Ethnic differences in diet: A focus on methodology, determinants and Type 2 Diabetes Mellitus
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CHAPTER 1

General introduction
Diet is an important modifiable risk factor of diseases such as type 2 diabetes mellitus (T2DM) [1]. A Western dietary pattern characterized by a high consumption of red and processed meats, high-fat dairy, refined grains and sweets has been associated with a higher risk of T2DM [1]. In Western societies, ethnic minority populations are suffering a disproportionate burden of disease [2]. In the Netherlands, where a large proportion of minority populations originated from Suriname, Turkey or Morocco, the disease risk profile has been shown to differ from that of the majority population. For example, the risk of T2DM among South Asian migrants is five times higher than among those of Dutch origin [3, 4]. Differences in diet may partly underlie these observed ethnic differences in disease risk. Insight in such differences in diet is warranted to inform public health nutrition efforts addressing current health disparities across ethnic groups.

There is strong evidence that traditional dietary habits differ considerably amongst ethnic populations in European countries [5]. This is not surprising as diet is governed by deeply rooted cultural norms and values, and has particular significance for ethnic and cultural identity [6]. Migration adds complexity to the observed differences in diet: following migration, ethnic minority populations may alter their eating habits, combining parts of their traditional diet with some of the less healthy elements of the Western diet. This complex change in diet may depend on factors such as socio-economic status (SES) [7-9] or elements associated with the actual migration such as age of migration, time since migration, generation status or e.g. being assimilated or integrated to the host culture [5, 10-13]. Insight in such determinants of diet may further inform public health nutrition efforts, e.g. should such efforts be targeted at a specific ethnic minority group or subgroup?

As dietary intake is likely to differ between ethnic groups, instruments to assess dietary intake in ethnically diverse populations may not necessarily be valid in ethnic minority groups. Dietary assessment instruments are typically developed for the native or host population, and are often not designed to assess the consumption of ethnic specific foods commonly consumed in ethnic minority groups. Therefore, current comparative research on dietary intake in ethnically diverse populations is limited. The development of validated dietary assessment instruments for ethnic minority groups is required in order to move the field of public health nutrition forward.

Up to now, most large population-based cohort studies have excluded ethnic minority populations [14]. The main argument of excluding these groups is in favor of ethnic homogeneity related to the internal validity and statistical power of the study. The more homogenous the study population, the more likely it will be that the observed associations have not been biased due to confounding introduced by a multi-ethnic population. However, the more homogeneous the study population, the less closely it will resemble the heterogeneity of the ‘real-world’ population. Large population based multi-ethnic studies using ethnic specific measurement instruments to assess dietary
intake are therefore warranted in order to provide a concrete basis for future interventions aiming to improve healthy dietary behaviour amongst all.

This thesis aims to contribute to a scientific basis for the analysis of the role of diet in the observed ethnic disparities in T2DM prevalence. The research presented here focuses on the development of validated instruments to assess dietary intake in a multi-ethnic population, on the influence of SES and cultural determinants of diet, and examined the health consequences of diet in different ethnic groups.

This introductory chapter is composed of three main sections. In the first section methodological concepts such as the development of ethnic specific instruments to assess dietary intake and methods to describe dietary patterns are discussed. The second section focuses on the determinants of diet in multi-ethnic populations. In the third section, the association between diet and T2DM is described with a primary focus on ethnicity. Subsequently, the main research questions addressed in this thesis are presented, followed by an overview of the data used in each of the studies and a general outline of the thesis.

PART 1 | Methodological concepts when studying dietary intake in multi-ethnic settings

FFQ development
Assessing habitual dietary intake is one of the greatest challenges in dietary research, especially in ethnic minority groups. Issues such as language, culture and the relatively low SES of ethnic minorities have formed barriers for their inclusion in research. Furthermore, differences in dietary habits, a lack of food composition data on ethnic foods [5] as well as a lack of validated dietary assessment instruments further complicates the collection of accurate and representative dietary intake data in ethnically diverse populations [5, 15].

Diet differs between ethnic groups [5]. This implies that, before the dietary habits of ethnic groups can be assessed, an ethnic specific measurement instrument needs to be developed, taking into account ethnic differences in dietary habits [15, 16]. Food frequency questionnaires (FFQs) are an acceptable method for assessing habitual dietary intake [17] in large population based cohort studies as their administration does not require highly trained interviewers and may be self-administered in the participant’s preferred language. A problem is that FFQs should be adapted to the food habits of the target population, which may hamper comparability of collected intake data between different populations. A simple approach would be to apply a single FFQ in all ethnic groups. However, this option would either result in a very long questionnaire, especially in the case of large ethnic differences in diet, or in a compromise of its face validity.
To date, the literature on the adaptation of FFQs in order to assess dietary intake in multi-ethnic settings is scarce. The study of Shahar et al. [16] provides a good example of the development of a measurement instrument in a multi-ethnic population. The authors describe the steps undertaken in the development of a single FFQ among three ethnic groups living in the Negev area, in the south of Israel. They conclude that they observed large ethnic differences in dietary intake and eating patterns, but that practical concerns (i.e. food cross-over and the high rate of marriage between ethnic groups) supported a unified questionnaire for this Jewish population [16]. The multi-ethnic cohort developed a FFQ including many ethnic food items. However, after a calibration study they concluded that the performance of the questionnaire varied by ethnic group [18].

As large differences in dietary intake are expected between the main ethnic minority groups in the Netherlands, and a high rate of marriage between ethnic groups is not expected, we decided to develop ethnic specific FFQs. This way, the FFQs can be shorter, save time and expense in their administration, potentially improve compliance and enhance the efficiency of data management. Therefore, with the establishment of the Healthy Life in an Urban setting (HELIUS) study [19] and the development of ethnic specific FFQs within the HELIUS-Dietary Patterns study [20], we are able to assess the habitual dietary intake within the main ethnic minority groups in the Netherlands and to make a proper comparison with the dietary intake among those of Dutch origin.

Dietary intake versus dietary pattern analysis

Research into habitual dietary patterns as a whole has received increasingly more attention from researchers seeking to establish links between diet and chronic diseases. This, as the result of a recognition that nutrients do not exist in isolation; they are obtained from foods, containing a mix of different nutrients and bioactive substances. Information on disease risk associated with habitual food patterns may help in prioritizing public health efforts and provide a more concrete basis for improving food intakes; dietary changes may be more readily achieved if recommended foods are compatible with existing patterns of food consumption [21].

There are numerous methods to perform dietary pattern analysis such as widely used a-posteriori methods i.e. cluster analysis and principal component analysis (PCA) [22-24]. A posteriori methods are data driven methods, not based on a pre-defined hypothesis on the link between diet and disease. A posterior methods aim to reduce data into a smaller set of variables i.e. dietary patterns. Cluster analysis aims to minimize differences within each group (within-cluster homogeneity) while maximizing the differences across groups (between-cluster heterogeneity) [22-24]. PCA aims to explain the total variation in intake of many foods or food groups in terms of a few linear functions called principal components. It groups correlated food groups into
uncorrelated components, i.e. dietary patterns [22-24]. Another type of method involves a-priori diet-quality scores (Mediterranean diet score, Healthy Eating Index, etc.), which is a hypothesis-oriented approach as it is based on recommended diets or dietary guidelines [23-25]. Here, scientific evidence available prior to the current study is used to define dietary patterns. Both a-priori and a-posteriori approaches do not necessarily maximize the disease-predictive value of the dietary pattern. One limitation of both methods is that they are not designed to derive dietary patterns that are predictive of disease. For this reason hybrid methods, such as Reduced Rank Regression (RRR), have been proposed as an alternative. RRR combines a hypothesis on the occurrence of disease with multivariate dietary pattern analysis based on the study data [23, 26]. With this approach the relation between two groups variables can be analyzed by constructing linear combinations of one group of variables (for example food intakes) that explain as much variation as possible in the other variable group (for example biomarkers of disease or nutrient intakes) [26].

In this thesis different patterning approaches were applied in order to explore different facets of the patterns of dietary intake across ethnic groups. Cluster analysis is applied to study transitions of dietary patterns over time, PCA is applied to examine current behaviour based dietary patterns and RRR in order to explore potential differences in T2DM specific dietary patterns across ethnic groups and to derive a disease specific dietary pattern relevant to South Asian populations.

Changes in diet over time
Dietary intake may change over time, due to factors associated with the occurrence of disease, changes in SES, food availability, demographics, or, among ethnic minority populations, because of alterations in eating habits following migration. Currently, the assumptions about the stability of diet, and consequently the use of repeated measurements when predicting health outcomes, vary widely in current research. It is to be expected that using repeated measurements may reduce the amount of measurement error in the estimates of dietary intake, but few studies have the possibility to use multiple repeated measurements in order to understand the nature of changes in dietary patterns over time.

Insight in dietary changes over time is important as the role for timing and targeting of a public health message has been highlighted [27]. Studying dietary change in a population which is not subjected to continuous demographic changes (e.g. migrant flows, socio-economic changes) may best inform us on long-term stability of diet. This thesis therefore investigates the reproducibility of dietary patterns within the Doetinchem cohort, in order to improve our knowledge about measures of the (internal) stability and reproducibility of dietary patterns and provides insight in the transitions of individuals between dietary patterns over time.
PART 2 | Determinants of diet

Migration to Western countries implies a shift in the environment, stimulating the adoption of dietary as well as other health-related habits of the host population that may potentially increase the risk of chronic disease such as T2DM. This environmental shift may include changes in food availability as well as changes in attitudes, knowledge, beliefs, etc. [6]. Given these underlying dynamics – which may influence dietary habits as well as many other determinants of health – a precise description of the background of migrant (origin) groups, in terms of length of residence in the host country, extent of integration, SES, acculturation etc., is essential for a good understanding of the results of a study of dietary intake among ethnic minority groups. In this thesis we will explore the influence of socio-economic determinants, and the role of acculturation on the patterns of dietary intake among ethnic minority groups. A brief introduction on these concepts is given in the following sections. However, these concepts are extensively described in the HELIUS-Dietary Patterns design paper [20].

Socio-economic status
Understanding the role of dietary intake is relevant in high-risk groups, such as those of low SES, among which non-western immigrant populations are over represented. Data from studies in the Netherlands [28] as well as internationally [7] have suggested that lower SES groups are less likely to consume a healthy diet. Differences in diet and dietary patterns between ethnic groups that have been previously described may therefore partially be a reflection of differences in SES. Therefore, in order to understand the origins of ethnic differences in diet, there is a pressing need to address socio-economic differences with respect to dietary behaviour in multi-ethnic populations. To date, there is little evidence as to whether the well-known socio-economic gradient in diet - in which SES is positively associated with a diet quality - also applies to ethnic minority groups. The direction or strength of the association between SES and diet might not be similar across ethnic groups [29]. This, because of the complex interaction between diet and ethnicity; diet is governed by deeply rooted cultural norms and values, and has particular significance for ethnic and cultural identity. Some aspects of the diet may be relinquished or adopted more readily than others [30], which may lead to a different association with SES as compared to the host population.

Acculturation
The process of migration can result in cultural changes, affecting attitudes, orientations or behaviours [31], including eating habits [31-33], and this process is defined as acculturation [34, 35]. Age at the time of migration to the host country, length of residence in the new environment and generation status are often used in the literature as proxies...
of acculturation [36]. For example, it is observed that younger people of the second and third generations consume more processed foods such as snacks and sugar sweetened beverages than the first generation [5]. Such proxies are quick and convenient; however, many authors have criticized their use because of the assumption that the process of adaptation to the host culture is accompanied by the loss of the original culture [37, 38] – a unidimensional model of acculturation. The bidimensional model, in contrast, assumes that both cultural orientations are seen as relatively independent of one another. Individuals may adapt to the host culture without losing their attachment to the culture of origin [34].

Both models have been used to assess acculturation in nutritional epidemiology. Within this thesis we will investigate both unidimensional and bidimensional models of acculturation with respect to differences in the adherence to specific dietary patterns across ethnic groups.

PART 3 | The link between diet and type 2 diabetes mellitus

Dietary patterns and type 2 diabetes mellitus in a multi-ethnic cohort

Considering the increased risk of T2DM among migrant origin groups in the Netherlands, knowledge on the (mediating) role of ethnicity and the link between diet and T2DM, as well as the generalizability of the occurrence of disease specific dietary patterns among different ethnic groups is relevant for the planning of nutritional interventions. Therefore this thesis aims to explore the role of ethnicity in the association between diet and T2DM. In general, a so called “Western” dietary pattern characterized by a high consumption of red and processed meats, high-fat dairy, refined grains and sweets has been associated with higher risk of T2DM [1]. However, such a dietary pattern may not necessarily be associated with T2DM within different ethnic groups. It has often been observed that following migration dietary patterns are altered, combining part of the traditional diet with some of the less healthy aspects of the “Western” diet [5, 39]. Nevertheless, among a large proportion of migrants the intake of staple foods (i.e. rice, ethnic breads, noodles) remain [5]. Additionally, sources of macronutrient intake may differ across ethnic groups, e.g. a high proportion of South Asian migrants follows a vegetarian diet in which the main source of protein is derived from cereal intake instead of meat intake [40]. This may also be the case for micronutrients; ethnicity is an independent correlate of biomarkers of micronutrient intake and status in American adults [41]. Such ethnic specific differences in the composition of dietary patterns may affect the association between diet and disease across ethnic groups.

In this thesis we will assess the association between diet and T2DM not only within the main ethnic minority groups in the Netherlands, but also in an international comparison of South Asian migrant origin populations residing in Asia and Europe.
Main aim of thesis and research questions
The overall aim of this thesis is contributed to a scientific basis of dietary analysis within an ethnically diverse population in the Netherlands. More specifically, this thesis aims to assess ethnic differences in dietary patterns, to examine the association between socio-economic determinants, acculturation and dietary patterns, and to investigate the role of diet in T2DM. Three research questions are addressed:
1. How feasible it is to develop ethnic specific food frequency questionnaire and how stable are dietary patterns over time?
2. What are the dietary patterns of the main migrant groups in the Netherlands and what is the association between social-economic status, acculturation and these dietary patterns?
3. What is the association between diet and T2DM and what is the role of ethnicity in this respect?

Data and methods
The studies described in this thesis were based on four sources of data.

The HELIUS and HELIUS-Dietary Patterns study
Participants in the HELIUS-Dietary Patterns study are recruited within the HEalthy LIfe in an Urban Setting (HELIUS) study [19]. The HELIUS study is designed as a prospective cohort study, and is being carried out in Amsterdam, the Netherlands. The study has the primary aim to unravel the causes of the unequal burden of disease across ethnic groups, and consists of an extensive questionnaire and a physical examination. It includes people of Dutch origin along with individuals with African origin Surinamese, South Asian origin Surinamese, Turkish, Moroccan, and Ghanaian backgrounds, which are the largest ethnic minority groups in Amsterdam.

In the Netherlands, country of birth has become widely accepted as a basis for identifying ethnic groups. This is the definition used in the HELIUS study. Specifically, a person is defined as of non-Dutch ethnic origin if she or he fulfils one of two criteria: he or she was born outside the Netherlands and has at least one parent who was born outside the Netherlands (first generation); or he or she was born in the Netherlands but both parents were born outside the Netherlands (second generation). In addition, to differentiate between ethnic subgroups a question on self-identification was included in the questionnaire. This enabled us to differentiate between African origin Surinamese, commonly referred to as Creole, and South Asian origin Surinamese, commonly referred to as Hindustani. The African origin group has a mixed African and European ancestry and the Hindustani originated from the Indian sub-continent. Subjects in the age range of 18 to 70 years are randomly sampled, stratified by ethnic origin, through the municipality registry of Amsterdam. This registry contains data on the country of birth of residents.
and their parents, which are used to determine ethnic background.

The HELIUS-Dietary pattern study is based on a subsample of the HELIUS study [20]. Participants of the HELIUS study that gave consent to taking part in additional studies were eligible to participate in the HELIUS-Dietary Patterns study and were asked to fill in a supplementary Food Frequency Questionnaires (FFQ) to assess dietary intake. Approval for the HELIUS study and the HELIUS-Dietary patterns study has been given by the Amsterdam Medical Center (AMC) Medical Ethics Committee.

The Doetinchem Cohort Study
The Doetinchem Cohort Study is a population based longitudinal cohort study in which participants were randomly selected from an age- and sex-stratified sample from the civil registries of the town of Doetinchem aiming to study the impact of (and changes in) lifestyle factors and biological risk factors on aspects of health [42]. A two-third random sample was invited for follow-up measurements at 6, 11 and 16 years after the first survey, during 1993–1997 (survey 2), 1998 –2002 (survey 3), and 2003–2007 (survey 4). At every re-examination, lifestyle factors and biological risk factors were assessed by questionnaires and a physical examination at the research centre. The response rates for all follow-up measurements varied between 75% and 80%, which has led to the inclusion of 6113, 4916 and 4520 participants for survey 2, 3 and 4, respectively. All participants gave written informed consent. From survey 2 (1993) onwards, an extensive nutrient and food group validated FFQ was administered. This FFQ was developed for the EPIC-Study, a prospective study into nutrition and cancer [43, 44]. The EPIC FFQ contains questions on the habitual frequency of consumption of 79 food groups during the year preceding enrolment. Further information was sought on consumption frequency for different sub-items, preparation methods and additions, which ultimately allowed the estimation of consumption for 178 food items. The study was approved by the external Medical Ethics Committee of the Netherlands Organization of Applied Scientific Research according to the guidelines of the Declaration of Helsinki.

SUNSET study: Surinamese in the Netherlands: Study on Ethnicity and health
The SUNSET study was based on a stratified random sample of 2975 individuals, aged 35 to 60 years of age, drawn from the population register of two neighbourhoods in Amsterdam. These two neighbourhoods were selected due to their large concentration of Surinamese-origin residents. For the sampling procedure the ethnicity of respondents was determined by the country of birth of the respondent and of his/her parents. Thus, subjects were considered to be of Dutch origin if they and their parents were born in the Netherlands and to be Surinamese if they or their parents were born in Suriname. During the interview, the ethnicity of Surinamese respondents was further determined by self-report, i.e. if they considered their origin to be South Asian or African. The Medical
Ethical Committee of the Amsterdam Academic Medical Centre approved the study protocols.

**The Singapore Prospective Study Program**

The Singapore Prospective Study Program (SP2), conducted between 2003-2007, was a follow-up of persons participating in four previous Singaporean population-based studies: the Thyroid and Heart Study [45], the National Health Survey-1992 [46], National University of Singapore Heart Study [47] and the National Health Survey-1998 [48]. These studies used a stratified random sampling method, disproportionate for ethnicity (Chinese, Asian Indian, and Malay) to increase representation of the minority Malay and Asian-Indian ethnic groups. For the SP2 study, standardized interviewer-administered questionnaires including a FFQ was completed during a home visit by 7744 participants, and 5163 of these participants attended a clinic visit. Data on demographic and lifestyle characteristics and medical history were collected during the interview and fasting blood samples were obtained during the clinic visit for measuring biochemical markers [49]. The SP2 study was approved by the Singapore General Hospital and the National University Hospital Institutional Review Boards.

**Outline of the thesis**

Table 1 summarizes the topics covered in each chapter. The first part, which includes chapters 2, 3 and 4, focuses on the methodological concepts. Chapter 2 presents the design of a multi-ethnic comparative study, the HELIUS-Dietary Patterns study, to assess habitual diet to study determinants and health consequences of dietary behaviour. Chapter 3 described the development of ethnic-specific FFQs to study the habitual dietary intake of Surinamese (African and South Asian), Turkish, Moroccan and Dutch origin residents of the Netherlands. The underlying aim in the developing these ethnic-specific FFQs was to develop comparative FFQ in order to conduct research into ethnic differences in the association between diet and health.

The focus in the second part of this thesis is on determinants of dietary patterns in those of Dutch origin, South Asian Surinamese and African origin Surinamese. In chapter 4 we evaluated how dietary patterns of South Asian Surinamese and African origin Surinamese vary with acculturation, measured using both unidimensional and bidimensional models of acculturation. Chapter 5 aimed to examine ethnic differences in dietary patterns and the role of socio-economic indicators on dietary patterns within a multi-ethnic population. Principal component analysis was used to identify dietary patterns. Levels of education and occupation were used to indicate SES.

In the third section we focus on the link between diet and T2DM in different ethnic groups. Chapter 6 presents the results on the association between serum ferritin and the prevalence of T2DM and fasting glucose concentrations in a population-based...
multi-ethnic cross-sectional study including men and women of African Surinamese, South-Asian Surinamese and Dutch origin. In this study we examined whether differences in the association between serum ferritin between men and women varied between these ethnic groups. Chapter 7 describes the dietary patterns within five ethnic groups by using two empirical methods to derive dietary patterns (behavior based PCA and disease specific RRR) and presents how much ethnic heterogeneity in such patterns exists. In this paper we examined the association between such patterns and biomarkers for T2DM in order to compare dietary patterns within five ethnic groups and to examine their association with biomarkers of T2DM. In chapter 8 we evaluated the generalizability of a T2DM specific dietary pattern observed in different South Asian migrant populations, residing in Asia and Europe.
Table 1. Overview of the topics covered in each paper

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