered Ghanaians aged 25 to 70 who lived in urban and rural Ghana as well as in Amsterdam, Berlin, and London during the years of 2012 and 2015. A well-standardized method of data collecting was employed at all study locations as a key component of the RODAM project. Since, previous research in European communities of African descent, demonstrated that local authorities' participation enhances study participation, community leaders from Ghana were involved in all five geographical sites of the project.

In Ghana, the urban and rural recruitment locations were two specifically designated cities and 15 villages in the Ashanti region. Participants were chosen at random from a list of the Ashanti region's 30 enumeration zones based on the 2010 census. The Amsterdam Municipal Health Register, which contains information on the nation of birth of residents and their parents, was used to select Ghanaian participants at random from Amsterdam. This allowed for sampling based on the Dutch standard indication for ethnic origin. There was no demographic registration in London specifically for immigrant groups. Consequently, the sampling frame consisted of Ghanaian organizations or societal groups. In the cities considered to have the greatest population of Ghanaians, for example in London, lists of participants were collected from the Ghanaian Embassy and Ghanaian Churches. The same was done for participants recruited in Berlin. All chosen participants were issued a written invitation, along with written study details and a response card, to all European sites. After receiving a favourable response, a phone call was made to participants to set up a time and location for an interview with a trained research assistant, or they could choose to administer the paper questionnaire themselves or complete the digital online version, depending on their preferences.

The participation rates rural and urban Ghana was 76% and 74%, respectively. 75% of those who were invited and enrolled with one of the several Ghanaian organizations in London consented to participate in the survey. The percentage in Berlin was 68%. In Amsterdam, 67% of those who were invited responded, either through response card or following a house visit from an interviewer who matched their ethnicity. 53% of them consented and took part in the survey. Most (99%) of Ghanaians living in Europe were first-generation immigrants.

2.2.2. Ethical approval Consideration

The study received ethical approval from the School of Medical Sciences, Komfo Anokye Teaching Hospital, Committee on Human Research, Publication and Ethical Review Board; CHRPE/AP/200/12, Ghana, Institutional Review Board of AMC, University of Amsterdam; W12_062, London School of Hygiene and Tropical Medicine Research Ethics Committee; 6208 and Ethics Committee of Charite-Universtatsmedizin Berlin; EA1/307/12.

2.2.3. Assessment of biochemical markers

Fasting venous blood samples was taken by certified researcher in all locations. According to routine operating procedures, all blood samples were processed and aliquoted as soon as they were collected (within 1 hour to 3 hours of the vena puncture), and they were then temporarily held at the nearby research facility at 20 °C. The separated samples were then delivered to the labs of the nearby research centers, where they were examined, recorded, and kept at 80 °C. The preserved blood samples from the regional research centers were shipped to Berlin for biochemical tests to prevent intra-laboratory variability. Using the enzyme hexokinase, the concentration of fasting plasma glucose was determined. An ABX Pentra 400 chemistry analyzer (ABX Pentra; Horiba ABX, Germany) was used for all biochemical assays. HbA1c was measured using high-performance liquid chromatography (TOSOH G8 HPLC analyzer) and was presented as percentages or mmol/mol. T2DM was classified by the WHO as having a fasting plasma glucose level of less than 7.0 mmol/L, a HbA1c level of less than 6.5% (53 mmol/mol), the documented use of a glucose-lowering drug, or self-reported diabetes (Unwin 2006). Serum lipid profile (total cholesterol, triglycerides, high-density lipoprotein (HDL)-cholesterol, and low-density lipoprotein (LDL)-cholesterol) was assessed using immuno-turbidimetric techniques. Spectrophotometric method was used in the measurement of liver enzymes (liver function comprised C-reactive protein (CRP), aspartate aminotransferase (AST), alanine aminotransferase (ALT) and γ-glutamyl transferase (GGT). Again, serum creatinine was collected and measured by a kinetic colorimetric spectrophotometric isotope dilution mass spectrometry calibration method used by Roche Diagnostics. Using the 2009 chronic kidney disease-EPI (CKD Epidemiology Collaboration) creatinine equation, the estimated glomerular filtration rate (eGFR) was determined (Levey et al. 2009). On a urine sample collected in the early morning, direct tests of urinary albumin and creatinine levels were carried out. An immunochemical turbidimetric technique was used (Roche Diagnostics) to determine the urinary albumin content. A kinetic Spectro-photometric technique was used (by Roche Diagnostics) to determine the urinary creatinine concentration (in mol/L). Calculated by dividing the ratio of urine albumin and creatinine concentrations, the urinary albumin-creatinine ratio (ACR) is reported in mg/mmol.

2.2.4. Assessment of diabetic complications

Albuminuria and/or low eGFR were used to characterize nephropathy for the purposes of microvascular problems (Lamb et al. 2013). The 2012 kidney disease: Improving Global Outcomes (KDIGO) criteria were used to categorize albuminuria and estimated glomerular filtration rate (eGFR). Low eGFR was classified as having a drastically elevated eGFR of 60 mL/min/1.73 m^2 (Haneda et al. 2015). Stroke, coronary artery disease, and peripheral artery disease were used as the basis for macrovascular problems. The ratio of the resting systolic blood pressure at the ankle to the resting systolic brachial pressure at the arm was used to calculate the ankle brachial pressure index (ABI). This was determined utilizing the Microlife Watch BP Office to measure the blood pressure on both the right and left side of the legs and arms. ABI ≤ 0.90 was used to define peripheral arterial disease (Barrett et al. 2017). Using the WHO Rose angina questionnaire, coronary artery disease was evaluated. If you answered "yes" to the questions "Have you ever experienced any chest pain or discomfort?" and "Do you get this pain or discomfort when you walk uphill or hurry?" you have angina. A yes response to the question "Have you ever had a stroke?" was used to define stroke.

To define NAFLD, Fatty liver index (FLI) and liver biomarkers (CRP, AST, Alt and GGT) served as proxy marker. Each participant's FLI was determined using the algorithm developed by Bedogni et al. (2006). The algorithm considers the BMI, waist size, triglycerides, and GGT (Bedogni et al. 2006). In this epidemiological analysis, the FLI, in the absence of excessive alcohol consumption (defined as >21 units (168 g) for males and >14 units (112 g) for women per week), verifies the criteria of NAFLD.

2.2.5. Dietary Assessment

A standardized Food Propensity Questionnaire (Ghana-FPQ), which asks about the typical eating frequencies of food groups over the previous 12 months, was used to measure food intake at all RODAM trial sites. The Ghana-FPQ includes 134 items based on a multilingual semi-quantitative European Food Propensity Questionnaire (EFPQ) (Kaaks and Riboli 1997). Additionally, we included typical Ghanaian foods that were discovered in the Ghana Demographic and Heath Survey (2008, (GSS 2009)) and in earlier research among Ghanaians in Amsterdam (the GHAIA study (Agyemang et al. 2013)) and metropolitan Ghana. Common household items in Ghana made it easier to describe serving quantities uniformly. By combining

consumption frequencies and typical portion sizes, we were able to determine the average daily intake of meals in grams. The EFPQ portion sizes were used for foods from Europe.
Also, 24-hour dietary recall (24HDRs) was conducted among random sub-sample of 251 RODAM research participants. This was done by trained personnel using ace-to-face interviews. Again, to assist the standardised quantification with recognizable and uniform cooking tools, the interviewers were given a luggage filled with typical Ghanaian household utensils. The 24HDR gave important information, such as recipes and foods that are representative of a certain food type, for the computation of the average nutrient composition of Ghana-FPQ products. For individuals from rural Ghana, urban Ghana, and Europe separately, the 24HDRs also gave data on portion sizes that were assigned to the Ghanaian meals covered in the Ghana-FPQ. The Ghana-FPQ was linked to the most recent iterations of the German Nutrient Database (Bundeslebensmittelschlüsse (BLS 3.01)) and the West-African food composition tables for the estimation of total energy intake and macronutrients.

2.2.6 Assessment of covariates

A well-trained study personnel or a standardized self-administered questionnaire were both used to collect information on socio-demographics, medical history, and lifestyle factors. Participants' educational backgrounds were divided into never/elementary, lower, intermediate, and higher/tertiary levels. Smoking status was divided into non-smokers and smokers, either present or former. Physical examinations conducted across all study sites used validated equipment in accordance with operational standards. With SECA 877 scales, weight was estimated to the nearest 0.1 kg while wearing light clothing and no shoes. With a handheld stadiometer (SECA 217), height was measured without shoes to the nearest 0.1 cm. Weight (kg) divided by the square of height (m2) was used to calculate BMI. Obesity was defined as a BMI of 30 kg/m2 and overweight as a BMI of 25 kg/m^2 (Organization 2011). Waist circumference was taken in centimetres at the point where the lower rib and the higher iliac crest meet. According to WHO cut-offs, abdominal obesity was classified as having a waist circumference of more than 88 cm (> 88 cm) for women and more than 102 cm (> 102 cm) for males (Organization 2011). The same assessor measured each anthropometric trait two times, and the average of those measurements was used for analysis. WHO STEPS questionnaire (WHO Stepwise approach to chronic disease risk factor surveillance; Geneva: World Health Organization, 2005) was utilized to calculate the amount of exercise in metabolic equivalent hours per week, which considered both work and leisure time.

2.2.7. Data analysis

Handling of missing and implausible data

The Statistical Analysis Software (SAS) (version 9.4) was used for all data processing and analysis. The analysis featured two parts, mainly the use of complete case data for the analysis of RRR-DPs related with NAFLD and the associations T2DM and the use of imputed data for the analysis of LCD score and the association with T2DM and its complications. The use of listwise deletion was applied to complete case since most the variables were missing completely at random (MCAR). Thus, the omission of these missing may not affect estimate and consecutive result (Kang 2013). However, in our second analysis, both imputed data and complete case were used. The reason being that there was large amount of missing data in self-reported complications, and imputation provided an improvement in data analysis techniques. **Figure 6** describes further detail for missing variable elimination. A total of 3687 people made up the final analytical sample. Continuous variables with a normally distributed distribution are shown as means with standard deviations (SDs), while skewed continuous variables are shown as medians (interquartile ranges).

To boost statistical power and lessen the possibility of selection bias, multiple imputation (n = 10; discriminant fully conditional specification (FCS) approach) was used for missing data for the variables of interest (McCoach et al. 2018). We used the FCS method because the data have numerous patterns of missing values and are both continuous and categorical. Data were missing for at least one of the important variables for a total of 2537 participants. In **figure 7**, imputed raw data details are presented. 5,898 individuals made up the total sample used for the analysis. Both the exposure and the outcome variables were imputed. To further understand the representativeness of those with missing data compared to those without, we compared the characteristics of the analytical sample, which included imputation for a sizable portion of the study population, to those without.

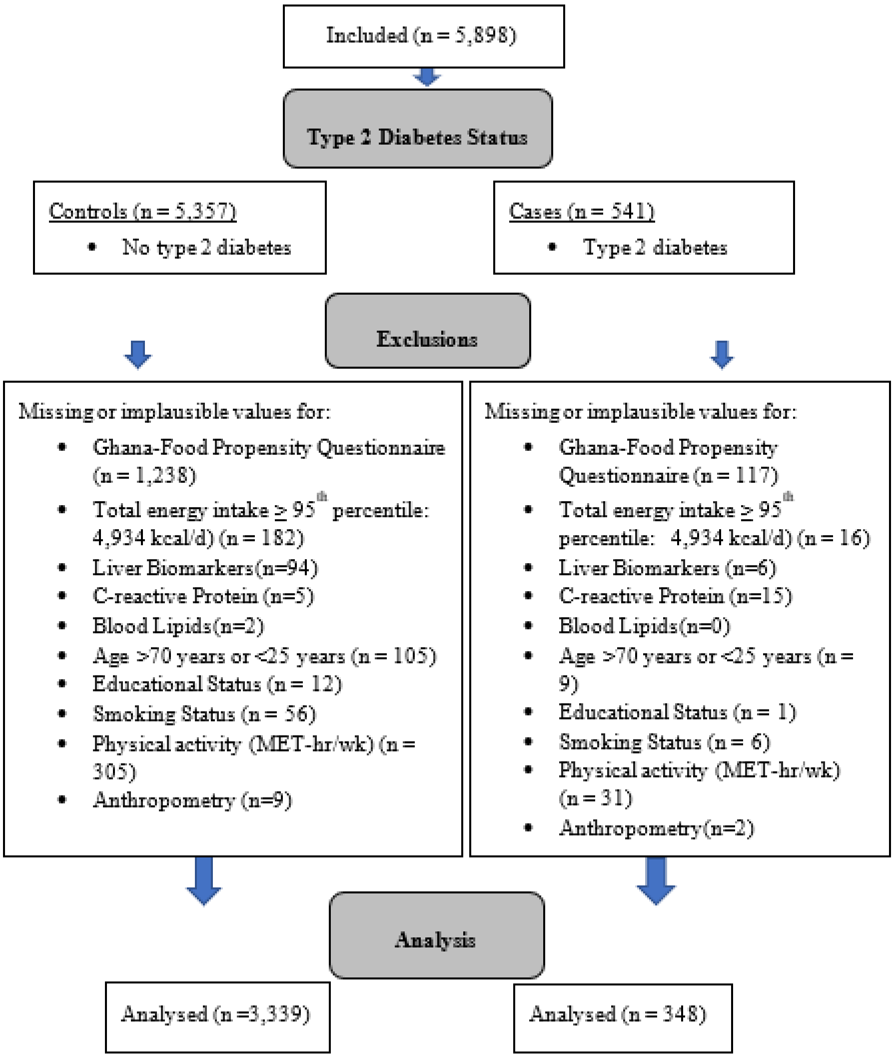

Figure 6: Flow diagram of listwise deletion of variables, missing completely at random. A total of 3687 were included in the final analysis.

Adopted from my published paper (Osei et al. 2021).

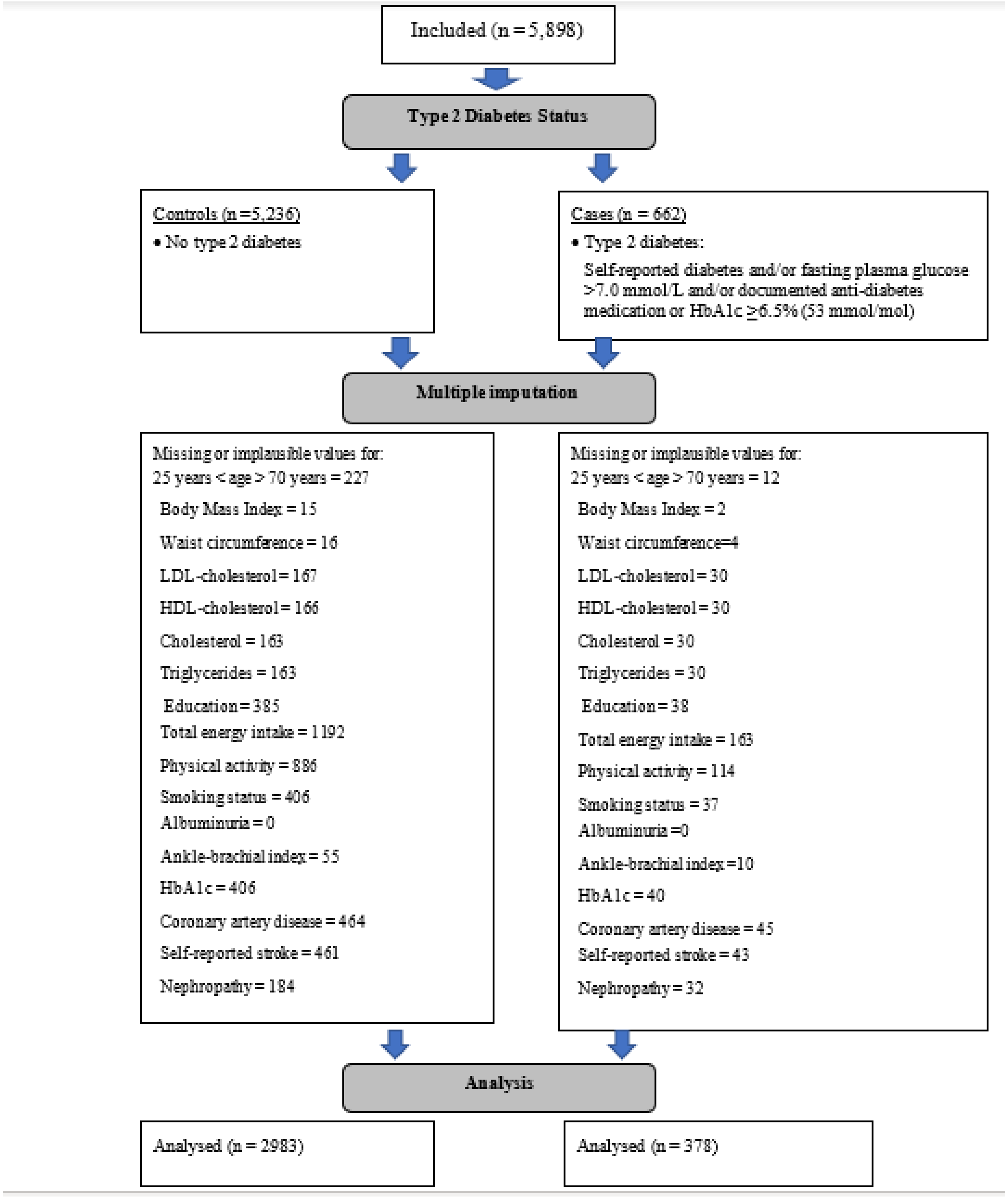

Figure 7: Flow chart for imputed data for both exposure and outcome variables with missing. Data. A total of 5898 participants were included in the analysis.

Derivation of dietary patterns by reduced rank regression

Sex-specific derived DPS analysis was done separately for both men and women due to the variation in eating patterns, adipose tissue distribution, and observed T2DM that exist among sexes. In accordance with their nutrient profiles and culinary applications, the food items were divided into 30 food groups. The classified foods that were subjected to RRR included whole-grain cereals, refined cereals, sweet spreads, dairy products, fruits, nuts and seeds, roots, tubers and plantains, potatoes, fermented maize products, vegetables, legumes, vegetable soups, stews, sauce, rice and pasta, eggs, red meat dishes, cakes and sweets, coffee and tea, alcoholic beverages, sodas and juices, palm oil, olive oil, other oils, margarine, cooking fats, and condiments. As a first step, RRR approach was used to calculated DP scores out of the 30 food groups, using log transformed FLI as a response variable for NAFLD. The same was done for NAFLD biomarkers (AST, ALT, GGT, CRP, total cholesterol, HDL cholesterol, LDL cholesterol, and triglycerides). Thus, four distinct DPs were created, each of which accounted for the greatest amount of variation in the FLI and NAFLD biomarkers for both men and women.

Logistic regression analysis for the associations of RRR-derived DPs with T2DM

Data was analysed according to quintiles. Using the first quintile as the reference point, logistic regression was used to determine the association between DPs and T2DM, by calculating the odds ratio at 95% confidence intervals (CIs). Again, linear trend between quintiles were tested by modelling the median of each quintile as a continuous variable. Finally, three models were considered in the adjustment of covariate. Model 1 considered sociodemographic factors such as age (years) and study site (categorical) as well as education status, model 2 added lifestyle factors such as energy intake (kcal/d), smoking status, physical activity, and alcohol consumption (g/day). The final model considered the addition of anthropometric measures such as BMI and waist circumference for the association between DPs and biomarkers.

To deal with a possible source of reverse causality, we eliminated subjects with self-reported T2DM from sensitivity analyses. Particularly, people with known T2DM who got medical care may have had different biomarkers and/or adjusted their diets. As a result, we conducted the RRR analyses once more using FLI or NAFLD biomarkers as the response variables for both genders. Logistic regression analysis was applied again to find the association between RRR-derived DPs and T2DM.

Operationalization of low-carbohydrate diets (LCDs)

To operationalize the consumption of LCD, we employed the scoring system developed by Halton et al. (2006). Participants were split into deciles for this LCD score based on the proportions of their energy intake from fat, protein, and carbohydrate. To lessen the likelihood of reverse causality, we employed the nutritional deciles in the non-diabetes group (**see table 2**). This speaks to the potential for dietary changes among those with long-term T2DM. Participants in the highest decile had a score of 10, while those in the lowest stratum had a score of 0. Carbohydrates, on the other hand, received the reverse score point distribution. The points for the three macronutrients were added up to produce a total LCD score, which ranged from 0 to 30. A higher score indicated a larger percentage of total fat and protein and a lower percentage of carbohydrates in the diet.

Table 2: Scoring criteria for low-carb high fat diet score, based on the distribution among individuals without type 2 diabetes in the complete-case dataset (N=2983).

Score points	Carbohydrate intake (energy%)	Protein intake (energy%)	Total fat intake (energy%)
0	>65.46	<9.95	<22.03
1	61.48-65.46	9.95-11.01	22.03-25.01
2	58.69-61.48	11.01-11.78	25.01-27.18
3	56.41-58.69	11.78-12.38	27.18-29.0
4	54.33-56.41	13.38-12.96	29.0-30.55
5	52.34-54.33	12.96-13.55	30.55-32.4
6	50.21-52.34	13.55-14.19	32.40-34.4
7	47.87-50.21	14.19-14.92	34.40-36.8
8	44.92-47.87	14.92-15.81	36.80-40.12
9	40.70-44.92	15.81-17.02	40.12-44.50
10	<40.7	>17.02	>44.5

Regression analyses for the associations of LCDs with glycaemic control and diabetic complications

After testing the assumptions of linearity, adjusted linear regression models were calculated for natural log transformed for HbA1c as a continuous outcome using energy intake and macronutrient consumption as a continuous exposure, stratified by T2DM status. The association considered the adjustment of site, sex, and age in the first model and accounted for other lifestyle activities such as smoking status, educational status, degree of physical activity, and diet high in fibre in model 2. The ß-coefficients, their 95% confidence intervals (CIs), and p-values per one standard deviation (SD) rise of the exposure variable were calculated using the SAS PROC MIANALYZE method. For the log transformed HbA1c, stratified by T2DM status, linear regression models were fitted for the LCD score and macronutrients. In Models 1 and 2, the same set of adjustment variables was applied. Finally, logistic regression models were calculated for the associations of the LC-diet score with diabetic complications among participants with T2DM, using the same set of potential confounders in Models 1 and 2.

Sensitivity Analysis

Sensitivity analysis was conducted to determine how reliable our imputed results were. All participants from the dataset who had missing values were removed. All analysis were carried out again using the complete-case dataset.

3. RESULTS

3.1. Findings of the systematic literature review

3.1.1. Characteristics of included studies

The meta-data of the 68 articles included in this SLR are displayed in **figure 8**. In total, 864,518 participants from 55 population-based research are included in the data in these papers. Having an average of 861 participants, the different studies' participant counts ranged from 116 to 441,199. About 44 publications provided data about adults (aged 18 and older), 12 studies concentrated on children (under 18), and 12 articles incorporated results of both children and adults. In majority of the articles (59/68), both men and women participated. Yet, eight articles dealt only with women, while one publication was men-only (Pachankis et al. 2017).

Various publications had different definitions of "migration status." The authors of six articles mentioned populations of migrants but did not specify how they defined "being a migrant." This was primarily observed in writings that were released between 1988 and 2008. The country of birth was used to define migratory status in 11 articles, whereas the origin of birth of either parent served as the definitional criterion in 17 articles. In 15 articles, foreign place of birth and parents who were born abroad were combined. 11 articles utilized citizenship to define migrant status, whereas four articles used registration at a refugee camp or reception facility. Name-based algorithms were used in three papers (Krist et al. 2020; Spallek et al. 2009; Spix et al. 2008) to register information for the purpose of identifying people with migratory backgrounds. The definition criterion for the German Competence Network for HIV/AIDS (KompNet Cohort) was observer-determined ethnicity (white vs. black) (Wyen et al. 2011).

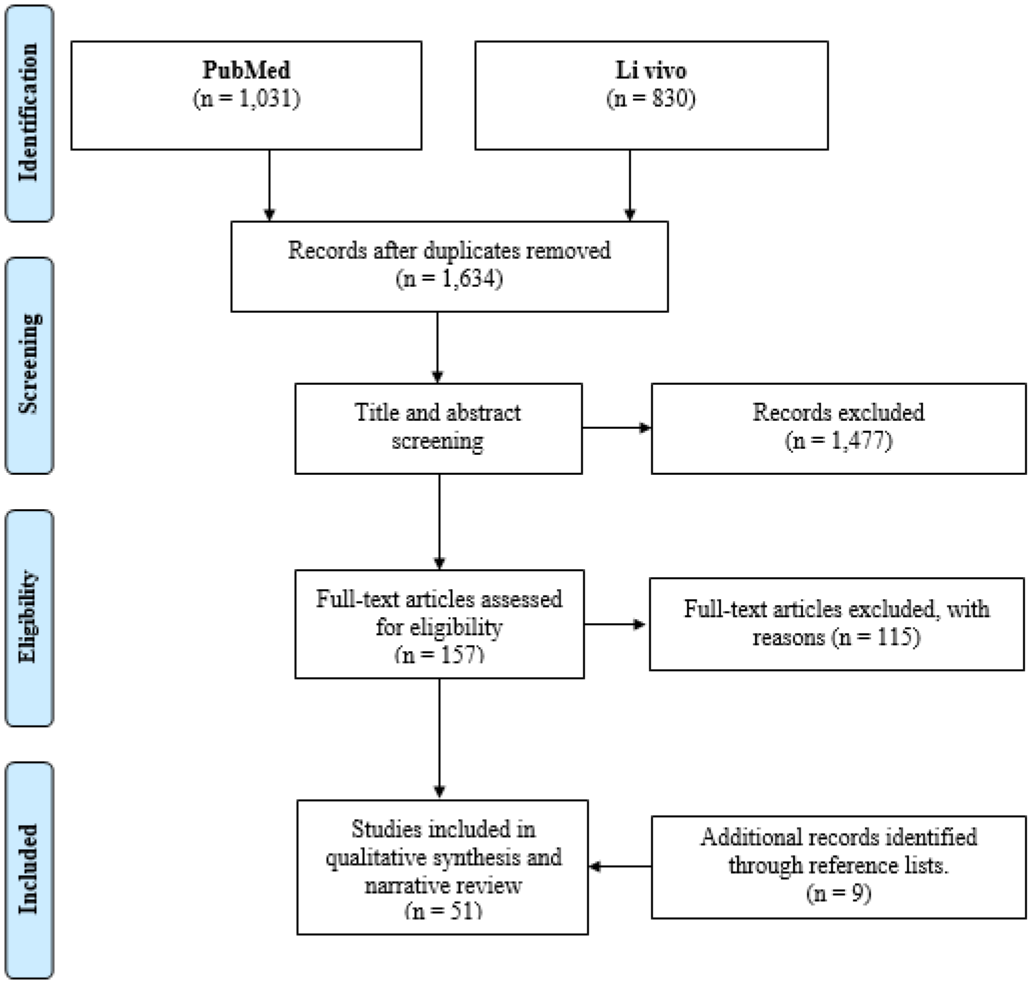

Figure 8: Flow chart of articles included.

Adopted from my published paper (Osei et al. 2022)

3.1.2. Quality assessment

The quality evaluation assessment using the CASP checklists are shown in supplementary **Table 3** and summarised in **Figure 8**, except for the intervention study by Arendt and Karadas, 2019. The CASP RCT checklist for the intervention study did not show any appreciable risk of bias. Because of how the intervention was designed, only the study personnel for the intervention group was not blinded (Arendt and Karadas 2019b). In general, older papers had a worse quality than those that had been published after 2015. This was primarily observed for internal validity impairment. For instance, 26 out of 56 cross-sectional studies and one out of 11 cohort studies lacked precision measurements for the effect estimates, such as confidence intervals (CI) or standard errors (SE). Additionally, about 16 out of 56 in potential confounding was overlooked during analyses.

We plotted the number of participants in each study by the year it was published (**See figure 9**) to roughly measure the assessment of publication bias. In two investigations, Reime et al. 2012 (N=441,199)) (Reime et al. 2012) and Spallek et al. 2009 (N=140,249) (Spallek et al. 2009), the sample sizes were extraordinarily large (>100,000 individuals). In general, sample sizes have grown with time, and larger studies (>10,000 participants) have fewer individuals than smaller studies (10,000 people). Low risk of publication bias is indicated by this.

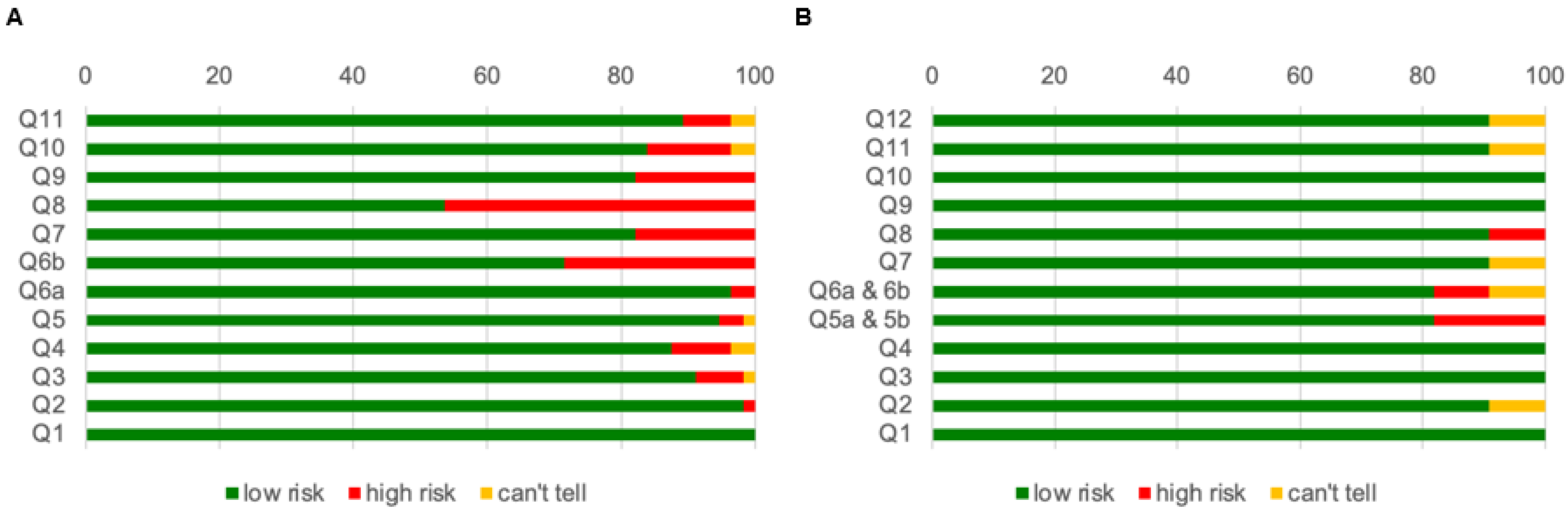

Figure 9: Percentages of articles with low, high and unknown risk of bias for (A) cross-sectional (n=56) data and (B) cohort studies (n=11)

Adopted from my published paper (Osei et al. 2022)

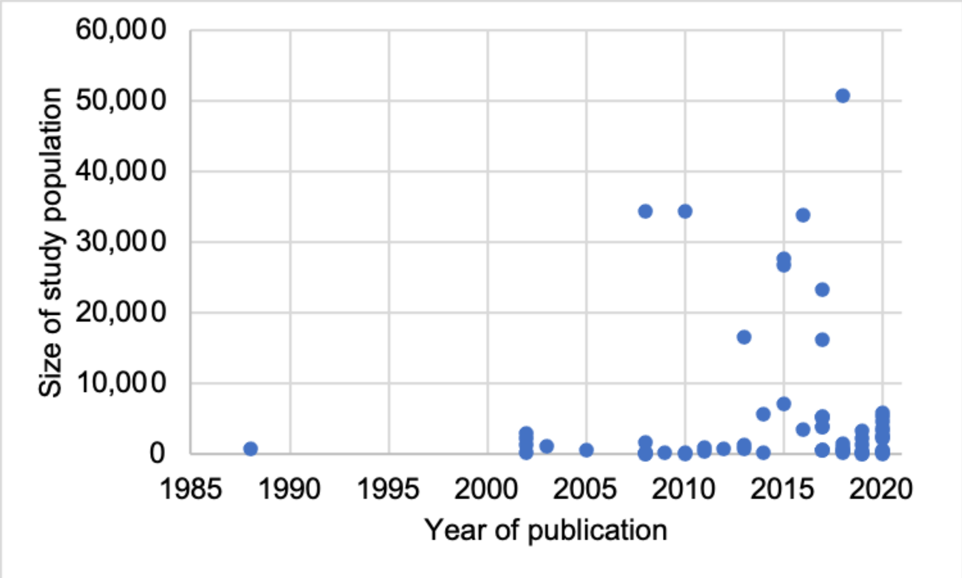

Figure 10: Sample size of each study, by year of publication

*Two extraordinarily sizable studies with over 100,000 participants are not displayed: Reime et al. 2012 (N=441,199) (Reime et al. 2012) and Spallek et al. 2009 et al. 2009 (N=140,249) (Spallek et al. 2009) both used large sample size.

Adopted from my published paper (Osei et al. 2022)

3.1.3. Synthesis of risk factors for diseases outcomes among migrants in Germany

According to the WHO major illness groupings, the risk factor-disease associations of the individual papers were categorized (World Health Organization (WHO) 2018). **Table 3** displays the findings for non-communicable disorders (class II), which includes vaccines. About 22 publications found connections with diverse mental health outcomes, while 15 articles presented relationships for cardio-metabolic diseases (Addo et al. 2017b; Boateng et al. 2017; Boateng et al. 2020; Chilunga et al. 2019; Commodore-Mensah et al. 2020; Dannemann et al. 2011a; Danquah et al. 2018b; Hampe et al. 2020; Hayfron-Benjamin et al. 2020; Lyons et al. 2020; Meeks et al. 2017a; Meeks et al. 2017; Scheuing et al. 2015; Will et al. 2005; Zhou et al. 2018). The other six articles, all of which dealt with Injury outcomes (class II), concentrated on mortality (n=2) (Ott et al. 2008; Ott et al. 2010), malignancies (n=2) (Spallek et al. 2009; Spix et al. 2008), oral health (n=1) (Solyman and Schmidt-Westhausen 2018), and atopic illnesses (n=1) (Gruber et al. 2002). The results for health behaviours, including smoking (n=4) (Brathwaite et al. 2017; Morgenstern et al. 2013; Reiss et al. 2015b), healthcare use (n=3) (Arendt and Karadas 2019; Wetzke et al. 2018), and lifestyle factors including physical activity (n=1) (Krist et al. 2020), diet (n=1) (Osei-Kwasi et al. 2020), screen time (n=1) (Iguacel et al. 2018), and sleep quality (n=1) (Voss and Tuin 2008). The many exposures included lifestyle elements, biological and clinical risk factors, socioeconomic factors, migration-related factors, demographic traits, and socioeconomic factors.

Figure 11 also displays a heat map of the meta-analysis of the risk factor-disease relationships. Overall, there were substantial and consistent correlations between demographic risk variables. Class I and class II outcomes, such as communicable diseases, maternal and child health issues, cardio-metabolic diseases, and mental health disorders, were mostly positively linked with age. Age had less of a direct correlation with other NCDs, such as cancer and dental health, as well as with unhealthy behaviours. Except for a female preponderance for obesity and a few mental health disorders, women appeared to have a generally better health profile than men. The selected articles also featured prominent exposures to socioeconomic risk factors. While greater education was not linked to communicable diseases, it was clearly protective of the likelihood of developing NCDs and engaging in unhealthy behaviours. Such inverse associations were apparent for most of the outcomes under study for occupational class. However, for cardio-metabolic illnesses, this was less obvious. It's interesting to note that the included research rarely evaluated wealth. Some wealth metrics (income, deprivation score, wealth score) were found to have negative correlations with smoking and communicable diseases. Negative associations with health outcomes were found in most studies that looked at factors related to migration, meaning that participants with longer stays in Germany, migrants of the second or third generation as opposed to those of the first, better German language proficiency, and longer residence permits in Germany had better health status. Cardio-metabolic disorders and other NCDs, such as malignancies, atopic diseases, and poor dental health, were an exception. Clinical, biochemical, and lifestyle variables were primarily evaluated in relation to disease groups with class I and class II classifications. Poor health was biologically associated with the presence of concurrent illnesses, higher BMI, and (epi)genetic variation in candidate genes. The papers, however, found no associations between obesity and concomitant disorders or infectious diseases. Finally, persistent direct links between poor eating habits and cardio-metabolic diseases as well as mental health problems as well as smoking and maternal and child health outcomes (class I) were found to exist. The associations between various NCDs and lifestyle factors were not discussed in any of the articles

Table 3: Associations with non-communicable diseases.

Adopted from my published paper (Osei et al. 2022)

Publication	Geographic origin	Statistical analysis/model	Adjustments	Associations with main outcome
Cardio-metabolic conditions				
Commodore-Mensah et al. 2020	Sub-Saharan Africa	Logistic regression	Age; physical activity; education; study site	Predicted 10-years CVD risk waist circumference: +
Hampe et al. 2020	Sub-Saharan Africa	Multiple-adjusted linear regression	Age, sex, education, BMI, waist circumference, smoking status, infection-related factors	Serum GAD65Ab concentrations urban vs rural: +; Europe vs rural: +; Serum ZnT8Ab concentrations urban vs rural: +; Europe vs rural: +. GAD65Ab positivity diabetes yes vs no: 0
Hayfron-Benjamin et al. 2020	Sub-Saharan Africa	Logistic regression	Age, sex, study site, smoking, BMI, blood pressure, LDL-cholesterol	Type 2 diabetes C-reactive protein: +; diabetes complications (peripheral artery disease and nephropathy) C-reactive protein: +
Lyons et al. 2020	Sub-Saharan Africa	Logistic regression	Age, BMI, CRP, smoking, alcohol intake, education	Increased HbA1c iron deficiency: + (in women), 0 (in men)
Boateng et al. 2019	Sub-Saharan Africa	Poisson regression	Study site; education; age at menarche; BMI; waist and hip circumferences	Predicted 10-years CVD risk sitting height: -; leg length: 0

Publication	Geographic origin	Statistical analysis/model	Adjustments	Associations with main outcome
Chilunga et al. 2019	Sub-Saharan Africa	Logistic regression	Socio-demographic factors, lifestyle factors, use of anti-diabetic medication, glucose control, length of stay	Lean type 2 diabetes urban vs rural: +; Europe vs. rural: +
Zhou et al. 2018	Various origins, mainly Turkey, Russia, Poland	Multivariate logistic regression	Demographics; household and parental characteristics; growth and development factors; length of child care attendance	Overweight/obesity female vs male sex: +; education: -; single parent vs conventional family: +; high vs normal birth weight: +; large for gestational age vs normal for gestational age: +;
Addo et al. 2017	Sub-Saharan Africa	Poisson regression	Age, BMI, physical activity, daily energy intake; separately for men and women	Diabetes educational level: -; occupational class: +
Boateng et al. 2017	Sub-Saharan Africa	logistic regression	Education, employment, source of income; physical activity, alcohol intake; psychosocial stress	Predicted 10-years CVD risk length of stay in Europe: + (in men) but 0 (in women)
Danquah et al. 2017	Sub-Saharan Africa	logistic regression	Age, sex, study site; education, energy intake, physical activity, smoking;	Diabetes mellitus Food Variety Score: -; Dietary Diversity Score: 0; DQI-I Variety: 0

Publication	Geographic origin	Statistical analysis/model	Adjustments	Associations with main outcome
			BMI, waist circumference	
Meeks, Henneman et al. 2017	Sub-Saharan Africa	Logistic regression	Age, sex, recruitment site, estimated cell distribution, hybridization batch, array position, principal component of genotyping data; false discovery rate	Obesity 3 DMPs associated (NLRC5, BCAT1, CPT1A)
Meeks, Stronks et al. 2017	Sub-Saharan Africa	Multivariate logistic regression	Age; sex; family history of diabetes, anthropometrics, health-related behaviors, study site	Impaired fasting blood glucose HOMA-IR: +++; inverse HOMA-beta: +
Scheuing et al. 2015	Various origins, Turkey, Southern Europe, Eastern Europe	Multivariable logistic or linear regressions	Age, sex, duration of diabetes	Glycemic control Turkish vs German: -; Southern Europe and Eastern Europe vs. German: +; diabetes therapy non-German vs German: -; hypoglycemia Eastern Europe vs German: +; other non-German vs German: 0; ketoacidosis Turkish and Southern Europe vs German: +; other non-German vs German: 0; hypertension Turkish and Eastern Europe vs German: +; Southern Europe vs German: -; dyslipidemia Southern Europe vs. German: -; other non-German vs German: 0; microalbuminuria non-German vs German: 0; hospitalization

Publication	Geographic origin	Statistical analysis/model	Adjustments	Associations with main outcome
				and outpatient visits Turkish vs German: +; other non-German vs German: 0
Dannemann et al. 2011	Various origins, mainly Turkey and Asia	Multiple-adjusted logistic regression	All factors in the model	Metabolic syndrome and its components female vs male: - (except for BMI and fasting insulin); Turkish vs German ethnic origin: +; age: +
Will et al. 2005	Turkey, Russia, Eastern Europe and Middle East	Logistic regression	Gender, social status, ethnic background, duration of stay	Overweight socio-economic status: +; migrant vs non-migrant: +:
Mental health				
Bauer et al. 2020	Syria	Multivariate linear regression	Socio-demographic factors, migration experiences	Perceived health status socio-economic status pre-migration: +; socio-economic status post-migration: 0
Begemann et al. 2020	Afghanistan, Nigeria, Syria, Iraq	Non-parametric trend tests	None	Global functioning and psychopathology number of risk factors (trauma, urbanicity, physical abuse, sexual abuse, alcohol, cannabis): +
Borho et al. 2020	Syria	Multivariate linear regression	None	Depressive symptoms length of stay: +; Anxiety disorders length of stay: -; Post-traumatic stress length of stay: -
Goreis et al. 2020	Russia	Mediation analysis	Age, sex	Perceived stress passive harm: +; everyday discrimination: +

Publication	Geographic origin	Statistical analysis/model	Adjustments	Associations with main outcome
Morawa et al. 2020	Turkey	Multiple linear regression	Age	Depressive symptoms female vs male gender: +; 2nd vs first generation: +; acculturation: -; no vs any partnership: +; education: -; unemployed vs employed: +
Walther et al. 2020	Syria, Afghanistan, Iraq, Eritrea	Poisson regression	Socio-demographic characteristics	Psychological distress female vs male gender: +; age: +; protection status vs unclear residence status: -; single vs in partnership: +; refugee housing vs private housing: +
Espinoza-Castro et al. 2019	Spain	Poisson regression	Age, education, time of residence	Major depressive syndrome migration experience: +
Bretz et al. 2019	Turkey	Multivariate linear regression	Socio-demographic factors	Uptake of psychotherapy female vs male sex: +; present depression: +; social support: +; number of children: +; educational level: +
von Haumeder et al. 2019	Syria	Logistic regression		Post-traumatic stress syndrome trauma-related coping self-efficacy: -; SES: -; food access: -; healthcare access: -; perceived discrimination: +
Georgiadou et al. 2018	Syria	Multivariate linear regression	all factors in the model	PTSD symptoms age: +; validity of residence permit: -; number of traumatic events: +; anxiety symptoms: +; Depression symptoms age: -; duration of escape journey: -; number of traumatic events: +; anxiety symptoms: +
Jesuthasan et al. 2018	Afghanistan, Syria, Iran, Iraq, Somalia, Eritrea	Logistic regression	age, family, status, education, work traumatic experiences	Quality of life age: -; present near-death experience: -; attack by family member: -; absent health care: -

Publication	Geographic origin	Statistical analysis/model	Adjustments	Associations with main outcome
Morawa et al. 2017	Turkey	linear regression analysis	age	PHQ-15 score and PHQ-9 score female vs male: +; 1st generation vs 2nd generation: +; number of diagnosed physical illnesses: +; language proficiency: -
Belhadj Kouider et al. 2014	various origins: mainly Turkey, Russia, Africa, Poland	Logistic regression	All factors in the model	mental health non-German vs German citizenship: 0; female vs male: +; substance abuse female vs male: -
Morawa et al. 2014	Turkey, Russia and Poland	Multiple-adjusted linear regression	All factors in the model	Perceived discrimination Turkish vs Polish: +; Depression Turkish vs Polish: +; married vs unmarried: -; Quality of life Turkish vs Polish: -
Belhadj Kouider et al. 2013	Turkey and Poland	Binary logistic regression	All factors in the model	Social behavior disorders female vs male: -; parental education: -; factors implicating psychosocial burden: +
Bogic et al. 2012	former Yugoslavia	Multivariable logistic regression	All factors in the models	Mental disorders female vs male: +; age: +; educational level: -; number of traumatic events: +; number of post-migration stressors: +; unemployed vs employed: +; temporary vs. permanent residence: +; feeling of acceptance vs unacceptance: -; substance use disorders age: -; female vs male: -; single vs partnership: +
Mewes et al. 2010	Turkey, Eastern Europe, Former Soviet Union	ANOVA	Age, sex, marital status, employment status	Depression, somatoform symptoms, anxiety female vs male: +; age: + readiness to visit a physician Eastern Europe vs Turkish: +
Schreyer et al. 2010	various origins	multivariate ANOVA	All factors in the model	Social behavior disorders socio-economic status: -; female vs male: -; Quality of life socio-economic status: -

Publication	Geographic origin	Statistical analysis/model	Adjustments	Associations with main outcome
Haasen et al. 2008	Russia, Iran	Pearson correlation	Not stated	Mental distress acculturation stress: +; depression score acculturation stress: 0
Irfaeya et al. 2008	Middle East	Linear and logistic regressions	None	Stress age: +; number of children: +; African origin vs European origin: +; ill vs healthy: +; negative vs positive migrant perception: +
Merbach et al. 2008	Poland, Vietnam	Linear and logistic regressions	Age, length of stay, ethnic group, sex, education	Anxiety female vs male: +; non-German vs German origin: +; structural assimilation: -; depression age: +; social assimilation: -
Fichter et al. 1988	Greece	ANOVA	Age	Mental illness age: -; female vs male: +; non-German vs German origin: +
Other non-communicable diseases				
Solyman et al. 2018	Syria, Iraq	Mann-Whitney U test, ANOVA, Kruskal-Wallis's test	None	Oral Health age: +; Iraq vs. Syria: 0; female vs. male sex: 0; years of Education: -; Knowledge age: 0; Iraq vs Syria: 0; female vs male sex: +; years of education: +; Attitude age: +; Iraq vs Syria: -; female vs male sex: 0; years of education: +; Practice age: 0; Iraq vs Syria: 0; female vs male sex: +; years of education: +
Ott et al. 2010	Former Soviet Union	Poisson regression	Age, calendar year and destination country	All-cause mortality in men duration of stay: -; CVD mortality in men duration of stay: +; cancer and external cause mortality in women duration of stay: -
Ott et al. 2008	Former Soviet Union	Poisson regression	Sex, 5-year age group, calendar year of death	Mortality female vs male: -

Publication	Geographic origin	Statistical analysis/model	Adjustments	Associations with main outcome
Spallek et al. 2009	Turkey	Poisson regression	Year of birth	Respiratory cancers among men old vs young birth cohorts: +; Malignant neoplasms among men middle-aged vs young/old birth cohorts: +; Breast cancer among women old vs young birth cohorts: -; Cancer of digestive organs in women old vs young birth cohorts: -; neoplasms in women old vs. young birth cohorts: -
Spix et al. 2008	Turkey	Log-rank test for Kaplan-Meier curves	None	Cancer survival probability sex: 0; age: 0
Grüber et al. 2002	Turkey	Logistic regression	Infections, BCG vaccination	Atopic sensitization and atopic diseases non-German vs German language: -; number of pets: -; maternal education: +; acculturation: -

Outcome is underlined; +, positive association; –, negative association; 0, null association.

Risk factor		**Class I**		**Class II**			**Health behaviors**	
		Communicable diseases	Maternal and child health conditions	Cardio-metabolic conditions	Mental health conditions	Other NCDs	Smoking	Poor healthcare uptake
Demographic	Age							
	Female vs. male							
Socio-economic	Educational level	n.a.						
	Occupational class					n.a.		
	Wealth			n.a.	n.a.	n.a.		
Migration-related	Length of stay							
	Migration generation	n.a.	n.a.	n.a.		n.a.		
	German language skills			n.a.			n.a.	n.a.
	Length residence permit	n.a.	n.a.	n.a.		n.a.	n.a.	n.a.
Biological and clinical	(Epi)genetic variation		n.a.		n.a.	n.a.	n.a.	n.a.
	Concomitant diseases					n.a.	n.a.	n.a.
	Adiposity (y vs. n)				n.a.	n.a.	n.a.	n.a.

Risk factor		**Class I**		**Class II**			**Health behaviors**	
		Communicable diseases	Maternal and child health conditions	Cardio-metabolic conditions	Mental health conditions	Other NCDs	Smoking	Poor healthcare uptake
Lifestyle	Smoking (y vs. n)			n.a.	n.a.	n.a.	n.a.	n.a.
	Unhealthy diet (y vs. n)	n.a.	n.a.			n.a.	n.a.	n.a.

Figure 11: Heat map of risk factor-disease associations among migrants in Germany

Adopted from my published paper (Osei et al. 2022)

Inverse/ negative association | Null association | Direct/ positive association | n.a. Not assessed

3.1.4. Geographical origins, predominating risk factors, and the predominant health consequences

Figure 12 shows the proportions of the outcomes and geographic origins under investigation. According to this Sankey graphic, the Middle East accounted for the bulk of research looking at risk factor-disease associations, followed by Turkey, sub-Saharan Africa, Eastern Europe, Russia/the former Soviet Union (FSU), and the Mediterranean region. There were few papers that discussed migrant communities from central Europe or Asia. According to the WHO categorization, class II (NCDs), class I (communicable, maternal, perinatal, and nutritional disorders), and health behaviors were the main health outcomes. None of the research that was reviewed looked at migrant populations' risk variables for class III (accidents and injuries) events.

All studies' health outcomes were different for each population group, as shown in **figure 12.** For instance, class II outcomes (NCDs) were the subject of over half of the research among groups with Turkish ancestry, African descent, and Middle Eastern origin. While the majority of the NCDs under consideration for sub-Saharan African migrants were cardio-metabolic illnesses, mental health issues were emphasized among people of Turkish and Middle East ancestry. Like studies among people from Eastern Europe, mental health predominated as the consequence. Maternal and pediatric health issues, which fall under class I of the WHO's major illness groups, made up a significant portion of the conditions under review.

One-third of the research focused on infectious diseases as a factor in class I results for migrants with African ancestry. Class I, class II, and the study's health behaviors were evenly divided among groups of Asian and Mediterranean ancestry, making up each third (**see figure 12**).

The predominant exposure-outcome connections under study are shown in **figure 13**. The majority of research evaluated socioeconomic, demographic, and migration-related risks, with mental health disorders predominating as outcomes. both migration generation and legal status of residency (4/68). Mental health and lifestyle factors dominated the results in respect to migration-related factors (see Figure 12). Socio-economic variables included occupational class (8/68), educational attainment (13/68), and some indicator of wealth (8/68) (such as income, wealth score, or deprivation score). These studies examined the impact of socioeconomic status on lifestyle variables, obesity, cardio-metabolic illnesses, and mother and child health (**see figure 13**). The significance of clinical and biochemical factors in cardio-metabolic disorders and the connection between alleged discrimination and psychological well-being were two other notable risk factor-disease pairings.

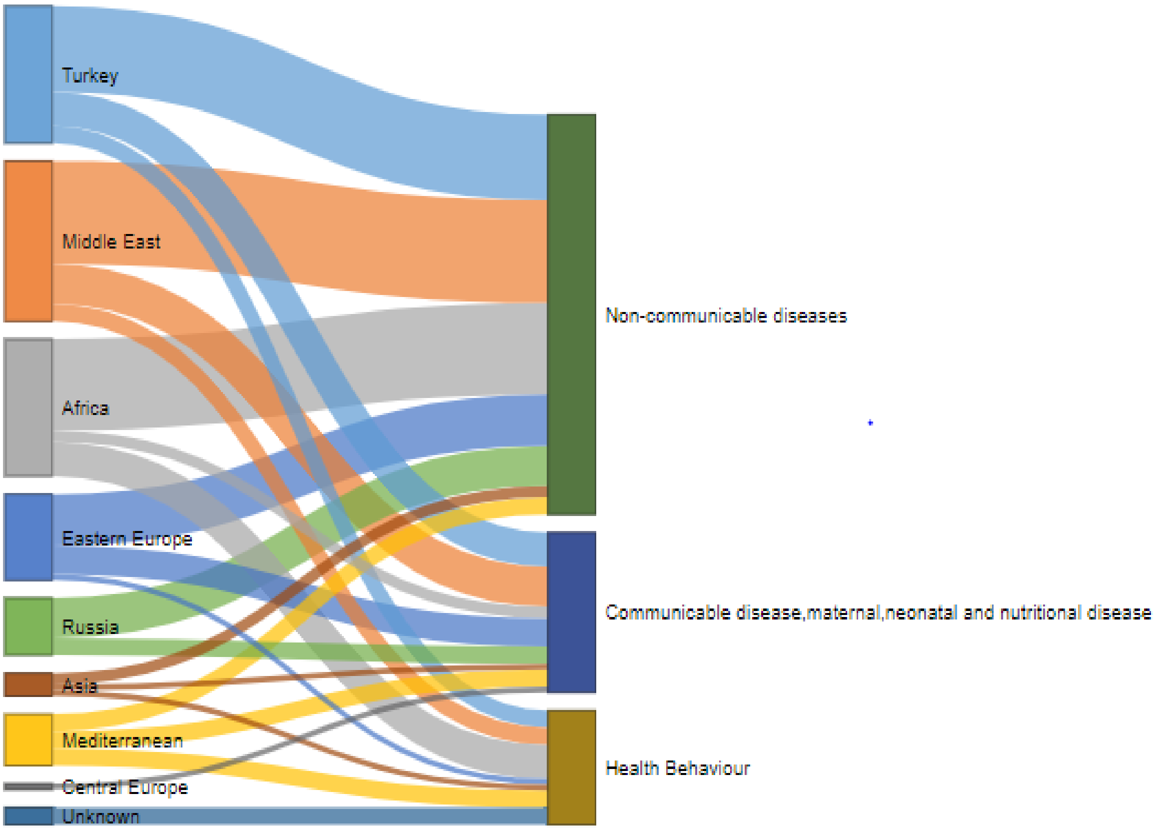

Figure 12: Sankey diagram showing the primary disease groupings and their regions of origin.

Adopted from my published article (Osei et al. 2022).

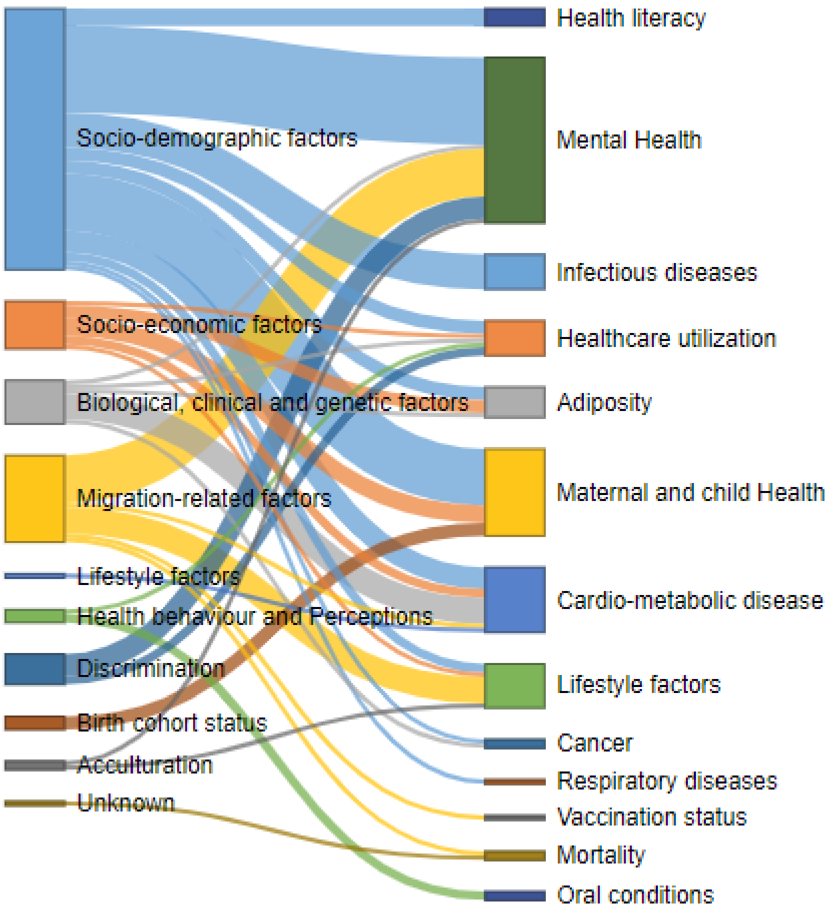

Figure 13:Sankey diagram for exposures and health outcomes under study

Chart shows absolute numbers of exposures-outcome combinations mentioned in 68 articles.

Adopted from my published article (Osei et al. 2022)

3.2. Findings from the RODAM Study

3.2.1. Characteristics of the study population base on baseline data

According to study site and sex, **Table 4** displays the general characteristics of the RODAM study population. Participants tended to be female (63.0%) and in their middle years (46.1–11.1) of life. Although mean age varied little between research locations, males were often older than females. Males had more educational attainment than females, while London had the largest percentage of persons with advanced degrees. Males reported drinking more alcohol than females, and had higher proportion of smokers, but were more physically active. Males had lower mean BMI (24.84.4 kg/m2 compared to 27.85.7 kg/m2) and waist circumference (8712.1 cm compared to 9112.5 cm) than females. Participants in London were the least physically active (median: 28; interquartile range: 5- 112 min/day), had the highest BMI (29.44.8 kg/m2), and had the largest waist circumference (95.411.3 cm), while those in rural Ghana were the most active (median: 90; interquartile range: 36-161 min/day), had the lowest BMI (22.74.3 kg/m2), and had the smallest waist circumference (81.210.9 cm). According to sex and research site, there were substantial changes in liver biomarkers and lipid profile. ASAT and ALAT were greater in males than in females (median: 35.1; IQR: 29.1-43.1 U/L and median: 23.0; IQR: 17.4-31.2 U/L, respectively). Females, on the other hand, exhibited greater levels of FLI (2.04–5.38), triglycerides (median: 0.95; IQR: 0.72-1.27 mmol/L), HDL cholesterol (1.27–0.35 mmol/L), and serum LDL cholesterol (3.13–1.0 mmol/L).

Energy, nutrients, and food group intakes

The daily mean energy consumption was 2533 837 kcal. This was greater in Berlin than London, rural Ghana, Amsterdam, and urban Ghana, and higher in men than women (**see table 4**). The average daily energy contributions from carbohydrates, total fats, and protein were 32.2, 8.2, 13.8 and 2.9%, respectively. Both men and women experienced this in a similar way. Across study sites, different macronutrients contributed differently to energy intake. In London and Amsterdam, lipids and proteins made up most of the energy consumed, whereas in rural and urban Ghana, carbohydrates made up most of the energy proportion. LCD score recorded the highest mean in London and the lowest in rural Ghana. The average daily calorie consumption (g/day) for each food group is shown by sex in **figure 14.** Males consumed more alcohol, sodas, juice, and coffee and tea than females did ***(*****see figure 14a**). While women's diet comprised of mixed vegetarian dishes, cakes, and sweets than men did, and this was equally true for red meat, poultry, processed meat, and eggs (**see figure 14b**)

.

Table 4: Characteristics of the study population

Adapted from published paper: (Osei et al. 2021)

Characteristics	Total (n=3687)	Men (n=1366)	Women (n=2321)	Rural Ghana (n=820)	Urban Ghana (n=1358)	Amsterdam (n=707)	Berlin (n=451)	London (n=351)
Sex (female%)	63.0	-	-	61.6	72.2	60.1	45.0	59.0
Age (years)	46.1±11.1	46.9±11.3	45.6±10.9	46.7±12.6	45.3±11.4	46.6±8.5	45.2±10.4	47.9±10.9
Education								
Never or elementary%	37.6	21.9	46.9	56.8	43.9	35.5	9.3	9.1
Low	37.7	41.6	35.5	31.6	38.9	37.8	50.1	31.6
Intermediate	16.2	22.5	12.5	7.9	12.5	21.8	26.6	24.8
Higher vocational	8.5	14.1	5.2	3.7	4.71	5.0	14.0	34.5
Length of stay (years)	-	-	-	-	-	16.4±8.1	17.0±10.9	17.2±11.0
Body mass index (kg/m2)	26.7±5.5	24.8±4.4	27.8±5.7	22.7±4.3	26.9±5.4	28.9±5	27.6±4.8	29.4±4.8
Waist circumference (cm)	89.5±12.5	87±12.1	91±12.5	81.2±10.9	89.4±11.8	94.6±11.6	92.2±11.5	95.4±11.3
Smoking (current or former%)	9.3	19.6	3.2	7.9	6.9	11.6	18.4	5.4
Physical activities (MET-min/day)	72 (14-168)	96 (28-196)	56 (10-156)	90 (36-161)	60 (6-156)	88.7 (26-258)	72 (12-198)	28 (5-112)
Total Energy intake (kcal/day)	2533±837	2628±827	2477±817	2594±828	2298±661	2478±854	2929±944	2898±953
Carbohydrate intake (energy%)	53.0±9.1	52.2±9.5	53.5±8.9	56.4.5±8.3	54.5±8.1	50.5±8.3	48.5±10.9	50.2±9.6
Fat intake (energy%)	32.2±8.2	32±8.6	32.3±8	31.4±7.3	31.6±7.2	32.1±8.3	33.7±10.6	34.1±9.6
Protein intake (energy%)	13.8±2.9	13.9±3.1	13.8±2.9	11.5±2.2	13.6±2.4	15.8±2.7	14.8±3.1	15.1±2.9
LCD score	15.2 ± 7.8	15.3 ± 7.8	15.1 ± 7.8	10.4 ± 7.7	14.7 ± 7.5	16.9 ± 6.9	16.8 ± 7.8	17.2 ± 7.4
Alcohol intake (g/day)	0 (0-0.1)	0 (0-0.3)	0 (0-0.1)	0 (0-0.1)	0 (0-0.1)	0.1 (0-0.4)	0.1 (0-0.6)	0 (0-0.1)
ASAT U/L	32.3 (26.6-39.8)	35.1 (29.1-43.1)	30.6 (25.3-37.7)	36.1 (30.4-43.1)	34.4 (28.7-41.5)	26.1 (22.4-30.8)	28.9 (24.7-34.9)	34.1 (28.0-43.1)
ALAT U/L	19.2	23.0	17.6	19.2 (15-24.9)	19.3 (15-25.8)	17.4 (13.7-23.0)	19.9	22.5

Characteristics	Total (n=3687)	Men (n=1366)	Women (n=2321)	Rural Ghana (n=820)	Urban Ghana (n=1358)	Amsterdam (n=707)	Berlin (n=451)	London (n=351)
	(14.9-25.7)	(17.4-31.2)	(13.9-22.7)				(14.8-26.9)	(18.3-30.3)
GGT U/L	30.8 (23.2-43.1)	37.4 (27.3-52.6)	27.9 (21.7-37.3)	29.5 (22.3-42.2)	31.4 (23.9-42.9)	30.2 (22.8-42.0)	32.9 (24.7-46.1)	30.6 (22.7-43.9)
CRP mg/L	0.7 (0.2-2.5)	0.5 (0.1-1.5)	0.9 (0.2- 3.2)	0.7 (0.2-2.6)	0.9 (0.2-3.1)	0.8 (0.2-2.3)	0.5 (0.2-1.9)	0.8 (0.2-2.3)
Total cholesterol (mmol/L)	5.0±1.1	4.9±1.1	5.1±1.1	4.6±1.1	5.2±1.2	5.0±1.1	5.1±1.1	5.0±1.0
LDL-cholesterol (mmol/L)	3.2±1.0	3.1±1.0	3.2±1.0	2.8±1.0	3.4±1.0	3.2±0.9	3.2±1.0	3.3±0.9
HDL-cholesterol (mmol/L)	1.3±0.4	1.3±0.4	1.3±0.4	1.2±0.4	1.3±0.3	1.4±0.3	1.5±0.4	1.3±0.3
Triglycerides (mmol/L)	0.9 (0.7-1.2)	1.0 (0.7-1.3)	0.9 (0.7-1.2)	1.0 (0.8- 1.3)	1.0 (0.8-1.3)	0.8 (0.6-1.0)	0.9 (0.6-1.1)	0.8 (0.6-1.1)
Fatty Liver Index	2.6±6.3	2.0±5.4	2.9±6.8	1.0±3.2	2.8±6.7	3.3±7.2	3.1±7.3	3.1±6.0

Means, standard deviations, and medians (IQR) are used to express continuous variables. Percentages (%) are used to express categorical variables. The abbreviations AST, ALT, CRP, GGT, HDL, and LDL stand for aspartate aminotransferase, alanine aminotransferase, and gamma-glutamyl transferase, respectively. LCD (low-carbohydrate diet score) was adopted from imputed data.

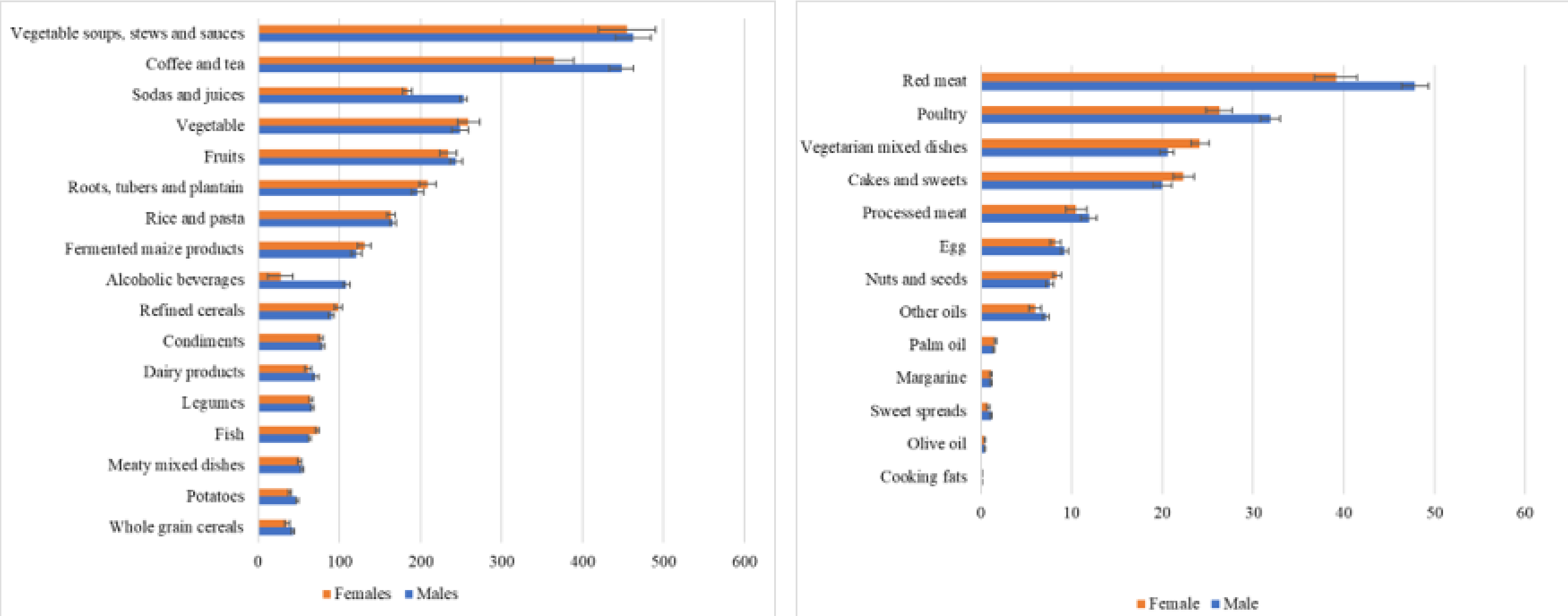

Figure 14: Standard deviations (g/day) and mean intakes (g/day) for (a) 16 food groups with mean intakes of less than 50g and (b) 13 food groups with mean intakes of less than 50.

Adapted from published paper (Osei et al. 2021)

Proportions of diabetic complications

The proportions of microvascular and macrovascular problems in 662 individuals with T2DM are depicted in basic form in **figure 15**. Overall, coronary artery disease (12.11%), self-reported stroke (10.9%), nephropathy (24.26%), peripheral artery disease (9.3%), and coronary artery disease were the most frequent complications, respectively.

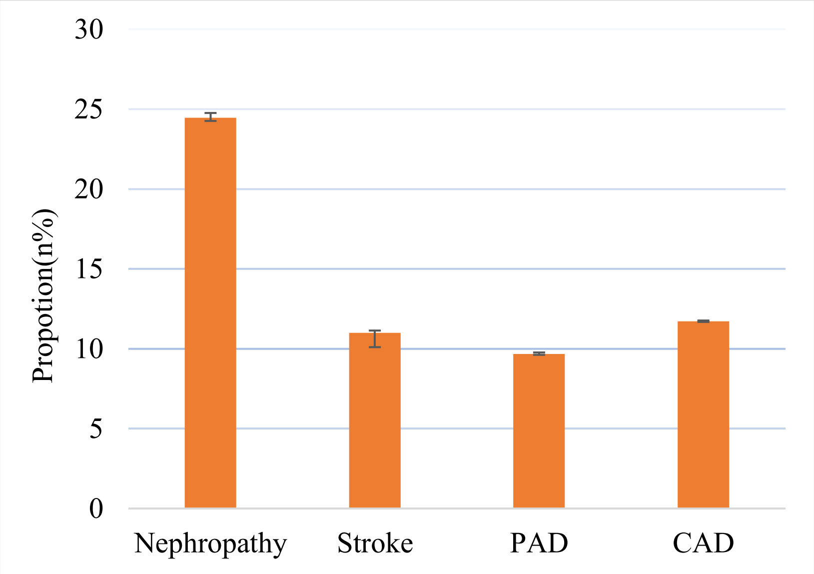

Figure 15: crude percentages (%) of patients with type 2 diabetes who also had diabetic complications (n=662). The 95% confidence intervals (CIs) are shown by error bars.

Stroke was self-reported. PAD: Peripheral Artery Disease; CAD: Coronary Artery Disease.

3.2.2. RRR-derived pattern related to fatty liver index (FLI)

For both males and females, **table 5** displays the explained variance and the factor loadings of dietary groups connected to FLI. For men and women, respectively, the DP scores explained 9.9% and 6.5% of the overall difference in food category intake. Additionally, the pattern scores produced from the RRR were positively correlated with FLI and explained 16.0% of the FLI variation in males (beta = 0.4) and 8.8% of the FLI variation in females (beta = 0.3). Increase consumption of poultry, whole grain cereals, coffee and tea, condiments, and potatoes were associated with a high DP score in males, while palm oil, roots, tubers, and plantains, refined cereals, and fermented maize products were negatively correlated. When it comes to females, the DP score that comprise of frequent use of coffee and tea, poultry, whole grain cereals, margarine, fish, and alcoholic beverages and by infrequent consumption of roots, tubers, and plantains, fermented maize products, palm oil, and refined cereals.

Similar DP ratings were found in a sensitivity analysis (**see table 6**) when self-reported T2DM cases were omitted. Food group consumption among males had an explained variation of 9.6%, and FLI had an explained variation of 15.5%. These percentages were 6.3% and 8.9%, respectively, for females.

Table 5: Food intake and factor loadings of 30 food groups of the RRR-derived dietary pattern scores related to FLI for males and females, expressed as a percentage of explained variation.

Adopted from my published paper (Osei et al. 2021)

Food group	**Men (n = 1,366)**		**Women (n = 2,321)**	
	Explained variation (%)	Factor loading	Explained variation (%)	Factor loading
Poultry	**30.8**	**0.32**	**16.6**	**0.29**
Whole grain cereals	**21.5**	**0.27**	**15.8**	**0.29**
Coffee & tea	**19.9**	**0.26**	**21.0**	**0.33**
Condiments	**18.3**	**0.25**	**15.7**	**0.28**
Potatoes	**17.8**	**0.25**	2.1	0.10
Alcoholic beverages	**10.3**	**0.19**	**7.5**	**0.20**
Margarine	**10.2**	**0.19**	**10.6**	**0.23**
Olive oil	7.7	0.16	0.4	0.04
Processed meat	7.2	0.16	0.3	0.04
Other oils	5.5	0.14	2.4	0.11
Dairy products	4.9	0.13	0.4	0.04
Sodas & juices	3.8	0.11	1.8	0.10
Cakes & sweets	3.4	0.11	0.6	-0.05
Red meat	2.6	0.09	0.0	0.01
Vegetables	2.5	0.09	5.2	0.16
Sweet spread	1.7	0.08	0.0	-0.01
Cooking fats	1.5	0.07	0.2	-0.03
Egg	1.3	0.07	2.1	-0.10
Rice & pasta	1.1	0.06	1.7	0.09
Vegetable soups, stews, sauces	0.9	0.06	0.0	-0.01
Nuts and seeds	0.5	0.04	1.5	0.09
Fish	0.1	0.02	**9.5**	**0.22**
Meat mixed dishes	2.1	-0.08	1.3	-0.08
Fruits	4.1	-0.12	1.6	-0.09
Legumes	4.8	-0.13	2.4	-0.11
Vegetarian mixed dishes	7.2	-0.16	0.9	-0.07
Fermented maize products	**18.4**	**-0.25**	**19.8**	**-0.32**
Refined cereal	**22.4**	**-0.27**	**13.3**	**-0.26**
Roots, tubers & plantain	**28.7**	**-0.31**	**22.0**	**-0.34**

Food group	Men (n = 1,366)		Women (n = 2,321)	
Palm oil	**35.1**	**-0.34**	**17.3**	**-0.30**
Total explained variation in biomarker profile	**9.9**		**6.5**	

Factor loadings are correlations between food groups and the dietary pattern score. Figures in bold represent food items with relevant contribution to the dietary pattern score (≥20% explained variation).

Table 6: Sensitivity analysis without study subjects who self-reported having diabetes. Percentage of food intake variation across genders that can be accounted for by factor loadings and dietary pattern scores.

Adopted from my published paper (Osei et al. 2021)

Food group	Men (n = 1366)		Women (n = 2321)	
	Explained variation (%)	Factor loading	Explained variation (%)	Factor loading
Poultry	**29.63**	**0.32**	17.08	0.30
Coffee and tea	**20.66**	**0.27**	**20.64**	**0.33**
Cereal	**19.81**	**0.26**	14.60	0.28
Condiments	**19.06**	**0.26**	15.44	0.29
Potatoes	**14.01**	**0.22**	1.81	0.10
Margarine	7.28	0.16	11.92	0.25
Alcohol	9.61	0.18	6.12	0.18
Fermented maize products	17.98	-0.25	19.73	-0.32
Refined and cereal	**25.21**	**-0.30**	11.48	-0.25
Roots, tubers & plantain	**27.56**	**-0.31**	**21.68**	**-0.34**
Palm oil	**31.18**	**-0.33**	15.70	-0.29
Total explained variation in biomarker profile	9.6		6.3	

Factor loadings are correlations between food groups and the dietary pattern score. Figures in bold represent food groups with relevant contributions to the dietary pattern score (≥0.20% explained variation in the factor loadings for either males or females).

3.2.3. RRR-derived patterns related to biomarkers

We also retrieved two DP scores related to NAFLD biomarkers (liver enzymes, blood lipids, and CRP) in addition to the FLI-associated DP scores. These DP scores and the accompanying factor loadings for the dietary groups are displayed in **table 7.** The DP score explained 2.8% of the total biomarker variance in men, with AST variation accounting for the majority of this explanation (7.4%) and having a response weight of 0.58. Following this were LDL-cholesterol (4.2%) and total cholesterol (4.5%), both of which had favourable response weights with respect to the DP score calculated from the RRR (**see table 8**). Whole-grain cereals, coffee, and tea (both r = 0.20), were the main contributors to the correlations with AST. Additionally, whole-grain cereals, potatoes, and condiments were primarily responsible for the positive response weights for the total cholesterol and LDL-cholesterol among men (**see supplementary Table 4**). The explained overall variation in NAFLD biomarkers in females was 4.5%, with the AST at 12.3% (response weight: 0.58), triglycerides at 11.1% (response weight: 0.55), and HDL cholesterol at 8.6% (response weight: 0.49) making important contributions (**see table 8**). Vegetarian mixed dishes and palm oil were the key drivers of these associations for AST and triglycerides (both r = 0.20), while coffee, tea, and potatoes were the main drivers of the link for HDL cholesterol among women (**see supplementary table 5**).

We found similar DP scores for NAFLD proxy indicators in our sensitivity analysis when subjects with self-reported T2DM were excluded from the analysis. Males' DPs scores explained 3.3% of the variation in biomarkers of NAFLD and 11.0% of the variation in food category intake overall (**see table 9**). Females' DPs accounted for 4.5% of the overall variation in NAFLD biomarkers and 12.0% of the difference in dietary groups.

Table 7: Factor loadings of 30 food groups and the percentage of gender-specific food consumption variation explained by the RRR-derived dietary pattern scores for NAFLD biomarkers.

Adopted from my published paper (Osei et al. 2021)

	Men (n = 1,366)		Women (n = 2,321)	
Food group	**Explained variation (%)**	**Factor loading**	**Explained variation (%)**	**Factor loading**
Whole grain cereals	**36.5**	**0.33**	**25.3**	**-0.26**
Poultry	**26.6**	**0.28**	**35.1**	**-0.31**
Dairy products	**25.8**	**0.28**	13.4	-0.19
Coffee and tea	**23.8**	**0.27**	**44.9**	**-0.35**
Condiments	**21.4**	**0.25**	**33.0**	**-0.30**
Potatoes	**19.0**	**0.24**	**28.7**	**-0.28**
Margarine	**12.8**	**0.20**	**14.6**	**-0.20**
Olive oil	**13.6**	**0.20**	**18.3**	**-0.22**
Sodas and juices	7.9	0.15	6.1	-0.13

Food group	Men (n = 1,366)		Women (n = 2,321)	
	Explained variation (%)	Factor loading	Explained variation (%)	Factor loading
Sweet spread	7.8	0.15	6.6	-0.13
Rice and pasta	7.5	0.15	0.7	-0.05
Processed meat	5.5	0.13	5.7	-0.13
Palm oil	**32.7**	**-0.31**	**27.1**	**0.27**
Roots, tubers & plantain	**30.6**	**-0.30**	12.4	0.18
Fermented maize products	**23.5**	**-0.26**	6.1	0.13
Vegetarian mixed dishes	10.5	-0.18	**27.3**	**0.27**
Refined cereals	5.6	-0.13	7.4	0.14
Cakes and sweets	4.0	0.11	7.5	-0.14
Vegetables	3.9	0.11	9.2	-0.16
Meaty mixed dishes	4.1	-0.11	0.9	0.05
Legumes	3.9	-0.11	0.5	-0.04
Other oils	2.8	0.09	4.2	-0.11
Cooking fats	1.5	0.07	0.1	-0.01
Fish	1.6	-0.07	13.1	0.19
Fruits	1.4	-0.06	1.7	-0.07
Egg	0.9	0.05	5.9	-0.13
Vegetable soups, stews & sauces	0.3	0.03	0.1	0.01
Red meat	0.3	-0.03	1.1	-0.05
Nuts and seeds	0.4	-0.03	0.0	-0.01
Alcoholic beverages	0.1	-0.02	6.3	-0.13
Total explained variation in biomarker profile	**11.2**		**12.1**	

Factor loadings are correlations between food groups and the dietary pattern score. Figures in bold represent food items with relevant contribution to the dietary pattern score (≥20% explained variation).

Table 8: Percentage of gender-specific variance in response weights and NALFD biomarkers from the RRR-derived dietary pattern score.

Adopted from my published paper (Osei et al. 2021)

Biomarker	Men (n = 1,366)		Women (n = 2,321)	
	Explained variation (%)	Response weight	Explained variation (%)	Response weight
Cholesterol	**4.5**	**0.45**	0.3	0.09
LDL-Cholesterol	**4.2**	**0.44**	1.0	0.16
HDL-Cholesterol	2.9	0.36	**8.6**	**-0.49**
ASAT	**7.4**	**-0.58**	**12.3**	**0.58**

Biomarker	Men (n = 1,366) Explained variation (%)	Men (n = 1,366) Response weight	Women (n = 2,321) Explained variation (%)	Women (n = 2,321) Response weight
GGT	1.5	-0.26	0.3	0.09
Triglycerides	1.3	-0.24	**11.1**	**0.55**
C-reactive protein	0.3	-0.12	0.4	0.11
ALAT	0.2	0.08	2.2	0.25
Total	**2.8**		**4.5**	

Biomarkers with significant connections to the dietary pattern score (response weight >|0.35|) are shown in bold in the figures.

Table 9: Sensitivity analysis removing subjects with self-reported diabetes. Explained variation in gender specific dietary intake and factor loadings of dietary pattern scores, as well as explained variation in NAFLD biomarkers and response weights.

Adopted from my published paper (Osei et al. 2021)

	Men (n =1,250)		Women (n = 2,178)	
Food group	**Explained variation (%)**	**Factor loading**	**Explained variation (%)**	**Factor loading**
Whole grain cereal	34.3	0.32	24.93	-0.26
Coffee tea	25.07	0.28	44.64	-0.35
Condiments	21.03	0.25	33.11	-0.3
Dairy products	23.24	0.26	14.13	-0.2
Fermented maize products	22.09	-0.26	5.58	0.12
Margarine	16.35	0.22	15.2	-0.21
Olive oil	14.54	0.21	19.13	-0.23
Palm oil	30.83	-0.31	26.89	0.27
Potatoes	18.69	0.24	27.82	-0.28
Poultry	24.99	0.27	34.85	-0.31
Roots, tubers & plantain	30.95	-0.31	12.26	0.18
Vegetarian mixed dishes	9.38	-0.17	27.32	0.28
Total	**11.03**		**12.02**	
Biomarker	**Explained variation (%)**	**Response weight**	**Explained variation (%)**	**Response weight**
Cholesterol	5.46	0.46	0.25	0.08
LDL-Cholesterol	5.47	0.46	0.86	0.15
HDL-Cholesterol	2.84	0.33	8.31	-0.48
ASAT	7.76	-0.55	12.6	0.59
GGT	2.67	-0.32	0.39	0.10
Triglycerides	1.5	-0.24	10.93	0.55
C-reactive protein	0.3	-0.11	0.37	0.10
ALAT	0.07	0.05	2.35	0.26
Total	**3.25**		**4.51**	

3.2.4. Associations of FLI-related dietary patterns with T2DM

In **Table 10,** the relationships with T2DM are displayed per quintile and each 1 standard deviation of the DP scores obtained using the RRR. Higher DP score adherence among men was linked to a higher risk of T2DM. This was a common pattern across the DP score quintiles, and these relationships were more significant with each additional score-SD. The chances of T2DM were 55% greater per 1 score-SD (95% CI: 1.30-1.86) in the crude model. After adjusting for age and study location, the connection weakened (Model 1: 1.34; 95% CI: 1.04-1.73); after additional adjusting for socioeconomic and lifestyle characteristics, it remained steady (1.45; 95% CI: 1.10-1.93). The connections were weaker in women. After adjusting for demographic, socioeconomic, and lifestyle characteristics, the RRR-derived DP score positive association with T2DM per 1 score-SD rise was diminished (crude Model: 1.24; 95% CI: 1.07-1.44).

Table 10: Associations between gender-specific FLI-related dietary pattern scores with type 2 diabetes mellitus

Adopted from my published paper (Osei et al. 2021)

Model	Odds Ratio (95% confidence interval)											
	Q1	Q2		Q3		Q4		Q5		p trend	per 1 score-SD	
Men												
Diabetes/Control	17/256	22/251		31/243		46/227		43/230				
Crude	1	1.32	0.69-2.54	1.92	1.06-3.56	3.05	1.70-5.47	2.82	1.56-5.07	<.0001	1.55	1.30-1.86
Model 1	1	1.41	0.71-2.79	1.79	0.90-3.56	2.30	1.07-4.97	1.97	0.89-4.35	0.11	1.34	1.04-1.73
Model 2	1	1.25	0.62-2.49	1.58	0.79-3.16	2.14	0.98-4.68	2.03	0.90-4.60	0.07	1.45	1.10-1.93
Women												
Diabetes/Control	25/439	38/426		32/433		47/417		47/417				
Crude	1	1.57	0.93-2.64	1.30	0.76-2.23	1.98	1.20-3.27	1.98	1.20-3.27	0.005	1.24	1.07-1.44
Model 1	1	1.59	0.93-2.71	1.31	0.75-2.30	2.05	1.19-3.54	1.98	1.09-3.59	0.02	1.23	1.03-1.48
Model 2	1	1.28	0.74-2.21	1.03	0.58-1.83	1.64	0.94-2.84	1.65	0.90-3.02	0.07	1.16	0.95-1.42

By modeling the median of the dietary pattern scores as the independent variable, Q1 as quintile 1, etc., p-values for the trend were ascertained using logistic regression to create odds ratios (ORs) with 95% confidence intervals (CIs). Model 1: Age (years) and study site categorical adjustments; Model 2: Model 1 with weekly physical activity (METs), daily caloric intake (kcal), education (4 categories), and smoking status.

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3.2.5. Associations of biomarkers-related dietary patterns with T2DM

The chances of T2DM across quintiles and per 1 SD of the RRR-derived DP scores related to NAFLD biomarkers are shown in **table 11** with sex-specific stratification. In the crude model there was positive association between DP score and T2DM status (P for trend across quintiles = 0.0002; OR per 1 score-SD increase: 1.42; 95% CI: 1.20-1.68). However, after accounting for anthropometry, socioeconomic status, lifestyle factors, and demographics, this connection was reduced to zero. The relationships between quintiles and T2DM status were not clearly linear, in contrast to men (p for trend >0.05). Positive relationships ranged from 8% higher chances of T2DM in the crude model (95% CI: 0.93-1.25) to 30% higher odds of T2DM in Model 3 (95% CI: 0.99-1.71) per 1 score-SD increase.

Table 11: Associations between gender specific biomarker-related dietary pattern scores with type 2 diabetes mellitus

Adopted from my published paper (Osei et al. 2021)

Model	Odds Ratio (95% confidence interval)											
	Q1	Q2		Q3		Q4		Q5		p trend	per 1 score-SD	
Men												
Diabetes/Control	15/258	27/246		33/241		47/226		37/236				
Crude	1.00	1.89	0.98-3.63	2.36	1.25-4.44	3.58	1.95-6.57	2.70	1.44-5.04	0.0002	1.42	1.20-1.68
Model 1	1.00	1.91	0.97-3.76	2.06	1.00-4.22	2.42	1.07-5.50	1.64	0.72-3.75	0.578	1.15	0.89-1.48
Model 2	1.00	1.76	0.89-3.50	1.80	0.86-3.75	2.07	0.90-4.78	1.44	0.61-3.40	0.743	1.13	0.86-1.49
Model 3	1.00	1.62	0.81-3.22	1.46	0.69-3.10	1.70	0.72-4.01	1.21	0.50-2.89	0.962	1.07	0.81-1.42
Women												
Diabetes/Control	37/427	38/426		36/429		36/430		44/420				
Crude	1.00	1.03	0.64-1.65	0.97	0.60-1.56	0.91	0.56-1.48	1.21	0.77-1.91	0.592	1.08	0.93-1.25
Model 1	1.00	1.24	0.76-2.05	1.63	0.84-3.14	1.46	0.73-2.92	1.69	0.84-3.39	0.229	1.35	1.05-1.73
Model 2	1.00	1.16	0.70-1.94	1.39	0.69-2.79	1.20	0.57-2.52	1.40	0.67-2.93	0.522	1.29	0.99-1.68
Model 3	1.00	1.11	0.66-1.86	1.32	0.65-2.67	1.20	0.57-2.57	1.42	0.67-3.02	0.422	1.30	0.99-1.71

By modeling the median of the dietary pattern scores as the independent variable, Q1 as quintile 1, etc., p-values for the trend were ascertained using logistic regression to create odds ratios (ORs) with 95% confidence intervals (CIs). Model 1: Age (years) and study site categorical adjustments; Model 2: Model 1 with weekly physical activity (METs), daily caloric intake (kcal), education (4 categories), and smoking status.

3.2.6. Associations of LCD score, total energy, and macronutrient intake with HbA1c

Table 12 shows the relationships between HbA1c and the LCD score, total energy intake, and macronutrient intakes by diabetes status. After adjusting for sociodemographic, lifestyle variables, and fibre diet, there was no significant correlation between the LCD score and HbA1c among patients with T2DM (model 2). While there were statistically significant associations in the subgroup without T2DM, the corresponding beta-coefficients per 1 SD increase in the outcome variables were small, ranging from |0.01| to |0.04|. The point estimates in the subgroup with T2DM were similar, although they were not statistically significant. All exposures of interest, including the low-carb diet score, showed this lack of connection. The complete-case dataset also yielded the same results (**see table 13**).

Table 12: Linear associations of low-carb diet score, total energy intake and the intakes of macronutrients with log transformed HbA1c in 5,989 Ghanaian adults, by diabetes status.

ln (HbA1c)		Crude model		Model 1		Model 2	
	SD	ß (95% CI)	p-value	ß (95% CI)	p-value	ß (95% CI)	p-value
Diabetes (n=662)							
Low-carb diet score (per 1 SD)	7.6	-0.002 (-0.03, 0.03)	0.881	0.02 (-0.01, 0.05)	0.311	0.02 (-0.02, 0.05)	0.370
Energy intake (per 1 SD) (kcal/day)	1090	-0.02(-0.05,0.10)	0.204	-0.01(-0.04,0.02)	0.391	0.05 (-0.02,0.12)	0.157
Carbohydrate (per 1 SD) (energy%)	9.7	0.01 (-0.02, 0.04)	0.533	-0.01 (-0.04, 0.02)	0.619	-0.01 (-0.05, 0.02)	0.494
Protein (per 1 SD) (energy%)	2.7	0.01 (-0.02, 0.03)	0.648	0.02 (-0.01, 0.05)	0.116	0.02 (-0.02, 0.06)	0.385
Total fat (per 1 SD) (energy%)	8.8	-0.01 (-0.03, 0.02)	0.653	0.002 (-0.03, 0.03)	0.906	0.01 (-0.03, 0.05)	0.569
No diabetes (n=5,236)							
Low-carb diet score (per 1 SD)	7.8	0.03 (0.02, 0.04)	<0.0001	0.02(0.01, 0.02)	<0.0001	0.01 (0.003, 0.02)	0.007
Energy intake (per 1SD) (kcal/day)	1178	-0.01(-0.01,0.001)	0.073	-0.002(-0.01,0.004)	0.505	0.01(-0.001,0.03)	0.062
Carbohydrate (per 1 SD) (energy%)	9.2	-0.03 (-0.3, -0.02)	<0.0001	-0.01 (-0.02, -0.01)	<0.0001	-0.01 (-0.01, 0.0004)	0.037
Protein (per 1 SD) (energy%)	2.7	0.04 (0.03, 0.04)	<0.0001	0.02 (0.01, 0.02)	<0.0001	0.01(0.01, 0.02)	0.0003
Total fat (per 1 SD) (energy%)	8.2	0.02 (0.01, 0.02)	<0.0001	0.01 (0.005, 0.02)	0.0004	0.01 (0.0001, 0.01)	0.046

Beta-coefficient (β), 95% confidence intervals (CIs) and p-values were calculated by linear regression. Model 1 accounted for age (years), sex, and study site (5 categories). Model 2: Model 1+ education (4 categories), smoking (yes/no), physical activity (MET-h/week), and fibre diet; SD: standard deviation.

Table 13: Linear associations per 1 standard deviation (SD) of total energy intake and the intakes of macronutrients with log-transformed HbA1c, by diabetes status in the complete-case dataset (N=3,361)

ln (HbA1c)	SD	Crude model		Model 1		Model 2	
		Std. ß (95% CI)	p-value	Std. ß (95% CI)	p-value	Std. ß (95% CI)	p-value
Diabetes (n=378)							
Low-carb diet score	7.3	-0.001 (-0.03, 0.03)	0.976	0.02 (-0.02, 0.05)	0.363	0.03 (-0.01, 0.07)	0.184
Total Energy (kcal/day)	837	-0.03 (-0.07, 0.01)	0.114	-0.02 (-0.06, 0.02)	0.271	0.03 (-0.03, 0.10)	0.327
Carbohydrate (energy%)	9.9	0.01 (-0.02, 0.04)	0.678	-0.01 (-0.04, 0.02)	0.621	-0.02 (-0.06, 0.02)	0.311
Protein (energy%)	9.1	0.01 (-0.02, 0.04)	0.479	0.03 (0.001, 0.07)	0.087	0.03 (-0.01, 0.07)	0.197
Fat (energy%)	2.6	-0.01 (-0.04, 0.02)	0.704	-0.003 (-0.03, 0.03)	0.986	0.02 (-0.02, 0.05)	0.424
No diabetes (n=2,983)							
Low-carb diet score	14.1	0.03 (0.02, 0.04)	<0.0001	0.02 (0.01, 0.02)	<0.0001	0.01 (0.01, 0.02)	<0.0001
Total Energy (kcal/day)	824	0.001 (-005.0, 0.006)	0.838	-0.001 (-0.01, 0.01)	0.974	0.02 (0.004, 0.03)	0.007
Carbohydrate (energy%)	8.9	-0.02 (-0.3, -0.2)	<0.0001	-0.01 (-0.01, 0.004)	0.003	-0.01 (-0.02, -0.003)	0.004
Protein (energy%)	2.6	0.04 (0.03, 0.04)	<0.0001	0.02 (0.01, 0.02)	<0.0001	0.02 (0.01, 0.02)	<0.0001
Fat (energy%)	8.1	0.01 (0.01, 0.02)	<0.0001	0.01 (0.003, 0.01)	0.0009	0.01 (0.003, 0.02)	0.004

Beta-coefficients (β), 95% confidence intervals (CIs) and p-values were calculated by linear regression. Model 1 accounted for age (years), sex, and study site (5 categories). Model 2: Model 1 + education (4 categories), smoking (yes/no), physical activity (METs-h/week), macronutrient intakes (carbohydrate/protein/fat).

3.2.7. Associations of the LCD score with diabetic complications

Table 14 shows the associations between the low-carb diet score and diabetes complications among individuals with T2DM (n = 662). In the final model, we observed a 5% reduced chance of self-reported stroke for each SD increase in the low-carb diet score (95% CI: 0.91, 0.99; p = 0.014). In the complete-case dataset, the corresponding OR was 0.93 (95% CI: 0.87, 0.98; p = 0.004) (**see table 15*).*** Both in the imputed dataset and the complete-case dataset, there were no relationships between the low-carb diet score and PAD, CAD, or nephropathy (**Table 14, Table 15**).

Table 14: Multiple-adjusted associations of the low-carb diet (LCD) score with diabetic complications among 662 participants with T2DM

Exposure	Cases/ non-cases	Crude model			Model 1			Model 2		
		OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Low-carb diet score										
Peripheral artery disease	64/598	0.99	(0.87, 1.13)	0.902	0.99	(0.87, 1.12)	0.901	0.99	(0.99, 1.14)	0.925
Coronary artery disease	74/588	1.01	(0.96, 1.06)	0.730	1.01	(0.96, 1.07)	0.618	1.04	(0.98, 1.10)	0.209
Self-reported stroke	68/594	0.91	(0.88, 0.95)	<0.0001	0.95	(0.92, 0.99)	0.013	0.95	(0.91, 0.99)	0.014
Nephropathy	157/505	1.08	(0.98, 1.20)	0.114	1.09	(0.98, 1.21)	0.122	1.09	(0.98, 1.21)	0.126

Odds ratio (ORs), 95% confidence intervals (CIs) and p-values were calculated by logistic regression. Model 1: adjusted for age (years), sex, and study site (categorical). Model 2: Model 1 + education (4 categories), energy intake (kcal/d), smoking (yes/no), physical activity (MET-h/week).

Table 15: Multiple-adjusted associations of the low-carb diet (LCD) score with diabetes complications among participants with diabetes in the complete-case dataset (n=378)

Outcome	Cases/ Controls	Crude OR	Crude (95% CI)	Crude p-value	Model 1 OR	Model 1 (95% CI)	Model 1 p-value	Model 2 OR	Model 2 (95%CI)	Model 2 p-value
Peripheral artery disease	36/342	0.97	(0.93, 1.02)	0.233	1.00	(0.95, 1.05)	0.991	1.01	(0.96, 1.06)	0.786
Coronary artery disease	55/323	0.98	(0.94, 1.02)	0.269	1.00	(0.96, 1.04)	0.834	1.00	(0.96, 1.05)	0.938
Self-reported stroke	58/320	0.90	(0.87, 0.94)	<0001	0.93	(0.89, 0.98)	0.003	0.93	(0.87, 0.98)	0.004
Nephropathy	92/286	0.99	(0.94, 1.00)	0.060	0.99	(0.96, 1.03)	0.579	0.99	(0.96, 1.03)	0.631

Odds ratios (ORs), their 95% confidence intervals (CIs), and p-values were calculated by logistic regression.

Model 1: adjusted for age (years), sex, study site (categorical).

Model 2: Model 1 + education (4 categories), energy intake (kcal/d), smoking (yes/no), physical activity (METs-h/week), and dietary fibre (g/d).

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4. DISCUSSION

This thesis aimed at gaining insights into the relationships of dietary behaviour with T2DM among African populations under transition. According to the conceptual model for the burden of T2DM among African populations (Agyemang et al. 2015) (**see figure 15**), the first step comprised a comprehensive overview and synthesis of the population-based evidence on health exposure–outcome relationships among migrant groups in Germany. This included genetic factors, contextual factors and early-life experiences, which form the basis for changes in lifestyle, such as diet, physical activity, smoking, alcohol consumption, and healthcare uptake. Possibly mediated by epigenetic processes and biochemical pathways, such as inflammation and fatty liver disease, this plethora of risk factors contributes to the differential burden of T2DM among sub-Saharan African populations living in rural and urban areas of the subcontinent and among migrants in Europe. Based on this evidence synthesis, this dissertation continued to dissect the role of dietary behaviour for glycaemic control, for aetiological pathways of T2DM through NAFLD, and for diabetic complications. Therefore, this study offers vital information that may support the prevention and management of T2DM among SSA populations under transition.

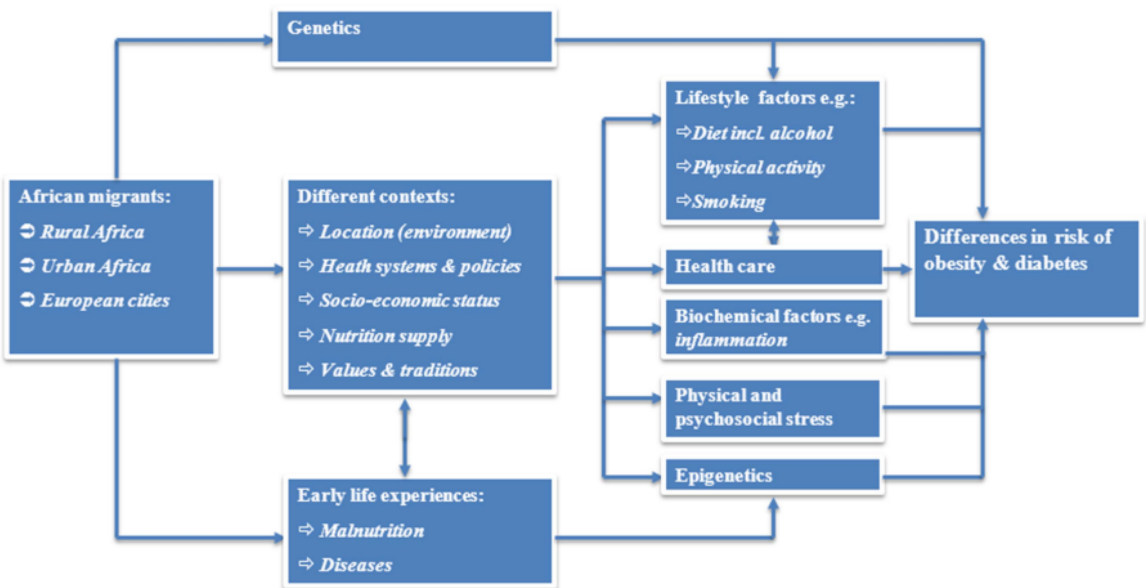

Figure 15: A conceptual model for the development of type 2 diabetes among African populations under transition (Agyemang et al. 2015).

4.1. Summary of key findings

While the findings of our systematic review provided valuable insights on risk factor-diseases association among migrants, we found low quality evidence on chronic diseases (such as T2DM) among migrants. Our findings also showed steady associations of demographic, socioeconomic and partly migration-related factors with ill health among migrants in Germany, while biological and lifestyle factors were barely assessed.

Again, based on prior information on the relationship between NAFLD and T2DM, the second objective applied the use of RRR method to create sex-specific DPs related with two proxy makers (FLL; liver enzymes, blood lipids and CRP) of NAFLD and evaluated the association with the DPs with the odds of T2DM. Our findings showed that the DPs related with FLI were characterised by high consumption of modernised diet and DP was positively associated with the odds of T2DM among men while among women the results were inconsistent. For DPs related with liver enzymes, blood lipids and CRP, they showed implausible association with odds of T2DM among women in the study population.

Finally, the third objective created LCD score among the Ghanaian population and determined the associated of the dietary score with glycaemic control using HbA1c as an indicator. Again, the present study determined the associations of LCD score with glycaemic control and T2DM complications. There were no significant associations between LCD score and HbA1c among participants with T2DM. This may be as a result of following the dietary advice given after detecting diabetes. In contrast, among participants without T2DM, these scores showed positive associations with HbA1c. Finally, the associations of the LCD score with diabetic complications were inconsistent.

4.1.1. Migration and Non-Communicable Diseases

In our literature search, NCDs was the most studied, constituting over two-thirds of the evidence based on migrant health. However, studies concentrated on mental health with little focus on cardiometabolic diseases such as T2DM. Also, the quality of data on migrant health are often unreliable and this might be due to the fact that data gathered are mostly from clinical records and not meant for use in research (Modesti et al. 2020). Paucity of data in terms of migrant health studies has been largely attributed to inadequate funding for long-term epidemiological investigations and basic scientific research to evaluate the aetiology and the important evidence in migrant population (Agyemang et al. 2021). Our findings now demonstrate the evidence that a small number of epidemiological research studies have studied the relevance of chronic diseases among migrant group especially in European countries.

It is also important to note that while communicable diseases like the human immunodeficiency virus (HIV)/acquired immune deficiency syndrome (AIDS), malaria, and tuberculosis have continued to pose significant challenges in sub-Saharan Africa (SSA), it is now clear that NCDs like T2DM are undoubtedly escalating the myriad burdens that countries in this region are already carrying (Tuei et al. 2010). In a meta-analysis that assessed migrants and refugees' health from 2003 to 2016 in Europe, it was reported that about 51% of migrants reported chronic diseases. And the highest prevalence was found among Africans, South Asians and Caribbeans while migrant from Iraq and Afghanistan had high rate of coronary heart diseases (Pavli and Maltezou 2017). Interestingly, in our study, the observed association among exposure-outcome investigated appeared to be peculiar among geographic origin of the study population with chronic diseases being the most research among African migrants. Studies have reported that diseases or illness are acquired either through geographic or environmental origin but in some situations, the origin of the immigrant population might have a strong effect on their health status (Gushulak and MacPherson 2006). This may possibility explain the dominance of the addition of many articles about risk factor-disease association from one large study among Ghanaian migrants. NCDs are experienced differently across geographical, ethnic, and racial lines. In some Asian societies, practising sport activities in public spaces, gyms or public parks are seen as inappropriate for women and this has led to higher rate of obesity among these women. It is therefore not surprising to higher prevalence of T2DM among women from Asian ethnicity upon migration due to less exercise (Davies et al. 2011).

Furthermore, changes in new environment can manifest patterns of disease risk which were formerly concealed (Habib and Saha 2010). Upon arrival, migrants may appear to be healthy. And this has been attributed to the "healthy migrant effect", which means the young and healthy migrant are likely to travel or survive difficulties in the journey (Davies et al. 2009). However, migrants' may lose protection as they adapt to the changes in lifestyle, socioeconomic and demographic (Davies et al. 2011). In affluent countries, trade policies may promote big food corporation that restricts staple foods to processed foods and refined carbohydrates, creating obesogenic environment that increases the risk of obesity and T2DM (Mendenhall et al. 2017). Again, dietary practice and lifestyle which were different from premigration may have changed upon migration and this can unmask predisposition to the chronic disease like T2DM (Habib and Saha 2010). It is therefore unexpected that some studies have stated that prevalence of T2DM is higher among migrant population in Europe compared to populations in their country of origin (Agyemang et al. 2021).

It is an undeniable fact that the determinants of T2DM among migrants are multifaceted and may include premigration factors, post-migration factors, and genetic tendencies which may influence socioeconomic situations, behavioural and biological factors. And this eventually affect the action of insulin and the development of T2DM (Agyemang et al. 2021). The research found that the most reliable and consistent risk factors for the health of migrants in Germany were socioeconomic and demographic characteristics.

Although low socio-economic status (SES) has been constantly associated with T2DM in many studies (Davies et al. 2009; Kyrou et al. 2020), our findings showed a positive association of occupation with cardiometabolic diseases among migrants. It is assumed that when migrant find themselves in host countries, their SES may decline, and this may affect the affordability of certain commodities as they used to in their home countries (Davies et al. 2009). However, migration could be advantageous in terms of improving SES and this can also influence unhealthy life among migrant (Agyemang et al. 2021). This is because people with higher SES may have higher probability of eating energy dense foods and be physically inactive as standard of living improves (Addo et al. 2017).

Furthermore, the association of age with all diseases especially NCDs, corroborate with many studies which have reported that as people age, they become susceptible to diseases as their immune system is weak against various diseases (Ajaero et al. 2021).Yet, in a migrant research comparing African with T2DM living in France with their compatriot in Cameroon, NCDs such as T2DM was diagnosed in an early age among migrants in France compared to those in Cameroon (Choukem et al. 2014). Although late diagnosis could account for this observation among those in Cameroon, they did not exclude the fact that environmental influence on metabolic parameters may play a role. Interestingly, little is known about health behaviours in aging migrants, few studies have reported that migrant are less likely to participate in physical activities and consume more fruits and vegetables which can contribute to NCDs (Kristiansen et al. 2016). In our studies, the ability to identify sociocultural determinant affecting aging was restricted to three articles, which focused on perceived discrimination. However, it is paramount that studies are done to address more intersecting characteristics affecting healthy aging among migrants.

Acculturation in terms of length of stay has been positively associated with obesity and T2DM among migrants (Organization 2019). Again, upon arrival migrant enter into acculturation process and may tend to adopt western lifestyle habits such as and sedentary lifestyle, which worsens with the length of residence and increases the risk of obesity (Davies et al. 2011). Also, demand for more labour and socio-economic challenges among migrants may hinder their ability to participate in leisure activities leading to physical inactivity and eventually obesity (Combes et al. 2019; Commodore-Mensah et al. 2016). In line with our findings, a study on ethnic diverse sample of US migrants cohort reported that high increased length of stay (>10 years) was associated with higher prevalence of cardiometabolic risk (Commodore-Mensah et al. 2016). Our findings showed no association with language barrier, yet studies have reported that language barrier could be a major issue for healthy life choice among migrants (Organization 2019).

It is also important to acknowledge biological interaction between two diseases for a syndemic to occur. Epidemiological studies have shown that depression and T2DM may share biological origins especially through behavioural patterns which may include eating of energy dense foods, reduced physical activities, and the use of antidepressants that boost weight gain (Mendenhall et al. 2017). Another potential mechanism is the association of increased stress with inflammation and insulin disorder. Although, none of our findings showed association between these two-disease outcome, similar exposures which included behavioural and environmental risk were associated to both mental and cardiometabolic diseases or T2DM.

Again, like many other studies, positive association of epigenetic variations with all diseases especially, cardiometabolic diseases confirms the vital role genes in determining patterns of DNA methylation of metabolic parameters, although this also has been associated with other factors such as environmental exposures (Elliott et al. 2013). Some studies have reported that irrespective of where migrant may find themselves (home or abroad) they may demonstrate high prevalence of T2DM. For instance, Asian population living in home country and abroad showed high prevalence of T2DM when compared with control group of different ethnicities (Garduño-Diaz and Khokhar 2012). One of the main factors attributed to this observation was the implication of genes-environmental interactions. Likewise excessive adiposity is a significant risk factor for T2DM, mainly due to its ability to influence insulin resistance (Garduño-Diaz and Khokhar 2012). General obesity may not be a risk factor for many groups; however, some ethnic migrants have consistently shown higher BMI, and this has been associated with T2DM (Misra and Ganda 2007). This was observed among Japanese migrant with excess central abdominal fat (Misra and Ganda 2007). Recently, there is contention about whether it is necessary to modify the anthropometric measurements for SSA from the established conventional WHO cut-offs given that T2DM is prevalent even in thin persons (Tuei et al. 2010). Interestingly, among migrants the radically varied dietary intakes and physical activity patterns in the place of migration have been substantially responsible for the difference in body composition while having a common West African heritage (Misra and Ganda 2007).

Contrary to many studies that associated lifestyle behaviour such smoking to cardiometabolic diseases, our findings showed no association between the two (Ambrose and Barua 2004; Kondo et al. 2019). However, unhealthy dietary practice was associated with cardiometabolic diseases. Migrants may have high probability of being exposed to vulnerable lifestyle such as smoking, taking excessive and unhealthy food. This may be due to the disposal of income or high level of stress which may trigger the urge to smoke (Rawal et al. 2021; Sahle et al. 2021). A popular finding is the high prevalence of smoking especially in female migrants compared to the population in home country. This evidence was seen among Turkish female migrants in Europe who reported higher prevalence of smoking compared with females in Turkey. This observation was attributed to the influence of westernization on smoking behaviour among these women (Uitewaal et al. 2004). However, lack of association between smoking and cardiometabolic diseases among migrants may partially agree with other research especially those in the United State which have reported low prevalence of smoking among migrants compared to the autochthonous population (Bosdriesz et al. 2013; Khlat et al. 2019). This has also been related with reduced risks of smoking related diseases and has put forward as a significant factor for migrant health advantages. Again, this paradox could lie in the fact that smoking reduces weight, increases appetite-suppressant effect of nicotine, thus leading to high metabolic rate and high energy expenditure thus contributing to decreased risk of chronic diseases (Sahle et al. 2021).

Evidence shows that these DPs are common among migrants and may possibly account for the high prevalence of T2DM among them (Agyemang et al. 2021). Adoption of new diet by migrants have been largely attributed to the variability of new environment and food preparation practices as well as the non-availability of traditional foods (often characterised by whole grains, stable foods, fruits and vegetables) in host country (Garduño-Diaz and Khokhar 2012; Sturkenboom et al. 2016). Lack of availability of some traditional diets have affected some diet that have been thought to be related to one's identity. Migrants may then have to make a distinct shift from either traditional diet to host diet or combine both (Osei-Kwasi et al. 2023). This was observed in an evidence based dietary habit literature which reported that migrants combine traditional staple foods (such as rice, bread) with some processed food element from the European diet (Murphy et al. 2017). A typical example is the substitution of traditional vegetarian diet with lacto-vegetarian or ready to eat food(pizza and processed foods) by South Asian migrants in UK and this was associated with the over risk of T2DM (Garduño-Diaz and Khokhar 2012). It is therefore undeniable fact that as nutritional quality of diet depreciate, ethnic groups may become more vulnerable to diet-related diseases similar to those affecting the common population in Europe, such as obesity and T2DM (Gilbert and Khokhar 2008). Our findings therefore corresponds with the universal observation that unhealthy diet is associated with T2DM and other NCDs (Himmelgreen et al. 2014).

4.1.2. Dietary patterns and T2DM

It is therefore important that dietary modification is regarded as a crucial component of T2DM therapy since it has an impact on numerous metabolic and physiological circuits (Newson and Parody 2022). Now, the use of DPs has resolved concerns about the interactions between foods and nutrients and has provided a more realistic picture of an individual's eating behaviour and the association of chronic diseases such as T2DM (Marques-Vidal et al. 2018).

Dietary patterns and proxy markers of NALFD for T2DM risks

Using FLI as proxy marker as a first approach for NAFLD, DPs generated were characterised by increased intakes of poultry, whole-grain cereals, coffee and tea, condiments, potatoes, alcoholic beverages, margarine and fish, and inverse intake of fermented maize products, refines cereals, roots, tubers and plantains and palm oil. These DPs were similar among males and females and correlated with FLI. Also, DPs related with liver enzymes and blood lipid showed similar intake of food, except with the increase consumption of olive oil and diary product which were not part of FLI-related DPs. Most of the food intakes generated in the RRR-DPs (potatoes, condiments, margarine, poultry, and dairy products) shows the nutritional shift from typical traditional diet to modernised diet among these SSA population under transition. The reflection of dietary changes is associated with acculturation following urbanisation and migration. Interesting, studies have reported that DPs may contribute to the development of NAFLD and also form an integral part of its treatment (Kalafati et al. 2019; Salehi-Sahlabadi et al. 2021). This is because nutrient intake has effects on inflammatory pathways with the body and some food may contain pro-inflammatory compounds which may be common in the diet of a large population (Abdallah et al. 2023). For instance, a typical Mediterranean diet characterised by high intake of fruit, vegetables, whole grains, legumes and low intake of fat, dairy product and red meat have been proven to have a protective property against NAFLD. These benefits may be due to phytochemicals and antioxidant properties in fruit and vegetables which reduces oxidative stress and insulin resistance, the major factors to the onset of NAFLD (Aller et al. 2020; Hassani Zadeh et al. 2021). While accumulating evidence suggests that high-caloric diet, trans-fat and saturated fatty foods as well as foods rich in fructose promote obesity and the incidence of NAFLD (Salehi-Sahlabadi et al. 2021). Partly in line with a recent evidence from a meta-analysis, our findings identified positive correlation for some foods (such as dairy products, condiments and potatoes) with FLI which are typically affiliated with westernised DP, and these were associated with NAFLD risk (Hassani Zadeh et al. 2021). Also, foods like coffee and tea showed a positive correlation with FLI and this appears to go against the observed reduced risk of high liver enzymes associated with habitual intake of coffee and tea (Fan and Cao 2013). Research have shown that tea contains phytochemicals and antioxidants which reduce hyperglycaemia and improves insulin sensitivity (Birerdinc et al. 2012; Hassani Zadeh et al. 2021b). For coffee, scientist suspect that polyphenols and the caffeine help prevent hepatic damage (Perumpail et al. 2017). However, beverages like coffee and tea may not be taken in isolation, they may be sweetened by sugar and condensed milk, and this is usually not captured in the dietary assessment. Evidence was seen in a qualitative study among 20 focus group in Uganda where women cut down family expenditure by adding sugar cane molasses to sweeten tea (Kiguli et al. 2019). Thus, high glycaemic loads of refined sugar and condensed milk may possibly explain the positive corelation of coffee and tea with liver enzymes, blood lipids and FLI. Furthermore, trans fatty acid occurs naturally in certain foods such as dairy products and margarines because of bacterial metabolism and hydrogenation, and this have been found to increase blood lipid ratios and inflammatory markers (Zivkovic et al. 2007). In confirmation with our findings, a large Chinese cohort using RRR-derived DP related to inflammatory markers and characterized by increased intakes of sugar-containing foods reported a positive associated with NAFLD (Xia et al. 2020). Again, meat which is a major component in westernised DP may provide important nutrients such as iron, zinc and vitamin12 (Zelber-Sagi et al. 2018). However, some studies have suggested that animal protein sources are highly associated with the risk of NAFLD (Noureddin et al. 2020; Zelber-Sagi et al. 2018; Zhang et al. 2023). This is also due to the fact that meat contains saturated fat acids (SFA) and cholesterol which may be harmful to NAFLD patients (Zelber-Sagi et al. 2018). Interestingly, some studies have confirmed the benefit of white meat (poultry) and fish as part of healthy diet, however this might not always be the case (Abenavoli et al. 2019; Giraldi et al. 2020). In our studies, poultry and fish were positively correlated with both FLI and NAFLD biomarkers. Recent findings from a northern and southern Chinese cohort reported strong benefit against the risk of NAFLD after replacing animal protein such as processed meat, red meat and poultry with plant-based proteins like nuts, legumes and whole grain (Zhang et al. 2023). Association of poultry with NAFLD, may be due to the fact that poultry is not mostly examined individually but combined with overall consumption of meat in most studies and on the other hand, white meat are associated with westernised DPs (Hassani Zadeh et al. 2021). Thus, the overall effect of poultry with NAFLD remains unclear. However, fish contains omega-3-polyunsaturated fatty acids which is known to be advantageous in the prevention of NAFLD (Giraldi et al. 2020). Yet, the rise in the contamination of fresh water and sea fish by environmental toxins causes adverse consequences on the human health and this may contribute to the progression of liver diseases, hence possibly explaining our findings (Treviño and Katz 2018). Again, taking into consideration these findings our studies endorse the recommendation of intake of low glycaemic foods and saturated foods. Considering that NAFLD is possibly considered as additional features of Mets, we assumed that NAFLD-related DPs could affect the risk of T2DM among these population. Although DPs were similar among males and females, males had stronger adherence to the DPs and showed higher odds for T2DM compared to females. The strong adherence to the DP by males could reflect the influence by social and cultural context surrounding food and eating practices among these African population. Mostly men from this region are considered the head of households and given the first and best portion of the food particularly meat and fish while women and children share the subservient portions (Kiguli et al. 2019). This may also be the reason for high consumption of food seen among males compared to females in **figure 13**. Another possible explanation may also lie in fact that females of African ancestry tend to have more subcutaneous and less visceral fat at any given level of BMI than men. Thus, may metabolically tolerate a certain degree of obesity as compared to males (Goedecke and Olsson 2020).

Additionally, Frank et al. used RRR to construct a DP that was favourably correlated with serum lipids and negatively correlated with adiponectin in an urban Ghanaian case-control study. This pattern, which was defined by increased consumption of starchy foods and a reduced intake of fruits and vegetables, was associated with higher risk of T2DM. The DP shares some similarities with the DPs in this current analysis (Frank et al. 2015).

In our second approach, the inconsistent association between DP related with liver enzymes, blood lipids and CRP with T2DM may lie in the fact that the choice of biomarkers may not be specific enough to operationalise NAFLD, as they also show other metabolic pathways to T2DM, including chronic inflammation and dyslipidaemia (Feinglos and Bethel 2008). Interesting, in our model, the loss of association after accounting for lifestyle factors such as physical activities, smoking and alcohol intake endorses the fact that multiple factors act in the developmental pathway between NAFLD and T2DM. Although the amount of significant alcohol intake in patient with NAFLD is unclear (Chalasani et al. 2012), studies have shown that the absorption of increased microbial metabolite in the intestines as a result of alcohol intake is toxic to the liver (Perdomo et al. 2019). Several studies have shown that changing one's lifestyle such as increase physical activity and healthy eating has been shown to improve insulin sensitivity and reduce post-prandial hyperinsulinemia, hence decrease the risk of T2DM (McCarthy and Rinella 2012; Moore et al. 2020). Lifestyle modification improves liver enzymes such as ALT and slowed the progression of the diseases (Chalasani et al. 2012).

4.1.3. Associations of the low-carb diet (LCD) score with glycaemic control

Another popular dietary pattern score that has gained strong support and media attention over the years is the LCD. One main reason is its ability to cause weight loss and improved insulin sensitivity (Dyson 2015). Many studies have proven the beneficial effect of this diet on glycaemic control among people with T2DM (Ahmed et al. 2020; Chen et al. 2022; Sievenpiper 2020b; Stern et al. 2004). A meta-analysis that evaluated the effectiveness of LCD for T2DM management reported improve HbA1c, TG and HDL concentration among participant with T2DM (Meng et al. 2017). Again, in a 2-weeks short-term supervised inpatient study, limited energy consumption using LCD resulted in weight loss, improved insulin sensitivity and glycaemic control (mean haemoglobin A1c reduced by 0.5%) among obese patient with T2DM (Boden et al. 2005).

In our studies, macronutrient and LCD diet showed no association with HbA1c among participants with T2DM. The use of LCD diet may carry implications for other component of diet such as fat, proteins and fibre, unless controlled (Ma et al. 2006). Our findings may agree with studies that have suggested that the benefit of LCD diet lies not only in the reduction of carbohydrate but also in the overall quality of the carbohydrate and the diet (Dyson 2015).

Mostly, studies fail to address the type of carbohydrate included in LCD and this might have affected studies outcome. Dietary carbohydrate with low glycaemic index (GI) such as fruits, vegetables, whole grains and legumes have shown protective effect against the risk of T2DM (Dyson 2015) while high intake of high-GI foods such as refined carbohydrate incite rapid increase in glucose concentration and has been associated with T2DM risks (Maki and Phillips 2015). Indeed, some research suggests that LCD would not satisfy this criterion because it restricts dietary options. Partially in line with our studies, the Nurses' Health study reported that stronger adherence to low carbohydrate high fat diet score was associated with high HbA1c among individuals with and without diabetes in their study (Churuangsuk et al. 2020).

The principal mechanism in which LCD improves glycaemic control lies in the reduction of insulin levels due to restriction of carbohydrate, thus allowing for lipolysis and the use of non-esterified fatty acids as substitute energy source (Ahmed et al. 2020). However, high plasma free fatty acid as a results of increased fatty acid oxidation has been associated with insulin resistance (Sidossis and Wolfe 1996). Studies have shown that free fatty acids in patient with NAFLD is the main contributor to liver triacylglycerol content either in the fasted or the fed state (Zivkovic et al. 2007). This may possibly explain the positive association of LCD with HbA1c with participants without T2DM.

Among non-diabetic individuals, few studies have investigated the role of LCD in glycaemic control and these findings contradict. A 6 weeks randomised control trail , showed improvement in fasting blood glucose and lipid profile among non-diabetic obese men after administering LCD (Sharman et al. 2004). Yet, a 3-days short-term intervention study on LCD among men under physiological conditions showed elevated postprandial plasma glucose and GLP-1 levels (Numao et al. 2012). It is noteworthy that although the duration of the intervention may affect the studies, the restriction of carbohydrate in a diet may affect result outcome.

4.1.4. Associations of the low-carb diet (LCD) score with diabetic complications

The impact of low-carb diet on cardio metabolic health is an ongoing debate. Some studies have reported that low-carb diet may increase blood lipid levels and lead to increased risk of cardiovascular disease (CVD) as they are associated with higher total and saturated fat intakes (Wang et al. 2023). While other studies have shown that LCD diet can help improve lipid profile that are indicative of atherogenic dyslipidaemia by encouraging an increase in HDL and a decrease in plasma triacylglycerol. The amount of carbohydrates consumed, and the sources of macronutrients may be the primary cause of discrepancies between our findings and those of earlier studies carried out in Europe. Recently, studies have indicated that paramount changes in macronutrient that is geared towards plant proteins and vegetable oil in low-carb diet are broadly accepted therapeutic patterns in the improving glycaemic control and CVD risk factors (Jenkins et al. 2022). Conversely, the replacement of carbohydrate by saturated fat particularly from animal source may have adverse effect on components of metabolic syndrome (Ebbeling et al. 2022).

Again, in our study, LCD scores showed no association with nephropathy a microvascular complication among participants with T2DM. In the nurse's health study, LCD showed no association with the risk of coronary heart disease among women. However, these advantages remain contentious as some studies have reported increase in more atherogenic and established lipids (LDL-cholesterol, non-HDL-cholesterol), targeted for cardiovascular risk in both, people with and without T2DM (Sievenpiper 2020). Increased dietary fat absorption or lipid metabolism may be the cause of this paradox (Creighton et al. 2018). Macrophages consume and process lipids mostly known as modifying LDL when exposed to a hyperlipidaemic milieu as a result of elevated lipolysis and low lipogenesis (Remmerie and Scott 2018; Schaftenaar et al. 2016). When these macrophages gather to form plaques in the sub-endothelium of the arteries, atherosclerosis may arise (Remmerie and Scott 2018). It is therefore important that a practical guidance of LCD focus on cutting back on refined carbohydrates and saturated fat intake while increasing plant proteins, and vegetables intakes.

4.2. Strengths and limitations

A significant benefit of this study is the representation of large sample size of genetically homogeneous community of Ghanaians living in various environments in Africa and Europe and the use of the same measurement techniques across all sites, gathering high-quality and comparable data (Galbete et al. 2018), however, the lack of heterogeneity of the population also limits the application of finding to other ethnic groups and African population.

Our systematic review however limited this disadvantage by representing heterogeneous migrant population with various health needs and experiences. Another advantage of the systematic review is the limitation of selection bias since studies were separately searched, screened, and retrieved by four authors. But there are some significant flaws with the review. First, majority of published studies included were cross-sectional and causal inference is thus restricted. Again, findings could be biased because we restricted our literature search to quantitative study types and only selected studies that focused on the main migration groups in Germany. Second, it's possible that we missed publications that weren't listed in either PubMed and LIVIVO or that weren't published in either German or English. Additionally, the inclusion of all types of migrant groups (refugees, legal migration, first, second, and third, re-emigration) and recruitment strategies (registered base, community oriented) complicated the generalisability of risk factor-disease relationships, limiting data comparability. Nonetheless, our review provides a thorough analysis of the links between exposure and outcomes regarding health risk among migrant groups.

As far as we are aware, this is the first research to investigate how diverse NAFLD-DPs affect the risk of developing T2DM among the Ghanaian population under transition. Of note, there aren't many studies in this field, thus the findings of the current study can make a significant addition to efforts to understand the role of nutrition in the development and treatment of NAFLD in association with T2DM. Despite that, it is important to recognise several limitations when analysing the outcomes of our research. The use of FLI as a proxy measure instead of a liver biopsy or imaging to define NAFLD may hide specific information about how severe a fatty liver is (von Eckardstein 2015). However, liver biopsy is invasive, uncomfortable, and technically impractical in extensive epidemiological research (Lim and Kim 2020). While, the FLI has demonstrated better agreement with the histology and imaging criteria for NAFLD, making it a viable predictor for a fatty liver (Olubamwo et al. 2019). At the same time, we acknowledge that further research is needed to confirm the FLI among communities in sub-Saharan Africa. Misclassification of NAFLD cannot be entirely ruled out because information on the presence of viral hepatitis was not provided in our investigation. However, our study offers novel understandings into the relationship between food and disease in T2DM in a large sub-Saharan adult sample. By projecting the FLI response variable onto the dietary classes as predictor variables, the DP building approach considers any possible connections between NAFLD and T2DM. We are also aware that this strategy has drawn criticism for the proxy measures it chose, which may only accurately represent T2DM's early clinical stages. In fact, prior research in Ghanaian adults suggests that elevated blood triglycerides are a significant risk factor for T2DM (Danquah et al. 2012; Frank et al. 2015). The final regression model for the association of FLI-related DP scores with T2DM did not consider the BMI and waist circumference since they are already embedded in the formula of FLI. However, this may have led to some residual confounding and overestimation of the observed DP-T2DM relationships.

Considering that some study participants with T2DM might have received treatment for their condition which may include lifestyle counselling, reverse causation cannot be completely excluded in our investigation.

Again, the use of Ghana-FPQ may not have captured absolute dietary intake. However, for the construction of the LCD score, it was useful in the ranking of participants according to their intakes. LCD score was not calculated based on absolute cut-offs as suggested by Halton et al. (Halton et al. 2006). Rather, according to the distribution of macronutrient intakes among the non-T2DM group to account for the imprecision of the assessment tool and to eliminate potential reverse causation among individuals with long-standing T2DM. Also, the main strength of the use of the LCD score lies in the realistic method for evaluating food patterns that considers the integration of another macronutrient instead of concentrating on a single nutrient that is never consumed alone. Again, impaired fasting glucose conditions was not accounted for in the control group, and this could dilute the effects. Notably, stroke was only self-reported, which could have led to measurement error and the low statistical power to detect effects. In the evaluation of CAD, coronary arteriography was not performed due feasibility however, the use of WHO Rose Angina Questionnaire has been proven to be a useful predictor for CAD by many epidemiological studies (Rahman et al. 2013). The HbA1c is a short-term measure of glycaemic control and is associated with many limitations in the African population. Limitation could be the level of haemoglobin, episodes of malaria infection, and anti-retroviral therapy. Imputed data might have caused possible bias on reported risk estimate, yet similar results were obtained in the complete case data set. Finally, our findings were not consistent with many data. However, our study differs from the previous studies in its design.

4.3. Recommendations for policy makers and future research

4.3.1. Integration of migrant health in public health and health services

The integration of migrant health in public health and health services is becoming essential especially in European countries where the number of foreign populations is increasing (Carballo et al. 1998). Yet there are difficulties in the gathering of information on migrants as well as challenges in the conceptual and methodological research in migrant. For example, Germany, do not formally collect ethnic data due to the concerns that it may induce memories of categorisation or incite racism (Rechel et al. 2013). However, it is undisputable fact that this account for the lack of understanding in migrant health and possibly insufficient evidence on specific diseases such as T2DM which is a significant cause of morbidity and death among migrant population. Our study recommends the collection of routine health data among migrants which can result in the update of food consumption, disaggregated by ethnicity, to reflect the requirements of migrant communities in health care plans and provide opportunity for research to explore the associations of dietary behaviours and its impact on NCDs. Also, we recommend that researchers consider the degree to which NCDs especially T2DM reflect morbidity and mortality among migrant population and integrate suitable research intervention which understand the cultural, social and environmental factors which influences dietary practice among migrant (de Smalen et al. 2021).

4.3.2. Development of lifestyle interventions targeted at behavioural changes.

Although, this study provides additional prove that diet and environmental risk factors can impact the pathophysiological pathway of T2DM, improvement of health and its social determinants among migrants cannot be achieved without a significant action on the prevention. Our findings encourage policy makers to laydown strategies (such as taxation and regulations) which allows migrant to take control and make behavioural changes as well as address the external environment factors (diet, alcohol consumption, smoking, obesity, SES inequalities) that contributes to NCDs among migrants.

Also, similar to the recommendation for the management of T2DM by the American diabetes association (Association 2016), our study encourages the development of lifestyle intervention geared toward diet and physical activity. The first focus should be on enhancing dietary and lifestyle habits among the public by promoting the preparation of healthy meals and discouraging the exposures of processed foods that are high in calories and low in micronutrients. Once more, government and stakeholders should alter urban plans particularly in developed SSA regions to encourage community physical activity such as adding bike lanes, walkways, and parks (Bellentani et al. 2008).

For people with NAFLD and T2DM, we encourage patients to eat a healthy dietary pattern and well-balanced nutrients that is tailored towards low saturated fat, calories, but high fibre (Hannah Jr and Harrison 2016). Also, a well-designed dietary intervention trial is recommended to provide firm, evidence-based dietary recommendations for NAFLD.

4.3.3. Individualised dietary approaches

How much carbohydrate should a person with T2DM consume remains a topic. Similar to the recommendation of both American Diabetes Association and Diabetes UK, we advocate a personalized strategy where health experts collaborate with the diabetic person to determine appropriate eating pattern that is based on the person's lifestyle, culture, and preferences (Dyson 2015). Also, a longitudinal study is recommended to improve dietary compliance on the long-term efficacy of LCD especially among African population where data is rare. Finally, the promotion of LCD particularly macronutrients intake should be within healthy eating guidelines and tailored according to culinary environment of the popular of interest (Ma et al. 2006).

4.4. Conclusions

This piece of work has addressed the high burden of NCDs among African populations under transition. More precisely, this thesis synthesised population-based studies focusing on health exposure–outcome relationships among migrant groups in Germany, identified dietary patterns related with biomarkers of NAFLD and established their associations with T2DM among adults from Ghana; and determined the associations of LCD diets with glycaemic control and diabetic complications in the same high-risk population.

The SLR demonstrates that the corpus of evidence for aetiological study on immigrants' health in Germany is expanding. It appears that some understanding exists regarding the direction of relationships between various risk factor types and the major disease group. Yet, the body of evidence remains limited and calls for major investments in research on the health of migrants in Germany.

We discovered DPs that showed positive relationships to the FLI, a surrogate marker for fatty liver disease, and evidence of adherence to modernised diets. Particularly in males, these DPs were positively associated with the odds of T2DM. Our studies support the idea that metabolic pathways leading to NAFLD and T2DM may be underpinned by modernised dietary behaviours among adults from Ghana going through economic and societal transitions. This study is the first study among Ghanaians that provides clinicians and dietitians practical information on the dietary risk factors behind the increase in NAFLD and its association with T2DM using reduced rank regression method.

Again, findings from the LCD score and T2DM adds to the growing body of proof that LCD cannot adequately support blood glucose control. However, our results do not back up the hypothesis that LCD might be associated with the onset of diabetic complications. Although this is a cross-sectional study, the evidence points to the fact that consuming quality carbohydrates is more important than reducing carbohydrate intake for glycaemic control, at least among Ghanaian populations who rely mostly on staple foods. However, more investigation is therefore required to determine the long-term effects of LCDs on T2DM management in this African population.

There is unmistakable proof that these populations bear a heavy burden of NCDs. Along with the application of accepted techniques for assessing community prevalence, there is an urgent need for targeted and long-term responses to address both immediate and long-term needs to enhance individual and societal health as well as to guarantee the future viability and efficacy of health services in these neighbouring host countries.

5. SUMMARY

One of the major contributing factors to the increase in type 2 diabetes mellitus is nutrition transition which is described as the change in dietary patterns and nutrient intake when communities embrace contemporary lifestyle during economic and social development. For sub-Sahara Africa population under transition, the contribution of dietary factors in the development of type 2 diabetes and its complication is unclear. This study therefore aimed at gaining insight into the relationships of dietary behaviour with type 2 diabetes mellitus among African populations under transition. The main objectives included (i) to synthesise population-based studies focusing on health exposure–outcome relationships among migrant groups in Germany, (ii) to identify a dietary pattern related with biomarkers of non-alcoholic fatty liver diseases and to evaluate the association of this dietary pattern with type 2 diabetes among adults from Ghana (iii) to determine the associations of low-carbohydrate diets with glycaemic control and diabetic complications among adults from Ghana.

In answering objective one, a systematic search was conducted on the relevant existing evidence on population-based studies focusing on health exposure–outcome relationships among migrant groups in Germany. While the second and third studies used data from the multi-country Research on Obesity and Diabetes among African Migrants study. Objective two used reduced ranked regression to derive sex-specific dietary patterns associated with fatty liver Index and evaluated the association between these dietary patterns with type 2 diabetes mellitus using logistic regression. While objective three calculated low-carbohydrate diet score and identify the association between dietary pattern with microvascular (nephropathy) and macrovascular (coronary artery disease, peripheral artery disease, stroke) complications using logistic regression.

The following findings were made:

First, the systematic review included 68 publications. In these articles, 56 were cross-sectional studies, 11 cohort studies, and one intervention study. Also, health outcome under studies were particular to population groups under studies. And the demographic and socioeconomic characteristics showed consistent association to poor health among immigrants in Germany while other risk factors did not. Second, dietary pattern scores in males explained 16.0% of the variation in the fatty liver index and 9.9% of the variation in food consumption. This dietary pattern was characterized by high intakes of poultry, whole-grain cereals, coffee and tea, condiments, and potatoes and the odds of type 2 diabetes was 45% higher per 1 dietary pattern

score-standard deviation while dietary patterns had inconsistent associations with type 2 diabetes mellitus among women.

Third, the low-carbohydrate diet score was associated with glycated haemoglobin among individuals with type 2 diabetes. While among individuals without type 2 diabetes, the beta coefficients varied between |0.01| and |0.04|, yet the relevant associations were statistically significant. In terms of complications, there was a negative correlation between the low-carbohydrate diet score and self-reported stroke (adjusted OR: 0.95; 95% CI: 0.91, 0.99). Other diabetic complications had no associations with low-carbohydrate diet score.

Although findings from the systematic review gave a valuable insight on risk-factor diseases association among migrants, low quality of evidence on chronic diseases demonstrated the lack of investment in research. And this may be the reason for the lack of clarity on the pattern on the relationship between a large variety of risk factors and disease grouping. Again, dietary patterns generated among these African under transition showed a nutritional shift from typical traditional diet to modernised diet. The changes seen may be associated with acculturation following urbanisation or migration. Finally, the lack of association seen between low-carbohydrate diet and glycated haemoglobin among participant with type 2 diabetes as well as inconsistent association with the complication may reaffirm the evidence that glycaemic control lies not only on the reduction of carbohydrate but rather the quality of the entire diet.

To conclude, the findings of the study contribute to a wide range of different insight on the aetiological study on migrant health. Again, this study promotes the idea that that metabolic pathway leading to non-alcoholic fatty liver diseases and type 2 diabetes mellitus maybe supported by modernized dietary practices among transitioning Ghanaians. As well as adds to the body of evidence that have proofing that low carbohydrate could support blood glucose control.

Zusammenfassung

Einer der wichtigsten Faktoren, die zur Zunahme von Typ-2-Diabetes mellitus beitragen, ist die Ernährungsumstellung, die als Veränderung der Ernährungsgewohnheiten und der Nährstoffaufnahme beschrieben wird, wenn sich Gemeinschaften im Zuge der wirtschaftlichen und sozialen Entwicklung einen modernen Lebensstil zu eigen machen. Für die Bevölkerung in Subsahara-Afrika, welche sich in einer Übergangsphase befindet, ist die Rolle von Ernährungsfaktoren bei der Entwicklung von Typ-2-Diabetes und dessen Komplikationen unklar. Ziel dieser Studie war es daher, einen Einblick in die Zusammenhänge zwischen dem Ernährungsverhalten und Typ-2-Diabetes bei afrikanischen Bevölkerungsgruppen im Übergang zu gewinnen. Zu den Hauptstudienzielen gehörten (i) die Zusammenfassung bevölkerungsbezogener Studien, die sich auf die gesundheitliche Expositions-Ergebnis-Beziehungen bei Migrantengruppen in Deutschland konzentrierten, (ii) die Identifizierung eines Ernährungsmusters, welches im Zusammenhang steht mit Biomarkern für nicht alkoholische Fettlebererkrankungen, und die Bewertung des Zusammenhanges dieses Ernährungsmusters mit Typ-2-Diabetes bei Erwachsenen aus Ghana, (iii) die Bestimmung der Zusammenhänge von kohlenhydratarmen Diäten mit der glykämischen Kontrolle und diabetischen Komplikationen bei Erwachsenen aus Ghana.

Diese Ziele wurden mit Hilfe einer Vielzahl von Studieninstrumenten und statistischen Ansätzen erreicht. Zur Beantwortung des ersten Ziels wurde eine systematische Suche nach relevanter vorhandener Evidenz zu bevölkerungsbasierten Studien durchgeführt, die sich auf die Expositions-Ergebnis-Beziehungen bei Migrantengruppen in Deutschland konzentrieren. In der zweiten und dritten Studie wurden Daten aus der länderübergreifenden Studie „Research on Obesity and Diabetes among African Migrants“ verwendet, in welchem ghanaischen Migranten in drei europäischen Ländern mit Nicht-Migranten in städtischen und ländlichen Gebieten Ghana verglichen wurden. Im Rahmen von Ziel zwei wurde eine reduzierte Rangregression verwendet, um geschlechtsspezifische Ernährungsmuster abzuleiten, welche mit dem Fettleber-Index in Verbindung stehen. Der Zusammenhang zwischen diesen Ernährungsmustern und Typ-2-Diabetes mellitus wurde mittels logistischer Regression bewertet. In Ziel drei wurde eine Punktzahl für kohlenhydratarme Ernährung berechnet und deren Zusammenhang mit mikrovaskulären (Nephropathie) und makrovaskulären (koronare Herzkrankheit, periphere Herzkrankheit, Schlaganfall) Komplikationen mittels logistischer Regression bewertet.

Die folgenden Ergebnisse wurden erzielt:

Erstens umfasste die systematische Überprüfung 68 Veröffentlichungen. Bei diesen Artikeln handelte es sich um 56 Querschnittsstudien, 11 Kohortenstudien und eine Interventionsstudie. Außerdem waren die in den Studien untersuchten Gesundheitsergebnisse für die untersuchten Bevölkerungsgruppen spezifisch. Die demografischen und sozioökonomischen Merkmale zeigten einen konsistenten Zusammenhang mit einem schlechten Gesundheitszustand bei Einwanderern in Deutschland, während andere Risikofaktoren dies nicht taten.

Zweitens erklärte die Bewertung des Ernährungsmusters bei Männern 16,0 % der Variation des Fettleberindex und 9,9 % der Variation des Lebensmittelkonsums. Dieses Ernährungsmuster zeichnete sich durch eine hohe Aufnahme von Geflügel, Vollkorngetreide, Kaffee und Tee, Gewürzen und Kartoffeln aus. Die Wahrscheinlichkeit, an Typ-2-Diabetes zu erkranken, war pro 1 Ernährungsmuster-Score-SD um 45 % höher, während die Ernährungsmuster bei Frauen inkonsistent mit Typ-2-Diabetes assoziiert waren.

Drittens war der Wert der kohlenhydratarmen Ernährung bei Personen mit Typ-2-Diabetes mit dem glykosylierten Hämoglobin assoziiert. Bei Personen ohne Typ-2-Diabetes schwankten die Beta-Koeffizienten zwischen |0,01| und |0,04|, wobei die entsprechenden Zusammenhänge statistisch signifikant waren. Bei den Komplikationen bestand ein negativer Zusammenhang zwischen dem Ergebnis der kohlenhydratarmen Ernährung und selbstberichteten Schlaganfällen (bereinigte OR: 0,95; 95% CI: 0,91, 0,99). Andere diabetische Komplikationen standen in keinem Zusammenhang mit dem Ergebnis der kohlenhydratarmen Diät.

Obwohl die Ergebnisse der systematischen Überprüfung einen wertvollen Einblick in die Assoziation von Risikofaktoren mit Krankheiten bei Migranten lieferten, zeigte die geringe Qualität der Studien zu chronischen Krankheiten, dass es an Investitionen in diesen Forschungsbereich mangelt. Dies könnte der Grund dafür sein, dass das Muster der Beziehung zwischen einer Vielzahl von Risikofaktoren und Krankheitsgruppen unklar ist.

Die Ernährungsmuster zeigen auch eine Verschiebung von der typischen traditionellen Ernährung zur modernisierten Ernährung bei Afrikanern, welche sich in der Übergangsphase befinden. Die beobachteten Veränderungen könnten mit der Akkulturation nach der Urbanisierung oder Migration zusammenhängen.

Der fehlende Zusammenhang zwischen kohlenhydratarmer Ernährung und glykosyliertem Hämoglobin bei den Teilnehmern mit Typ-2-Diabetes sowie die uneinheitliche Assoziation mit Komplikationen bestätigen, dass die Kontrolle des Blutzuckerspiegels nicht nur auf der

Reduzierung von Kohlenhydraten, sondern vielmehr auf der Qualität der gesamten Ernährung beruht.

Zusammenfassend lässt sich sagen, dass die Ergebnisse der Studie zu einem breiten Spektrum von Erkenntnissen über die ätiologische Untersuchung der Gesundheit von Migranten beitragen. Auch diese Studie unterstützt die Idee, dass der Stoffwechselweg, der zu nicht alkoholische Fettlebererkrankungen und Typ-2-Diabetes führt, möglicherweise durch modernisierte Ernährungspraktiken bei ghanaischen Migranten unterstützt wird. Außerdem ergänzt sie vorhandene Forschungsergebnisse, welche nahelegen, dass eine kohlenhydratarme Ernährung die Blutzuckerkontrolle unterstützen kann.

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7. PERSONAL CONTRIBUTIONS TO DATA EVALUATION AND OWN PUBLICATIONS

Publications in peer-reviewed journals directly related to PhD thesis:

Osei TB, Mank I, Sorgho R, Schwerdtle PN, Hövener C, Fischer F, Razum O, Danquah I. Aetiological research on the health of migrants living in Germany: a systematic literature review. BMJ open. **2022** Jun 1;12(6): e058712. **doi:10.1136/bmjopen-2021-058712. Impact factor: 5.717 (2021).**

Own contributions: Together with my supervisor and the team of co-authors, I conceptualized the protocol of the systematic literature review, contributed to the selection of articles, and extracted the data. I drafted the tables and figures, as well as the initial version of the manuscript. With the contributions of all co-authors, I revised the manuscript and completed it for submission.

Osei TB, van Dijk AM, Dingerink S, Chilunga FP, Beune E, Meeks KA, Bahendeka S, Schulze MB, Agyemang C, Nicolaou M, Holleboom AG. Danquah I Reduced Rank Regression-Derived dietary patterns related to the fatty liver index and associations with type 2 diabetes mellitus among Ghanaian populations under transition: the RODAM study. Nutrients. **2021** Oct 20;13(11):3679. **https://doi.org/10.3390/nu13113679. Impact factor: 2.97 (2022)**

Own contributions: Under the lead of my supervisor and with the suggestions from the RODAM consortium members, I formulated the research question and planned the statistical analysis. I reviewed the data quality and completeness and conducted all statistical analysis. Also, I drafted the first version of the manuscript, and revised it for submission according to the contributions of all co-authors.

Manuscript under review:

Osei TB, Hibbah Osei-Kwasi, Juliet Addo, Meeks KA, Bahendeka S, Schulze MB, Agyemang C, Nicolaou, Charles F. Hayfron-Benjamin. Danquah I Association of low-carb diets with glycaemic control and diabetic complications among adult Ghanaians: The RODAM study (under co-authors review).

Own contributions: Also, for this publication, I was responsible for conceiving the research question and drafting an analysis proposal that was reviewed and approved by the Research and Publication Group of the RODAM Study. I conducted the statistical analysis, created the illustrations and tables to present the results, and drafted the first version of the paper.

Incorporating the feedback from co-authors, I am currently finalizing the manuscript to be approved for submission to a peer-reviewed journal.

Additional own publications:

Van Dijk AM, Dingerink S, Chilunga FP, Meeks KA, Bahendeka S, Schulze MB, Danquah I, **Osei TB**, Serné E, Agyemang C, Holleboom AG. Metabolic-associated fatty liver disease as assessed by the Fatty Liver Index among migrant and non-migrant Ghanaian populations. Journal of Clinical and Translational Hepatology. **2021** Aug 8;9(4):494. **Impact factor: 3.6 (2020).**

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Appendices

Appendix A: Supplementary analysis for the systematic literature review

Table S1. Literature search strings (Osei et al. 2022)

PubMed	**Search string:** (((((Alger* OR Angol* OR Benin* OR Botswan* OR Burkin* OR Burundi* OR Cabo Verd* OR Cameroon* OR Central African Republic OR CAR OR Chad* OR Comoros* OR Congo* OR Cote d'Ivoire OR Djibouti* OR Egypt* OR Guinea* OR Eritrea* OR Ethiopia* OR Gabon* OR Gambia* OR Ghana OR Ghanaian OR Kenya* OR Lesoth* OR Liberia* OR Libya* OR Madagascar* OR Malawi* OR "Mali"[Mesh] OR Mauritania* OR Maurit* OR Morocc* OR Mozambiqu* OR Namibia* OR Namibia* OR Niger* OR Rwanda* OR Sao Tome and Principe* OR Senegal* OR Seychelles* OR Sierra Leone* OR Somalia* OR South Africa* OR Sudan* OR Swaziland* OR Tanzania* OR Togo OR Tunisia* OR Uganda* OR Zambia* OR Zimbabw* OR "Africa"[Mesh] OR "Africa South of the Sahara"[Mesh] OR "Africa, Northern"[Mesh] OR Italy OR Italian OR Middle East* OR India* OR Pakistan* OR Iran* OR Iraq* OR Afghan* OR Armen* OR Syria* OR Oman* OR Yemen* OR Eastern Mediterranean OR Albania* OR Bulgar* OR Slovenia* OR Macedonia* OR Serbia* OR Kosov* OR Montenegr* OR Croatia* OR Bosnia* OR Herzegovin* OR Romania* OR Poland OR Polish OR Slovakia* OR Hungar* OR Leban* OR Palestin* OR Israel* OR Jordan* OR Turkish OR Turkey OR Russia* OR Belar* OR Ukrain* OR Moldaw* OR Georgia* OR Armen* OR Azerbai* OR Kasachst* OR Usbekist* OR Turkmenist* OR Kirgist* OR Tajikist* OR Spain OR Spanish OR Portug* OR Greece OR Greek)) AND (migrant* OR refugee* OR guest worker* OR foreign* OR asylum seek* OR countr* of origin OR home countr* OR homeland* OR native countr* OR country of birth OR ethnicit* OR minorit*)) AND (German OR Germany)) AND (odds* OR prevalence* OR risk OR risks OR hazard* OR influence* OR effect* OR associat* OR mean difference OR multi-center OR multi-centre OR "cross-sectional" OR case-control OR cohort OR intervention)) AND (overweight OR obes* OR adipos* OR triglyceride* OR cholester* OR lipids OR lipidem* OR diabetes OR blood pressure OR hypertens* OR physical activ* OR sport OR sports OR diet OR dietar* OR nutrition* OR behaviour* OR behavior* OR smok* OR cigarette* OR tobacco* OR cardiovascular risk OR cancer OR cancers OR tumor OR tumors OR carcinom* OR adenom* OR myelom* OR sarcom* OR mental* OR psychol* OR psychiat* OR infect* OR communicab* OR viral OR virus OR viruses OR bacterium OR bacteria* OR parasite* OR parasitol OR HIV OR AIDS OR TB OR tubercul* OR malaria* OR helminth* OR worm* OR neglected tropical disease* OR NTD) Filters: Humans
LIVIVO	**Specifications:**

	Databases: BASE; BfR; Catalogue of the NLM; Catalogue ZB Med; DissOnline; ETHMED; EZB; MEDLINE; Publishing Data; SOMED Subject: Medicine, Health Document type: article **Search string:** (((((Alger* OR Angol* OR Benin* OR Botswan* OR Burkin* OR Burundi* OR Cabo Verd* OR Cameroon* OR Central African Republic OR CAR OR Chad* OR Comoros* OR Congo* OR Cote d'Ivoire OR Djibouti* OR Egypt* OR Guinea* OR Eritrea* OR Ethiopia* OR Gabon* OR Gambia* OR Ghana OR Ghanaian OR Kenya* OR Lesoth* OR Liberia* OR Libya* OR Madagascar* OR Malawi* OR Mali OR Mauritania* OR Maurit* OR Morocc* OR Mozambiqu* OR Namibia* OR Namibia* OR Niger* OR Rwanda* OR Sao Tome and Principe* OR Senegal* OR Seychelles* OR Sierra Leone* OR Somalia* OR South Africa* OR Sudan* OR Swaziland* OR Tanzania* OR Togo OR Tunisia* OR Uganda* OR Zambia* OR Zimbabw* OR Italy OR Italian OR Middle East* OR India* OR Pakistan* OR Iran* OR Iraq* OR Afghan* OR Armen* OR Syria* OR Oman* OR Yemen* OR Eastern Mediterranean OR Albania* OR Bulgar* OR Slovenia* OR Macedonia* OR Serbia* OR Kosov* OR Montenegr* OR Croatia* OR Bosnia* OR Herzegovin* OR Romania* OR Poland OR Polish OR Slovakia* OR Hungar* OR Leban* OR Palestin* OR Israel* OR Jordan* OR Turkish OR Turkey OR Russia* OR Belar* OR Ukrain* OR Moldaw* OR Georgia* OR Armen* OR Azerbai* OR Kasachst* OR Usbekist* OR Turkmenist* OR Kirgist* OR Tajikist* OR Spain OR Spanish OR Portug* OR Greece OR Greek)) AND (migrant* OR refugee* OR guest worker* OR foreign* OR asylum seek* OR countr* of origin OR home countr* OR homeland* OR native countr* OR country of birth OR ethnicit* OR minorit*)) AND (German OR Germany)) AND (odds* OR prevalence* OR risk OR risks OR hazard* OR influence* OR effect* OR associat* OR mean difference OR multi-center OR multi-centre OR "cross-sectional" OR case-control OR cohort OR intervention)) AND (overweight OR obes* OR adipos* OR triglyceride* OR cholester* OR lipids OR lipidem* OR diabetes OR blood pressure OR hypertens* OR physical activ* OR sport OR sports OR diet OR dietar* OR nutrition* OR behaviour* OR behavior* OR smok* OR cigarette* OR tobacco* OR cardiovascular risk OR cancer OR cancers OR tumor OR tumors OR carcinom* OR adenom* OR myelom* OR sarcom* OR mental* OR psychol* OR psychiat* OR infect* OR communicab* OR viral OR virus OR viruses OR bacterium OR bacteria* OR parasite* OR parasitol OR HIV OR AIDS OR TB OR tubercul* OR malaria* OR helminth* OR worm* OR neglected tropical disease* OR NTD)

Table S2. Characteristics of included studies by year of publication and in alphabetical order of first authors (Osei et al. 2022).

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
Bauer et al.	2020	Syria	Germany	Retrospective cohort	2013-2016	2209	registered Syrian refugees; Syria as the country of origin	64.0%	>18 years	1. relationship between pre-migration SES and self-reported health indicators after migration
Begemann et al.	2020	Afghanistan, Nigeria, Syria, Iraq	Refugee camps in Southern Germany	Prospective cohort	June 2018-May 2019	133	registered refugees	38.0%	≤30years	1. risk load in young 'healthy' refugees; 2. first signals of behavioral abnormalities
Borho et al.	2020	Syria	Erlangen	Prospective cohort	2017-2019	518	Syrian refugees with residence permission in Germany and registered at the job center	68.5%	>18 years	1. change of the prevalence of mental disorders by length of stay; 2. change in relationship with pre- and postmigration factors
Commodore-Mensah et al.	2020	Ghana	Berlin	Cross-sectional	2012-2015	3661	born in Ghana or at least one parent born in Ghana	39.0%	40-79 years	1. performance of six anthropometric variables in estimating the predicted 10-year CVD risk
Goreis et al.	2020	Russia	Germany	Cross-sectional	2012 and 2015	308	first and second-generation immigrants who, in 2018, made up 79 and 21% of Russian immigrants	33.7%	18-77 years	1. associations between different forms of ethnic discrimination and levels of perceived stress

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
Hampe et al.	2020	Ghana	Berlin	Cross-sectional	2012-2015	5898	born in Ghana or at least one parent born in Ghana	38.0%	25-70 years	1. Population-specific GAD65Ab prevalence as a marker for autoimmune diabetes; 2. relationships with geographic location, sociodemographic and clinical factors
Hayfron-Benjamin et al.	2020	Ghana	Berlin	Cross-sectional	2012-2015	5248	born in Ghana or at least one parent born in Ghana	37.8%	25-75 years	1. association of CRP with diabetes, microvascular and macrovascular dysfunction
Koschollek et al.	2020	Sub-Saharan Africa	Munich, Rhine-Ruhr region, Cologne, Berlin, Frankfurt am Main, Hanover	Cross-sectional	2015-2016	2432	citizenship of a sub-Saharan African country who were officially registered in the respective city or region	54.5%	18-45 years	1. level of knowledge about HIV and STIs; 2. sub-groups with particular knowledge gaps; 3. information needs and preferences; 4. behavioural risk factors
Krist et al.	2020	Turkey	Berlin	Prospective cohort	2011-2012	557	own migration experience (1st generation); born in Germany (2nd generation)	39.1%	35-65 years	1. trajectories of PA behavior as well as predictors of these trajectories
Lyons et al.	2020	Ghana	Berlin	Cross-sectional	2012-2015	3377	born in Ghana or at least one parent born in Ghana	36.9%	25-70 years	1. prevalence of ID; 2. influence of ID on HbA1c categories

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
Morawa et al.	2020	Turkish	Essen	Prospective cohort	Dec 2011-Aug 2012	328	own immigration (1st generation), one parent immigrated or born as non-German in Germany (2nd generation)	38.7%	20-69 years	1. degree of depressive symptoms and life satisfaction (LS); 2. association between acculturation and depressive symptoms
Osei-Kwasi et al.	2020	Ghana	Berlin	Cross-sectional	2012-2015	4534	born in Ghana or at least one parent born in Ghana	38.0%	25-75 years	1. comparing food intake; 2. Associations between acculturation and food intake
Walther et al.	2020	Afghan, Iraq, Eritrea	Germany	Cross-sectional	2013 and 2016	2639	arrived in Germany between 1 January 2013 and 31 January 2016 and applied for asylum or were part of a humanitarian resettlement programme	63.4%	18-54 years	1. prevalence of psychological distress; 2. sociodemographic characteristics and postmigration factors
Arendt and Karadas (Arendt and Karadas 2019b)	2019	Turkey	Germany	Intervention study	Not stated	256	Not stated	51%	18-68 years	1. ethnic concordance causally linked with belief in the physician; 2. reduced reactance-related outcomes; 3. improved knowledge transfer

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
Boateng et al.	2019	Ghana	Berlin	Cross-sectional	2012-2015	3250	born in Ghana or at least one parent born in Ghana	20.2%	40-70 years	1. anthropometric markers of early-life environmental conditions associated with CVD risk
Breckenkamp et al. (Breckenkamp et al. 2019)	2019	Turkey and Lebanon	Germany	Prospective cohort	2011-2012	1413	women with own migration experience (1st generation immigrants)	0%	18-45 years	1. associations between migration status and admission for labor; 2. associations between admission time and rates of caesarian section
Bretz et al. (Bretz et al. 2019)	2019	Turkey	Berlin	Cross-sectional	Not stated	129	born in Turkish Republic or both parents born in Turkish Republic	34.1%	>18 years	1. associations between perceptions of psychotherapy and uptake of psychotherapy
Chilunga et al.	2019	Ghana	Berlin	Cross-sectional	2012-2015	2179	born in Ghana or at least one parent born in Ghana	50.9%	25-70 years	1. prevalence of type 2 diabetes in underweight/ normal weight; 2. proportions of diabetes by stratum; 3. determinants of diabetes; 4. contribution of beta cell failure and insulin resistance
Espinoza-Castro et al.	2019	Spain	Germany	Cross-sectional	Aug 2018-Jun 2019	409	being an au-pair in Germany; being born in a Spanish speaking country	9.0%	18-28 years	1. prevalence of Major Depressive Syndrome (MDS); 2. association with time of residence
von Haumeder et al.	2019	Syria	Germany	Cross-sectional	Nov 2017-Feb 2018	127	adult Syrian post-civil war refugees	84.0%	18-67 years	1. environmental factors for trauma

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
Georgiadou et al. (Georgiadou et al. 2019)	2018	Syria	Erlangen	Cross-sectional	July-December 2017	200	registered Syrian refugees; Syria as the country of origin	69.5%	18-60 years	1. assess mental health; 2. account for the circumstances in the country of origin, host country, and by escape conditions
Jesuthasan et al. (Jesuthasan et al. 2018)	2018	Afghanistan, Syria, Iran, Iraq, Somalia, Eritrea	Germany	Prospective cohort	2015-2016	663	registered asylum seeker according to their country of origin	0%	17-69 years	1. explore home countries' situation, motivations for fleeing, refugee experiences, quality of life, health, needs perception; 2. identify personal factors and refugee experiences associated with quality of life
Wetzke et al. (Wetzke et al. 2018)	2018	Various origins, mainly Eastern Mediterranean	Celle, Northern Germany	Cross-sectional	September – December 2015	1533	asylum seekers and registered upon arrival	72%	0-73 years	1. assess healthcare utilization
Mueller-Hermelink et al. (Mueller-Hermelink et al. 2018)	2018	Syria, Iraq, Afghanistan	Bochum and Hamburg	Cross-sectional	September 2015 – November 2016	968	presenting to asylum seeker reception center	53%	3 months -15 years	1. investigate the prevalence of tuberculosis infection
Solyman et al. (Solyman and Schmidt-Westhausen 2018)	2018	Syria, Iraq	Berlin	Cross-sectional	July – December 2016	386	registered as refugees in Germany within one year prior to the enrolment in the study	80%	18-60 years	1. determine the status of oral health; 2. explore knowledge, attitude and practices on oral hygiene
Zhou et al. (Zhou et al. 2018)	2018	Various origins, mainly Turkey, Russia, Poland	Hannover	Cross-sectional	2010-2014	50,716	Self-defined by parents	51.6%	5-7 years	1. examine ethnic differences in the prevalence

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
										of overweight in pre-school children
Addo et al. (Addo et al. 2017b)	2017	Ghana	Berlin	Cross-sectional	July 2012-December 2015	5290	born in Ghana or at least one parent born in Ghana	38%	25-70 years	1. socio-economic position and type 2 diabetes; 2. gender-differences by location; 3. mediating factors: obesity, physical activity
Boateng et al. (Boateng et al. 2017)	2017	Ghana	Berlin	Cross-sectional	July 2012-December 2015	3864	born in Ghana or at least one parent born in Ghana	55%	40-70 years	1. location as risk factor for predicted 10-year CVD risk; 2. modifiable risk factors for increased predicted 10-year CVD risk
Brathwaite et al. (Brathwaite et al. 2017)	2017	Ghana	Berlin	Cross-sectional	July 2012-December 2015	5265	born in Ghana or at least one parent born in Ghana	38%	25-70 years	1. smoking patterns by location; 2. factors associated with smoking
Danquah et al. (Danquah et al. 2018b)	2017	Ghana	Berlin	Cross-sectional	July 2012-December 2015	3810	born in Ghana or at least one parent born in Ghana	37%	25-70 years	1. dietary diversification and dietary patterns associated with type 2 diabetes; 2. contributions of dietary diversification to the patterns-diabetes-associations
Morawa et al. (Morawa et al. 2017)	2017	Turkey	Essen	Cross-sectional	December 2011-August 2012	605	having either immigrated themselves or having at least	37%	20-69 years	1. degrees of somatization according to socio-demographic and migration-related characteristics; 2. severity of somatization according to socio-

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
							one parent who immigrated			demographic and migration-related characteristics; 3. frequency of single somatic symptoms
Iguacel et al. (Iguacel et al. 2018)	2017	various origins, unclear		Prospective cohort	baseline: September 2007-June 2008; follow-up: September 2009-June 2010	16,228	origin of the parents: if one or both parents were born in a country different from where the study took place	51%	2-10 years	1. associations between social vulnerabilities and meeting physical activity and screen time recommendations
Jablonka et al. (Jablonka et al. 2017)	2017	various origins (Eastern Mediterranean, Africa)	Northern Germany	Cross-sectional	August 2015-September 2015	554	refugees in refugee camp	78%	1-67 years	1. seroprevalences against measles, rubella, varicella; 2. general risk of transmission of communicable; 3. evidence-based guidance for migrant vaccination against measles, rubella, and varicella
Meeks, Henneman et al. (Meeks et al. 2017a)	2017	Ghana	Berlin	Cross-sectional	July 2012-December 2015	547	born in Ghana or at least one parent born in Ghana	42%	50-51 years	1. epigenetic loci associated with general obesity (BMI) and abdominal obesity (waist circumference)
Meeks, Stronks et al. (Meeks et al. 2017b)	2017	Ghana	Berlin	Cross-sectional	July 2012-December 2015	5079	born in Ghana or at least one parent born in Ghana	37%	25-70 years	1. insulin resistance and beta-cell dysfunction for impaired fasting glucose; 2. socio-demographic, anthropometric, health-related behavior for insulin

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
										resistance and beta-cell dysfunction
Pachankis et al. (Pachankis et al. 2017)	2017	various origins: Africa, Eastern Mediterranean	Germany	Cross-sectional	June 2010-August 2010	23,371	country in which participants were born other than country in which they now live	100%	13-89 years	1. structural determinants of HIV risk
Beutel et al. (Beutel et al. 2016)	2016	various origins, mainly Poland and Turkey	Germany	Prospective cohort	April 2007-April 2012	3525	migrated to Germany after 1949, all non-German citizens born in Germany, citizens born in Germany with at least one parent born abroad	1st generation: 49%; 2nd generation: 51%	35-74 years	1. differences in mental health between 1st and 2nd generation migrants and native Germans; 2. differences in mental health between Turkish and Polish 1st generation migrants and non-migrants
Zeitlmann et al. (Zeitlmann et al. 2016)	2016	various origins, mainly Syria	Germany	Cross-sectional	March 2014 (for November 2013-January 2014)	33,874	individuals seeking asylum in German reception centers	unknown	unknown	1. proportion being vaccinated; 2. proportion of stool screening for polio; 3. feasibility of RKI recommendations for vaccination; 4. factors associated with difficulties of guideline adherence
Scheuing et al. (Scheuing et al. 2015)	2015	various origins, Turkey, Southern Europe, Eastern Europe	Germany	Prospective cohort	unknown	27,643	maternal country of birth	52% male	>20 years	1. the impact of maternal country of birth on type 1 diabetes therapy and outcome

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
Reiss, Breckenkam et al. (Reiss et al. 2015a)	2015	various origins: Lebanon, Turkey	Berlin	Cross-sectional	2011-2012	7100	country of birth being different from Germany, but permanent residence in Germany	0%	>18 years	1. compare the association of pre-pregnancy overweight/obesity with adverse pregnancy outcomes between immigrant and autochthonous women; 2. quantify the magnitude of this effect; 3. compare overweight/obesity and smoking in their respective contribution to adverse pregnancy outcomes in the two groups
Reiss, Schunck et al. (Reiss et al. 2015b)	2015	Turkey, Eastern Europe	Germany	Prospective cohort	1998-2012	26,848	foreign country of birth	53% (Turkish immigrants), 44% (Eastern European Immigrants), 48% (Non-Immigrants)	17-102 years	1. length of stay associated with smoking prevalence; 2. smoking prevalence according to immigrant groups and non-immigrant Germans
Belhadj Kouider et al. (Belhadj-Kouider et al. 2014)	2014	various origins: mainly Turkey, Russia, Africa, Poland	Bremen	Cross-sectional	2007-2011	5680	1st, 2nd and 3rd generation migrants	58%	3-18 years	1. ethnic differences beyond migrant status for mental disorders
Morawa et al. (Morawa and Erim 2014)	2014	Turkey, Russia and Poland	Germany	Cross-sectional	March 2007-June 2008 (Turkish); August 2009-October	218	immigrated to Germany or at least one parent immigrated to Germany	33%	18-72 years	1. differences of perceived discrimination between migrant groups; 2. comparison of depressiveness and health-related quality of life; 3. associations of perceived

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
					2010 (Polish)					discrimination, socio-demographic and other factors with depressiveness and health-related quality of life; 4. gender-differences
Belhadj Kouider et al. (Belhadj-Kouider et al. 2013)	2013	Turkey and Poland	Bremen	Cross-sectional	2010	779	immigrated to Germany or at least one parent immigrated to Germany or at least one grandparent immigrated to Germany	57%	12-18 years	1. psychosocial factors for conduct disorders; 2. psychosocial stress for aggressive behavior; 3. migrant status as a specific risk factor for aggressive behavior; 4. mental health care uptake
Morgenstern et al. (Morgenstern et al. 2013)	2013	various origins, unknown	Germany	Cross-sectional	2010	16,551	the country of birth of mother and father	51%	10-19 years	1. differences in SES and migration groups in movie smoking exposure; 2. SES and migration background as moderators for the association between movie smoking and adolescent smoking
Reeske et al. (Reeske et al. 2013)	2013	Turkey, Eastern Europe	Germany	Prospective cohort	September 2007–May 2008	1287	place of birth outside Germany or at least one parent born outside Germany	47-56%	2-9 years	1. variations in infant weight gain according to migration background; 2. contribution of pre- and perinatal factors

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
Bogic et al. (Bogic et al. 2012)	2012	former Yugoslavia	Germany	Cross-sectional	January 2005-November 2006	854	born within the territory of former Yugoslavia	48%	18-65 years	1. sociodemographic factors, war experiences and postmigration factors associated with mental disorders; 2. variability of associations across countries; 3. impact of each factor on mental disorders; 4. confounding of post-migration factors
Reime et al. (Reime et al. 2012)	2012	Mediterranean, Central Europe, Eastern Europe, Middle East, Africa, Asia, Turkey	Lower Saxony	Cross-sectional	2001-2007	441,199	country of origin	0%	>18 years	1. association between region of origin and severe illness bringing a mother close to death (near-miss)
Dannemann et al. (Dannemann et al. 2011b)	2011	various origins, mainly Turkey and Asia	Germany	Cross-sectional	January 2001-May 2008	1053	foreign country of birth or at least one parent born outside Germany or non-German mother tongue	48%	1-17 years	1. associations between ethnicity, elevated metabolic parameters and metabolic syndrome (MS) among overweight to obese children and adolescents
Wyen et al. (Wyen et al. 2011)	2011	various origins: Africa	Germany	Nested case-control	January 2006-October 2009	373	self-reported ethnicity	79%	26-82 years	1. associations of genetic variants with discontinuation within 3 months of initiating efavirenz-containing regimens; 2. associations with demographic factors incl. ethnicity, smoking habits, gender

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
Mewes et al. (Mewes et al. 2010)	2010	Turkey, Eastern Europe, Former Soviet Union	Germany	Cross-sectional	May 2007-June 2007	134	both parents born abroad	49%	14-93 years	1. somatoform symptomatology, anxiety, and depression according to migrant status; 2. healthcare uptake according to migrant status
Ott et al. (Ott et al. 2010)	2010	Former Soviet Union	Germany	Prospective cohort	1990-2004 (Israel); 1990-2005 (Germany)	563,241	migrants from selected countries of the FSU, who arrived between 1990 and 1999 in Israel and between 1990 and 2001 in Germany	45% (Israel); 48% (Germany)	mean age at immigration: 43.3 years (Israel); 40.0 years (Germany)	1. mortality in Germany and Israel; 2. duration of residence associated with major cause of death groups
Schreyer et al. (Schreyer and Petermann 2010)	2010	various origins	Bremen	Cross-sectional	October 2007	188	not born in Germany or at least one parent not born in Germany	51%	44-68 months	1. behavior problems; 2. health-related quality of life; 3. self-reported quality of life
Reime et al. (Reime et al. 2009)	2009	Central Europe (Russia), Eastern Europe, Mediterranean	Lower Saxony	retrospective cohort	data from 1990, 1995, 1999	182	holding another citizenship than the German one	0%	12-52 years	1. risk profile among women according to migrant status; 2. prenatal care as a mediator for the relationship between nationality and stillbirth risk
Spallek et al. (Spallek et al. 2009)	2009	Turkey	Hamburg	Cross-sectional	1990–2004	140,249	name-based algorithm	63% male (Turkish) 49% German	not specified	1. cancer incidence rate ratios

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
Haasen et al. (Haasen et al. 2008)	2008	Russia, Iran	Germany	Cross-sectional	unknown	302	born in Russia or in the Iran	four groups: 47%, 39%, 0%, 36%	four groups medians: 32.0, 27.5, 38.8, 45.9 years	1. relationship between acculturation stress and mental health problems
Irfaeya et al. (Irfaeya et al. 2008)	2008	Middle East	Cologne	Cross-sectional	April 2004-November 2005	116	Not reported	0%	mean age 32 years	1. psychological stress and associated factors using a Community Oriented Primary Care (COPC) approach
Merbach et al. (Merbach et al. 2008)	2008	Poland, Vietnam	Leipzig	Cross-sectional	not reported	222	holding a Polish or Vietnamese passport with residence in Leipzig	35%	19-63 years	1. acculturation factors for mental health
Ott et al. (Ott et al. 2008)	2008	Former Soviet Union	Germany	Prospective cohort	January 1990-December 2003 (Israel); January 1990-December 2005 (Germany)	34,393	people from the FSU who migrated voluntarily and arrived between 1990 and 2001 in Israel or Germany	not reported	≥15 years	1. comparative mortality from infectious diseases
Spix et al. (Spix et al. 2008)	2008	Turkey	Germany	retrospective cohort	1980-2005	1774	name-based algorithm, plus average duration of stay	59%	0-15 years	1. cancer survival

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
Voss et al. (Voss and Tuin 2008)	2008	Portugal, Morocco	Mainz and Frankfurt	cross-sectional	not reported	112	Not stated	0%	mean age: 31.7 years (Portuguese); 38.6 years (Moroccan)	1. cultural influences on lifestyle, coping style and sleep; 2. differences between the immigrant populations
Will et al. (Will et al. 2005)	2005	Turkey, Russia, Eastern Europe and Middle East	Bielefeld	cross-sectional	January 2002-December 2002	525	at least one parent born abroad	52%	6-7 years	1. differences in overweight and obesity among migrants and Germans
Porsch-Ozcurumez et al. (Porsch-Ozcurumez et al. 2003)	2003	Turkey	Germany	cross-sectional	not stated	1083	Not stated	60% (Germans); 56% (Turkish migrants); 62% (Turkish natives)	0-30 years	1. environmental settings associated with H. pylori seroprevalence
David et al. (David et al. 2002)	2002	Turkey, Lebanon, Yugoslavia	Berlin	cross-sectional	April 1995-March 2001	207	Not stated	0%	18-33 years	1. experience of migration associated with hyperemesis garvidarum (HG); 2. proportion of HG; 3. differences in risk factor perceptions; 4. mental problems associated with HG; 5. association with level of acculturation
Grüber et al. (Gruber et al. 2002)	2002	Turkey	Berlin	Cross-sectional	January 1998-June 1998	1365	non-German nationality of both parents	45-56%	not reported	1. prevalence of atopic sensitization and atopic disease at different levels of cultural adaptation

Authors	Year of publication	Geographic origin	Place of study conduct	Study design	Study duration	Total study population	Definition of "migration status"	Sex (male)	Age range (at baseline)	Objectives
Kistemann et al. (Kistemann et al. 2002)	2002	Eastern Europe, Russia	Cologne	ecological study	1986-1997	2903	non-German citizenship	not reported	not reported	1. inner-urban strength of association between TB and several potential risk factors within a small-area division based, GIS-supported ecological study
Penn et al. (Penn and Lambert 2002)	2002	India, Pakistan, Asia	Germany	Cross-sectional	1997-2000	2227	nationality of inhabitants or foreign-born parents	50%	16-25 years	1. attitudes towards ideal family size
Fichter et al. (Fichter et al. 1988)	1988	Greece	Munich	cross-sectional	July 1979-November 1980	867	Not stated	48%	13-19 years	1. acculturation level as risk factor for mental disorders

Table S3. Risk of bias assessment (quality appraisal) for 67 included observational studies (Osei et al. 2022)

#	Article	**Case Control CASP**	Q1 Clearly focussed issue	Q2 Appropriate Method	Q3 Accept. Recruitment Cases	Q4 Accept. Recruitment Control	Q5 Exposure Acc. Measured	Q6a Groups treated equal	Q6b Confound account.	Q7 Size Rx effect	Q8 Precise est. of Rx effect	Q9 Believe results	Q10 Applic. Local pop.	Q11 Results fit with evidence
		Cohort CASP	Q1 Clearly focussed issue	Q2 Accept. Recruitment	Q3 Exposure Acc. Measured	Q4 Outcome Acc. Measured	Q5a&b Confound Identified/Account	Q6a&b Follow up Complete /Long	Q7 Results	Q8 Precise Results	Q9 Believable Results	Q10 Applic. Local pop.	Q11 Results fit with evidence	Q12 Implica. Included
1	Bauer et al. 2020	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
2	Begemann et al. 2020	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🔴	🟢	🟢	🟢
3	Borho et al. 2020	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢	🟢	🟢
4	Chilunga et al. 2020	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢

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		Cohort CASP	Q1 Clearly focussed issue	Q2 Accept. Recruitment	Q3 Exposure Acc. Measured	Q4 Outcome Acc. Measured	Q5a&b Confound Identified/Account	Q6a&b Follow up Complete /Long	Q7 Results	Q8 Precise Results	Q9 Believable Results	Q10 Applic. Local pop.	Q11 Results fit with evidence	Q12 Implic a. Included
5	Commodore-Mensah et al. 2020	Cross-sectional	🟢	🟢	🟢	🟠	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
6	Goreis et al. 2020	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
7	Hampe et al. 2020	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
8	Hayfron-Benjamin et al. 2020	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢

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		Cohort CASP	Q1 Clearly focussed issue	Q2 Accept. Recruitment	Q3 Exposure Acc. Measured	Q4 Outcome Acc. Measured	Q5a&b Confound Identified/Account	Q6a&b Follow up Complete /Long	Q7 Results	Q8 Precise Results	Q9 Believable Results	Q10 Applic. Local pop.	Q11 Results fit with evidence	Q12 Implica. Included
9	Koschollek et al. 2020	Cross-sectional	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)
10	Krist et al. 2020	Cohort	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (orange)	● (orange)
11	Lyons et al. 2020	Cross-sectional	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (red)	● (green)	● (red)	● (red)	● (green)	● (red)
12	Morawa et al. 2020	Cohort	● (green)	● (green)	● (green)	● (green)	● (green)	● (orange)	● (orange)	● (green)	● (green)	● (green)	● (green)	● (green)
13	Walther et al. 2020	Cross-sectional	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (green)	● (red)	● (green)	● (green)	● (green)

#	Article	**Case Control CASP**	Q1 Clearly focussed issue	Q2 Appropriate Method	Q3 Accept. Recruitment Cases	Q4 Accept. Recruitment Control	Q5 Exposure Acc. Measured	Q6a Groups treated equal	Q6b Confound account.	Q7 Size Rx effect	Q8 Precise est. of Rx effect	Q9 Believe results	Q10 Applic. Local pop.	Q11 Results fit with evidence
		Cohort CASP	Q1 Clearly focussed issue	Q2 Accept. Recruitment	Q3 Exposure Acc. Measured	Q4 Outcome Acc. Measured	Q5a&b Confound Identified/Account	Q6a&b Follow up Complete /Long	Q7 Results	Q8 Precise Results	Q9 Believable Results	Q10 Applic. Local pop.	Q11 Results fit with evidence	Q12 Implica. Included
14	Boateng et al. 2019	Cohort	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
15	Bretz et al. 2019	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢
16	Breckenkamp et al. 2019	Cohort	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
17	Espinoza-Castro et al. 2019	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢	🟢	🟢

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		Cohort CASP	Q1 Clearly focussed issue	Q2 Accept. Recruitment	Q3 Exposure Acc. Measured	Q4 Outcome Acc. Measured	Q5a&b Confound Identified/Account	Q6a&b Follow up Complete /Long	Q7 Results	Q8 Precise Results	Q9 Believable Results	Q10 Applic. Local pop.	Q11 Results fit with evidence	Q12 Implica. Included
18	Osei-Kwasi et al. 2019	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
19	von Haumeder et al. 2019	Cross sectional	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢	🟢	🟢
20	Georgiadou et al. 2018	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
21	Jesuthasan et al. 2018	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢

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		Cohort CASP	Q1 Clearly focussed issue	Q2 Accept. Recruitment	Q3 Exposure Acc. Measured	Q4 Outcome Acc. Measured	Q5a&b Confound Identified/Account	Q6a&b Follow up Complete /Long	Q7 Results	Q8 Precise Results	Q9 Believable Results	Q10 Applic. Local pop.	Q11 Results fit with evidence	Q12 Implica. Included
22	Wetzke et al. 2018	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🟢	🟢
23	Mueller-Hermelink et al. 2018	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢
24	Solyman et al. 2018	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢
25	Zhou et al. 2018	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢

#	Article	**Case Control CASP**	Q1 Clearly focuss ed issue	Q2 Appropri ate Method	Q3 Accept. Recruitm ent Cases	Q4 Accept. Recruitm ent Control	Q5 Exposure Acc. Measured	Q6a Groups treated equal	Q6b Confou nd accoun t.	Q7 Size Rx effec t	Q8 Precise est. of Rx effect	Q9 Belie ve result s	Q10 Applic. Local pop.	Q11 Results fit with eviden ce
		Cohor t CASP	Q1 Clearly focuss ed issue	Q2 Accept. Recruitm ent	Q3 Exposure Acc. Measure d	Q4 Outcome Acc. Measure d	Q5a&b Confound Identified/Acc ount	Q6a&b Follow up Comple te /Long	Q7 Results	Q8 Preci se Resul ts	Q9 Believa ble Results	Q10 Appli c. Local pop.	Q11 Results fit with eviden ce	Q12 Implic a. Includ ed
26	Addo et al. 2017	Cross-sectio nal	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢
27	Boateng et al. 2017	Cross-sectio nal	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
28	Braithwait e et al. 2017	Cross-sectio nal	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟠	🟢
29	Danquah et al. 2017	Cross-sectio nal	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢

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		Cohort CASP	Q1 Clearly focussed issue	Q2 Accept. Recruitment	Q3 Exposure Acc. Measured	Q4 Outcome Acc. Measured	Q5a&b Confound Identified/Account	Q6a&b Follow up Complete /Long	Q7 Results	Q8 Precise Results	Q9 Believable Results	Q10 Applic. Local pop.	Q11 Results fit with evidence	Q12 Implica. Included
30	Morawa et al. 2017	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢
31	Iguacel et al. 2017	Cohort	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢	🟢	🟢	🟢
32	Jablonka et al. 2017	Cross-sectional	🟢	🟢	🟢	🟢	🟠	🟢	🔴	🔴	🔴	🟢	🟢	🟢
33	Meeks, Hennemann et al. 2017	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢

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34	Meeks, Stronks et al. 2017	Cross-sectional	🟢	🔴	🟢	🟢	🔴	🟢	🟢	🟢	🟢	🔴	🟠	🟢
35	Pachankis et al. 2017	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
36	Beutel et al. 2016	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢	🟢	🟢	🟢
37	Zeitlmann et al. 2016	Cross-sectional	🟢	🟢	🟢	🟢	🔴	🟢	🔴	🔴	🔴	🟢	🟢	🟢

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38	Scheuing et al. 2015	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
39	Reiss, Breckenkam et al. 2015	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
40	Reiss, Schunck et al. 2015	Cohort	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
41	Belhadj Kouider et al. 2014	Cross-sectional	🟢	🟢	🟢	🔴	🟢	🟢	🔴	🟢	🔴	🔴	🔴	🔴

#	Article	**Case Control CASP**	Q1 Clearly focussed issue	Q2 Appropriate Method	Q3 Accept. Recruitment Cases	Q4 Accept. Recruitment Control	Q5 Exposure Acc. Measured	Q6a Groups treated equal	Q6b Confound account.	Q7 Size Rx effect	Q8 Precise est. of Rx effect	Q9 Believe results	Q10 Applic. Local pop.	Q11 Results fit with evidence
		Cohort CASP	Q1 Clearly focussed issue	Q2 Accept. Recruitment	Q3 Exposure Acc. Measured	Q4 Outcome Acc. Measured	Q5a&b Confound Identified/Account	Q6a&b Follow up Complete /Long	Q7 Results	Q8 Precise Results	Q9 Believable Results	Q10 Applic. Local pop.	Q11 Results fit with evidence	Q12 Implica. Included
42	Morawa et al. 2014	Cross-sectional	Green	Green	Red	Red	Green	Green	Red	Green	Red	Green	Green	Green
43	Belhadj Kouider et al. 2013	Cross-sectional	Green	Green	Green	Green	Green	Green	Red	Green	Red	Green	Red	Orange
44	Morgenstern et al. 2013	Cross-sectional	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
45	Reeske et al. 2013	Cohort	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
46	Bogic et al. 2012	Cross-sectional	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green

#	Article	**Case Control CASP**	Q1 Clearly focussed issue	Q2 Appropriate Method	Q3 Accept. Recruitment Cases	Q4 Accept. Recruitment Control	Q5 Exposure Acc. Measured	Q6a Groups treated equal	Q6b Confound account.	Q7 Size Rx effect	Q8 Precise est. of Rx effect	Q9 Believe results	Q10 Applic. Local pop.	Q11 Results fit with evidence
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47	Reime et al. 2012	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢
48	Dannemann et al. 2011	Cross-sectional	🟢	🟢	🔴	🔴	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
49	Wyen et al. 2011	Case-control	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢
50	Mewes et al. 2010	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🔴	🔴
51	Ott et al. 2010	Cohort	🟢	🟠	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢

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52	Schreyer and Petermann 2010	Cross-sectional	🟢	🟢	🔴	🟢	🟢	🟢	🔴	🔴	🔴	🔴	🔴	🟠
53	Reime et al. 2009	Cohort	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
54	Spallek et al. 2009	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢	🟢	🟢
55	Haasen et al. 2008	Cross-sectional	🟢	🟢	🟠	🟠	🟢	🔴	🔴	🔴	🔴	🔴	🔴	🟢

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56	Irfaeya et al. 2008	Cross-sectional	🟢	🟢	🔴	🔴	🟢	🟢	🔴	🔴	🔴	🔴	🟢	🟢
57	Merbach et al. 2008	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🟢	🟢	🟢
58	Ott et al. 2008	Cohort	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢	🟢	🟢	🟢	🟢
59	Spix et al. 2008	Cohort	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🔴	🟢	🟢	🟢	🟢

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60	Voss et al. 2008	Cross-sectional	🟢	🟢	🟢	🔴	🟢	🟢	🔴	🔴	🔴	🔴	🔴	🔴
61	Will et al. 2005	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🟢	🟢	🟢
62	Porsch-Ozcurumez et al. 2003	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
63	David et al. 2002	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🔴	🟢	🟢	🟢

#	Article	**Case Control CASP**	Q1 Clearly focussed issue	Q2 Appropriate Method	Q3 Accept. Recruitment Cases	Q4 Accept. Recruitment Control	Q5 Exposure Acc. Measured	Q6a Groups treated equal	Q6b Confound account.	Q7 Size Rx effect	Q8 Precise est. of Rx effect	Q9 Believe results	Q10 Applic. Local pop.	Q11 Results fit with evidence
		Cohort CASP	Q1 Clearly focussed issue	Q2 Accept. Recruitment	Q3 Exposure Acc. Measured	Q4 Outcome Acc. Measured	Q5a&b Confound Identified/Account	Q6a&b Follow up Complete /Long	Q7 Results	Q8 Precise Results	Q9 Believable Results	Q10 Applic. Local pop.	Q11 Results fit with evidence	Q12 Implica. Included
64	Grüber et al. 2002	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
65	Kistemann et al. 2002	Eco-logical	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
66	Penn et al. 2002	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🟢	🟢	🟢
67	Fichter et al. 1988	Cross-sectional	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🔴	🔴	🟢	🟢	🟢

🟢 Yes (low risk of bias) 🔴 No (high risk of bias) 🟠 can't tell

Note: The experimental study by Arendt and Karadas, 2019 was evaluated using a different CASP RCT checklist, wherefore it was not added to the table.

Appendix B: Supplementary analysis for the association between RRR-derived related with NAFLD and T2DM

Table S4. Pearson correlations between the biomarker-related dietary pattern score, food intake frequencies, and NAFLD biomarkers (log-transformed) among men (n=1,366) (Osei et al. 2021)

Food groups	Cholesterol		LDL-Cho		HDL-Cho		ASAT		ALAT		GGT		Triglycerides		CRP	
	r	partial r	r	partial r	r	partial r	r	partial r	r	partial r	r	partial r	r	partial r	r	partial r
Whole grain cereals	0.10	-0.03	0.21	-0.03	0.13	0.02	-0.20	-0.01	-0.01	-0.03	-0.05	-0.05	-0.12	-0.08	0.00	0.05
Poultry	0.11	0.00	0.10	0.00	0.11	0.04	-0.14	0.02	0.05	0.02	-0.02	-0.01	-0.06	-0.03	-0.07	-0.04
Dairy products	0.10	0.05	0.09	0.04	0.13	0.08	-0.11	-0.01	0.02	0.00	-0.07	-0.06	-0.09	-0.05	-0.03	-0.01
Coffee & tea	0.08	-0.05	0.06	-0.05	0.11	0.00	-0.20	-0.02	-0.02	-0.02	-0.02	-0.01	-0.04	0.01	-0.05	-0.01
Condiments	0.11	0.04	0.10	0.03	0.11	0.04	-0.05	0.05	0.09	0.05	-0.04	-0.02	-0.05	-0.01	-0.05	-0.02
Potatoes	0.12	0.03	0.09	0.01	0.14	0.05	-0.10	0.06	0.05	0.06	0.03	0.04	-0.01	0.05	-0.05	-0.02
Margarine	0.04	-0.05	0.04	-0.04	0.05	-0.03	-0.16	-0.04	-0.01	-0.01	-0.02	-0.02	-0.05	-0.02	-0.06	-0.04
Olive oil	0.05	-0.02	0.06	-0.01	0.06	0.00	-0.11	-0.01	0.04	0.03	-0.06	-0.05	-0.07	-0.05	-0.05	-0.03
Palm oil	-0.13	-0.01	-0.11	0.00	-0.12	-0.04	0.15	-0.02	-0.04	-0.02	0.02	0.01	0.05	0.01	0.07	0.04
Roots, tubers & plantain	-0.12	-0.01	-0.12	-0.02	-0.09	-0.03	0.14	0.01	-0.02	0.02	0.08	0.08	0.07	0.05	0.00	-0.03
Fermented maize products	-0.10	0.01	-0.09	0.00	-0.07	0.03	0.18	0.03	-0.01	-0.01	0.02	0.01	0.03	-0.01	0.04	0.01
Vegetarian mixed dishes	-0.03	0.05	-0.01	0.06	-0.08	0.00	0.13	0.01	0.06	0.07	0.04	0.03	0.07	0.03	0.07	0.04

Food groups	Cholesterol		LDL-Cho		HDL-Cho		ASAT		ALAT		GGT		Triglycerides		CRP	
	r	partial r	r	partial r	r	partial r	r	partial r	r	partial r	r	partial r	r	partial r	r	partial r
Fish	0.02	0.05	0.05	0.07	-0.08	-0.02	0.07	0.01	0.03	0.02	0.05	0.04	0.03	-0.01	0.03	0.02

Partial correlation coefficients are adjusted for age, body mass index, and study site. Only food groups with factor loadings ≥0.15 are shown.

Table S5. Pearson correlations between the biomarker-related dietary pattern score, food intake frequencies, and NAFLD biomarkers (log-transformed) among women (n = 2,321) (Osei et al. 2021)

Food group	Cholesterol		LDL-Cho		HDL-Cho		ASAT		ALAT		GGT		Triglycerides		CRP	
	r	partial r	r	partial r	r	partial r	r	partial r	r	partial r	r	partial r	r	partial r	r	partial r
Whole grain cereals	-0.01	-0.04	-0.02	-0.03	0.15	0.00	-0.17	0.06	-0.02	0.07	-0.01	0.01	-0.21	-0.09	0.07	-0.02
Poultry	-0.03	-0.04	-0.05	-0.04	0.15	0.02	-0.24	-0.04	-0.08	-0.01	-0.04	-0.04	-0.19	-0.04	-0.03	0.00
Dairy products	0.00	0.01	-0.01	0.01	0.12	0.04	-0.11	0.01	-0.03	0.02	-0.01	0.01	-0.15	-0.06	-0.06	-0.04
Coffee & tea	0.01	-0.01	-0.02	-0.03	0.21	0.05	-0.27	-0.04	-0.13	-0.05	-0.03	-0.03	-0.19	-0.03	-0.03	0.01
Condiments	-0.02	0.01	-0.03	0.01	0.15	0.02	-0.22	0.00	-0.09	-0.01	-0.01	0.02	-0.20	-0.03	0.00	0.03
Potatoes	-0.06	-0.06	-0.08	-0.07	0.16	0.00	-0.18	0.01	-0.06	0.02	-0.03	-0.01	-0.19	-0.05	-0.02	0.03
Margarine	-0.01	-0.03	-0.02	-0.03	0.10	-0.01	-0.14	0.01	-0.05	0.01	-0.04	-0.04	-0.14	-0.05	-0.05	-0.03
Olive oil	-0.01	-0.03	-0.03	-0.04	0.15	0.08	-0.11	0.00	-0.05	-0.01	-0.04	-0.04	-0.17	-0.11	-0.06	-0.04
Palm oil	-0.03	-0.02	-0.02	-0.03	-0.17	-0.03	0.20	0.01	0.08	0.02	0.02	0.02	0.18	0.05	0.03	0.01
Roots, tubers & plantain	-0.06	-0.07	-0.04	-0.06	-0.14	-0.05	0.15	-0.02	0.05	-0.01	0.02	0.02	0.10	-0.02	0.00	-0.01

Fermented maize products	-0.04	-0.01	-0.03	-0.02	-0.09	0.02	0.11	-0.03	0.03	-0.03	-0.02	-0.01	0.07	-0.01	0.03	0.02
Vegetarian mixed dishes	0.08	0.09	0.09	0.08	-0.11	0.00	0.20	0.06	0.08	0.03	0.05	0.05	0.18	0.07	0.03	0.00
Fish	0.10	0.10	0.13	0.12	-0.10	-0.05	0.09	0.04	0.03	-0.01	0.06	0.05	0.12	0.07	0.06	0.03

Partial correlation coefficients are adjusted for age, body mass index, and study site. Only food groups with factor loadings ≥0.15 are sh

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PERSONAL DETAILS

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EDUCATION

DATE	QUALIFICATION	INSTITUTION
2019 – Today	Dr. sc. hum. Global Health	Heidelberg Institute for Global Health (HIGH), Medical Faculty and University Hospital, Heidelberg University
2017	M. Phil. Human Nutrition and Dietetics	Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana
2014	Bachelor of Education, Food and Nutrition	University of Cape Coast, Ghana

EMPLOYMENT HISTORY

DATE	POSITION / INSTITUTION	RESPONSIBILITIES
06/2016-12/2016	**Dietician Assistant** Korle-Bu Teaching Hospital Accra and Komfo Anokye Teaching Hospital, Kumasi, Ghana	• Assess clients' nutritional and health needs. • Counsel clients on nutrition issues and healthy eating habits. • Develop meal and nutrition plans, taking clients' preferences and budgets into account. • Evaluate and monitor the effects of nutrition plans and practices and make changes as needed.
09/2014-08/2015	**Nutritional Science Tutor** Vocational Training Institute, Upper West Region of Ghana	• Participated in organizing workshops, meetings, and trainings for research staff. • Responsibility of teaching and supervising student research. • Consolidated and reconciled full board meeting discussion with written comment from committee members into a single decision statement and communicated the modifications to investigators.

RESEARCH EXPERIENCE

DATE	POSITION / STUDY TITLE	RESPONSIBILITIES
2023	**Student Investigator** Associations of low-carb diets with glycaemic control and diabetic complications among adult Ghanaians: the RODAM study.	Responsible for success of the data cleaning, idea, manuscript writing, data analysis and the research report.
2022	**Student Investigator** Aetiological research on the health of migrants living in Germany: a systematic literature review.	Responsible for data search, data analysis, manuscript writing.
2021	**Student Investigator** Reduced Rank Regression-Derived Dietary Patterns Related to the Fatty Liver Index and Associations with Type 2 Diabetes Mellitus among Ghanaian Populations under Transition: The RODAM Study	Responsible for success of the data cleaning, idea, manuscript writing, data analysis and the research report.
2020	**Co-investigator** Non-alcoholic fatty liver disease as assessed by the Fatty Liver Index among migrant and non-migrant Ghanaian populations	Participated in reviewing literature.
2017	**Investigator** Nutritional status of children with sickle cell disease: A study at the Komfo Anokye Teaching Hospital of Ghana	• Drafting of the idea • Data collection • Responsible for overall success of the study and writing of the research report. • Publication of paper

SHORT COURSES/WORKSHOPS/CONFERENCES

DATE	INSTITUTION	OBJECTIVE / COURSES
2022	Trends in Nutrition Epidemiology, **University of Heidelberg.**	▪ Guide participants on novel approaches to model dietary exposures, ▪ Provide knowledge to the participants about healthy and environmentally friendly diets in specific population groups, ▪ Present methodological approaches to optimize the sustainability of diets, ▪ Introduce approaches for deriving dietary guidelines.
2022	European Diabetes Epidemiology Conference, **Greece.**	Presented on Associations of low-carb diets with glycaemic control and diabetic complications among adult Ghanaians: the RODAM study (**oral presentation**).
2021	European Diabetes Epidemiology Conference, **online.**	Presented on Reduced rank regression-derived dietary patterns related to the fatty liver index and associations with type 2 diabetes mellitus among Ghanaian populations under transition: the RODAM study **(**oral presentation**)**.
2021	Systematic literature, **Amrita university in India and university of Heidelberg.**	Creating Evidence for Improved Decision Making – Introduction to Systematic Literature Review.
2020	Epidemiology and biostatistics, **university of Heidelberg.**	▪ Overview, repetition of epidemiological and statistical concepts. ▪ How to measure risks ▪ Logistic Regression ▪ Longitudinal Data and Repeated Measurements ▪ Estimation Techniques and their Application in Generalized Linear Models + Practical Session

Skills

Software Skills: Microsoft Office, STATA, SAS, Data wrapper and SPSS

Data Collection tools: Epi Data Info, Google Docs, and Kobo tool kit.

VOLUNTEERING ACTIVITIES

2022: Assistant coordinator– Trends in Nutrition Epidemiology summer school, Heidelberg University.
2021 – 2023: Teaching assistant – supporting practical sessions and lectures in the MSc International Health, Epidemiology and Biostatistics Module at Heidelberg Institute for Global Health (HIGH)

Awards

DAAD German Academic Exchange Service: Research Grant Scholarship (2019-30/09/2023)

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Eidesstattliche Versicherung

1. Bei der eingereichten Dissertation zu dem Thema **„Dietary behaviour and type 2 diabetes mellitus among sub-Saharan African populations under transition"** handelt es sich um meine eigenständig erbrachte Leistung.

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