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Dekker, L.H.

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CHAPTER 10

General discussion
The overall aim of this thesis was to enhance the scientific basis for dietary analysis and the role of diet in type 2 diabetes mellitus (T2DM) prevalence in an ethnically diverse population. A large multi-ethnic population including five ethnic groups - South Asian origin Surinamese, African origin Surinamese, Turkish, Moroccan and Dutch origin - was utilized to achieve this goal. To address the main aim of this thesis the following questions were formulated:

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?

This final chapter addresses the key findings of this thesis, including some of the methodological considerations. The main findings are discussed in light of their relevance for public health nutrition. Finally, recommendations are made for future research and policy.

Summary of the main findings
How feasible it is to develop ethnic specific food frequency questionnaire and how stable are dietary patterns over time?

In chapter 3 we described the process of developing ethnic specific food frequency questionnaires (FFQs) in order to assess habitual dietary intake among the main migrant groups in the Netherlands. We developed four ethnic specific FFQs using a standardized approach. The FFQs included 189 (Moroccan) to 238 (Dutch) food items; differences in the number of items are due to inclusion of ethnic-specific food items. The FFQs covered more than 90% of the intake of the main nutrients associated with cardiovascular diseases and T2DM. The assessment of content and face-validity led to refinement of the FFQs, such as adaptations to the descriptions of food items, rephrasing long sentences, adaptation of portion size ranges, extra colour photos, and dropping the grid format in favor of multiple answer questions.

Chapter 4 provided insight into the reproducibility of dietary patterns and the transition of individuals between dietary patterns over time at three surveys within the Doetinchem Cohort Study. A “low fiber bread” dietary pattern and a “high fiber bread” dietary pattern were identified at all three surveys, with five year intervals. Over time, dietary patterns were comparable in terms of foods contributing most to total energy intake, suggesting good reproducibility of dietary patterns within this population. Nevertheless, only 42% of the participants were consistently assigned to the same
dietary pattern at all three surveys. Over time, dietary patterns seemed therefore more reproducible within a population than within individuals.

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?

Chapter 5 described the main dietary patterns among participants of South Asian origin Surinamese, African origin Surinamese and Dutch origin. We aimed to examine ethnic differences in the adherence to these dietary patterns. “Noodle/rice dishes and white meat”, “red meat, snacks, and sweets” and “vegetables, fruit and nuts” dietary patterns were identified. Compared to Dutch origin participants, Surinamese more closely adhered to the “noodle/rice dishes and white meat” dietary pattern which was characterized by foods typically consumed in a traditional Surinamese diet, such as rice and noodle dishes, chicken and roti. Closer adherence to the other two patterns was observed among those of Dutch origin compared to Surinamese.

In chapter 5 and 6 we investigated whether the ethnic differences in the adherence to dietary patterns identified among the Dutch, South Asian origin Surinamese and African origin Surinamese differed by socio-economic status (SES) and acculturation. Ethnic differences in dietary patterns persisted within strata of education level and occupation status. Among Surinamese, the adherence to the “noodle/rice and white meat” and the “red meat and snack” dietary patterns was independent of educational level or occupational status. Across SES strata Surinamese showed a high adherence to the “noodle/rice and white meat” dietary pattern. Among Dutch origin participants, higher SES was associated with greater adherence to the “vegetable, fruits and nuts” dietary pattern and lower adherence to the other two dietary patterns. Compared to Dutch origin participants, a similar SES gradient was only present among Surinamese in the adherence to the “vegetables, fruit and nuts” dietary pattern. The ethnic differences in the adherence to these dietary patterns among could not be explained by acculturation measured on a unidimensional scale (i.e. proxies of acculturation) or with a bidimensional model (i.e. acculturation strategies such as assimilation or integration). With few exceptions we found that regardless of residence duration, age at migration, generation status, or acculturation strategy (assimilation, integration, marginalization or separation), Surinamese origin participants adhered more to a dietary pattern that is characterized by traditional Surinamese foods than the other dietary patterns.

What is the association between diet and Type 2 Diabetes Mellitus and what is the role of ethnicity in this respect?

In chapter 7, 8, and 9 we presented results on the associations of serum ferritin and dietary patterns with T2DM. First, we explored the role of serum ferritin (a biomarker of
iron intake) in participants of Dutch and Surinamese origin (chapter 7). Serum ferritin was positively associated with T2DM and fasting glucose concentrations among women in all ethnic groups, but not among men. Moreover, the magnitude of sex differences in the association between serum ferritin and fasting glucose concentrations, but not T2DM, was greater in the African origin Surinamese group than in the Dutch origin and South Asian origin Surinamese groups.

In chapter 8 we aimed to compare dietary patterns within five ethnic groups and to examine their association with biomarkers of T2DM by applying Principal Component Analysis (PCA) and Reduced Rank Regression (RRR) analysis within each ethnic group. PCA derived behavioural based dietary patterns by taking into account the variance in food group intake. RRR derived biomarker-driven dietary patterns on the basis of association between foods and biomarkers for disease (i.e. HbA1c and fasting glucose concentrations). Within each ethnic group two behaviour-based dietary patterns were identified and labelled as a “meat and snack” dietary pattern and a “vegetable” dietary pattern. These dietary patterns were largely comparable across ethnic groups. Only the “meat and snack” pattern derived within the Dutch origin population was significantly associated with an increase in HbA1c and fasting glucose concentrations. The biomarker-driven dietary pattern showed large heterogeneity across ethnic groups. For example, among the Dutch origin group the biomarker-driven dietary pattern was characterised by red and processed meat (consistent with a western diet), but this was not the case among the ethnic minority groups. Within the ethnic minority groups, foods that characterized the biomarker-driven dietary patterns were in some cases ethnic specific (e.g. roti, couscous), and illustrated possible ethnic differences in the link between diet and disease (e.g. low-fat dairy).

In chapter 9 we derived insulin-resistant-related dietary pattern in a South Asian migrant population in Asia by applying RRR, and investigated the generalizability to predict fasting glucose concentrations in an South Asian origin migrant population in Europe. The insulin-resistant-related dietary pattern was characterized by high consumption of eggs, fish and seafood, roti, and sugar sweetened beverages, and low consumption of, high-fiber bread, breakfast cereal, root vegetables, fruit, fat-based savory sauces, cheese and low fat dairy products. This insulin-resistant-related dietary pattern was significantly associated with increasing fasting glucose concentrations among South Asian migrant population in Asia, as well as among South Asian migrants in Europe, after adjustment for potential confounders. Besides current evidence on the association between commonly defined dietary patterns and T2DM, results from this study suggests that other T2DM-related dietary patterns may exist that are generalizable across populations.
Methodological considerations

Results presented in this thesis should be interpreted in light of several methodological considerations.

Self-reported dietary intake

Within the HELIUS-Dietary Patterns study, Doetinchem Cohort Study and The Singapore Prospective Study Program (SP2), habitual dietary intake was assessed using a self- or interviewer-administered FFQ based on the average intakes over the last 4 weeks or last month. It is a retrospective method of dietary assessment and therefore relies upon the respondent’s memory, which may introduce bias. In addition, misclassification of dietary intake in relation to body weight is known as a major weakness of FFQs. However, data assessed with FFQs is generally representative of habitual intake and is a feasible method for data collection in large epidemiological studies [1]. The processing of the questionnaire is significantly less expensive than food records or diet recalls and the intent is to rank individuals according to intake, rather than calculating true intake [1].

Validation of an FFQ is necessary to understand the validity of habitual dietary assessment. The FFQs used in the SP2 and Doetinchem cohort Study were validated against 24 hour urinary samples from which total nitrogen excretion was assessed to validate protein intake. Additionally, the FFQ used in the Doetinchem cohort study was validated against basal metabolic rate, and serum beta-carotene and alpha-tocopherol levels were analyzed [2-4]. Within the HELIUS-Dietary Patterns study, several FFQ validation analyses were performed. First the FFQs were tested based on content and face validity using expert judgement by dieticians, plus-minus interviews, focus groups discussions and cognitive interviews. Secondly, the FFQs were validated in a sub-sample of the study population (n=200 per ethnic group) using two biomarkers: plasma carotenoid levels to indicate fruit and vegetables intake and fatty acid concentrations measured in cholesterol ester to indicate fat intake. The associations between diet and biomarker concentrations were consistent in all ethnic groups indicating that the four FFQs were relatively valid indicators of dietary intake (manuscript in preparation). Finally, we evaluated underreporting of energy intake using the resting energy expenditure of each individual calculated based on the Schofield equation [5]. Under-reporting of energy intake, based on the cut-offs recommended by Black and Cole [6] was common in our population (37.8-48.8% of participants) and was more prevalent among Surinamese. However, we found no evidence of differences in under-reporting of energy intake in the ethnic groups studied when differences in BMI were taken into account (data not shown).

A major obstacle in nutritional epidemiology research on the link between diet and disease is the inaccuracy with which food and nutrient intake can be assessed. It may therefore be useful to further explore the role of dietary biomarkers and their association
with disease outcomes. One such biomarker might be serum ferritin. Nevertheless, it is important to keep in mind that, like in dietary patterns analysis, the association between such dietary biomarkers and disease outcomes may be different across ethnic groups. For example, the effect of sex on the association between serum ferritin and fasting glucose concentrations may be different across ethnic groups as observed from in chapter 7.

**Non-response and representativeness**

Since the city of Doetinchem is a rural area in the eastern part of The Netherlands, and Amsterdam is an urban area, the study populations included in the Doetinchem Cohort Study, the HELIUS Study and the SUNSET Study may not be representative for the entire country. While response rates as well as representativeness of a study population are a problem for prevalence estimates, it is less a concern when estimating the magnitude of associations between exposure and disease if there is still reasonable variance in the data. Nevertheless, proper understanding of the possible implications of selection bias should be taken into consideration in large observational studies. The overall response rates were on average 62% (the Doetinchem cohort study), and 30% (the HELIUS study, large variation between ethnic groups) and 60% (the SUNSET study).

With respect to the HELIUS Study and the SUNSET Study, ethnic differences in response rates are important to consider because differences may affect observed diet-disease associations across ethnic groups. With regard to the SUNSET Study, the absolute and relative differences between participants and non-participants for general population characteristics were small and reported trends were similar across ethnic groups. Within the HELIUS Study, the response rate differed significantly across ethnic groups, with the lowest response rates among the Turkish participants at about 20%. Unfortunately, we do not have insight into the differences between responders and non-responders within the HELIUS-Study. Subjects in the age range of 18 to 70 years are randomly sampled, stratified by ethnic origin, through the municipality registry of Amsterdam. No other data then sex, age and ethnicity was available from non-responders.

Further selection might have occurred in the inclusion of participants in the HELIUS-Dietary Patterns Study. This study is an additional evaluation within the HELIUS Study. HELIUS participants who completed the HELIUS questionnaire, physical examination and agreed on future participation in additional evaluations, were asked to participate. From all HELIUS participants 82% Dutch origin participants and 55% Turkish participants filled in a FFQ. In a response analysis we found that participants of the HELIUS-Dietary Patterns Study were somewhat older with lower smoking rates compared to the general HELIUS participants. No statistical differences were observed with respect to educational level, BMI, and alcohol consumption.
Comparability of the ethnic-specific FFQs used to assess dietary intake in the HELIUS-Dietary Patterns Study

Minor differences in the ethnic-specific FFQs used in the HELIUS-Dietary Patterns Study may be a reason for the observed ethnic differences in dietary patterns. Nevertheless, sensitivity analysis revealed no differences in the contribution of commonly assessed food groups when ethnic specific foods were excluded from the analysis. The four ethnic-specific FFQs were developed with the aim of conducting comparable analyses and therefore had the same lay-out and consisted of similar, comparable food items, and were all developed using the same standardized methodology [7].

Operationalization of socio-economic status across ethnic groups

Within the HELIUS-Dietary Patterns Study population, Surinamese were mainly first generation migrants (85.4% and 89.0% in the South Asian origin and African origin Surinamese groups, respectively). Therefore, these participants completed their education primarily in Suriname. Educational status has different meanings over the life course and is likely to hold different significance in different countries and cultures [8]. Therefore, level of education might not be an optimal indicator of current SES in the context of dietary behaviour. Moreover, the level of occupational status may also reflect SES differently among ethnic minority groups [8]. The rates of unemployment are higher in ethnic minority groups than in the Dutch origin population and, when adjusted for general characteristics such as educational status or work experience, ethnic minorities do not have comparable chances on the labour market as those of Dutch origin [9]. Additionally, income (not assessed in the HELIUS Study) may vary by ethnic group within the same occupational class, so that occupation may not have equivalent meanings across groups [10].

Because no single SES indicator is likely to be completely suitable, future research should include multiple SES indicators [8, 9] and more research is needed on the operationalization of different SES indicators in ethnic minority groups. Researchers should therefore systematically explore the impact of their choice of SES indicator.

Generalizability of the results to other ethnic minority groups and subgroups such as younger generations

The studies described in this thesis were based in data collected in Amsterdam, Doetinchem, and Singapore. The studies had different designs and, consequently, different population characteristics. We need to be cautious in generalizing the current results. The results from chapter 6 on the role of acculturation in ethnic differences in dietary patterns among Surinamese may not be generalizable to other non-Western ethnic minority groups in the Netherlands. For example, Turkish and Moroccan populations, differ considerably in terms of language use, time since migration and
cultural attachment to the home culture. These are all factors that can largely affect acculturation [11]. The consistency of the findings reported in chapters 5 and 6 is underscored by comparable conclusions drawn from the SUNSET Study populations [12]. The HELIUS-Dietary Patterns Study participants were predominantly older and were primarily first generation migrants, which limits the generalizability to the younger Surinamese residents.

Dietary patterning methods applied in this thesis (such as cluster analysis, PCA and RRR) are highly data-driven and have an explorative nature. Dietary patterns are likely to vary according to sex and socioeconomic status (chapter 5), and ethnic group (chapter 5 and 8), especially when disease specific biomarkers are taken into account (chapter 8). Nevertheless, within specific ethnic groups, that share a common ancestry, it may be possible to generalize on the predictive value of dietary patterns (chapter 9). Taken together, however, it is necessary to replicate the results in diverse populations.

**Reflections on the main findings**
The following section reflects on the main findings of the studies presented in this thesis.

**Common and ethnic specific dietary patterns**
Comparable dietary patterns across ethnic groups were observed in this thesis (chapter 8) although ethnic specific patterns may describe dietary behaviour within ethnic groups depending on the contrast population (chapter 5). For example, a “meat and snack” dietary pattern and a “vegetable” dietary pattern described dietary behaviour within ethnic groups (chapter 8). However, Surinamese showed high adherence to a traditional Surinamese “noodle/rice and white meat” dietary pattern when their pattern of dietary intake was compared to that of Dutch origin participants (chapter 5). In supplementary analysis (data not shown) in which also habitual dietary intake data from Turkish and Moroccan participants was included, we also observed clear ethnic differences in the adherence to four dietary patterns. A first pattern was characterized by red meat, snacks, bread, cakes, cookies, sugar and sweets, potatoes and fries, dairy products, cheese, butter, fats and, in Turkish participants, borek/pocaga and filled vine leaves. Surinamese participants generally scored negatively on the first pattern. A second pattern was characterized by high intakes of vegetables, fruit, olive oil, nuts and seeds. This pattern was less relevant for the Surinamese and Moroccan groups when compared to the Dutch and Turkish groups. A third pattern was characterized by chicken, rice and noodle dishes, sugar-sweetened beverages and, in Surinamese participants, by roti and pom. Clearly, the Surinamese greatly adhered to this pattern compared to the other groups. Finally, dietary pattern 4 was characterized by beer, wine/sherry/port/vermouth, coffee and pancakes. Turkish and Moroccan participants showed low adherence to this
picture. Depending on the contrast populations, different dietary patterns are derived from the data. Moreover, these results underscore the finding that there are clear ethnic differences in the adherence to dietary patterns, which describe dietary intake within an ethnically diverse population.

The finding of the importance of ethnic specific dietary patterns is partly in line with previous research. For example, a traditional Korean pattern represented by high consumption of soybean paste, anchovies, kimchi, and seaweed, and low intakes of bread, was identified among Korean Americans in Michigan [13]. In an American cohort, four dietary patterns were derived, which, although overlapping, were predominantly associated with each ethnicity included in the study [14]. More recently, Brenner et al identified three predominant patterns in an ethnically diverse population living in Canada, termed “prudent”, “Western” and “Eastern” dietary patterns. Caucasians adhered significantly higher to the prudent dietary pattern than did Asians and South Asians, while Asians adhered significantly higher to the Eastern dietary pattern than did other ethnic groups [15]. Last, Abu-Saab et al showed large ethnic differences in dietary patterns labelled “ethnic” and “healthy”. Participants in the top “ethnic” dietary pattern intake tertile (97% Arab) had modified Mediterranean-style, Arabic dietary habits, whereas those in the bottom “ethnic” dietary pattern intake tertile (98% Jewish) had central/northern European-style dietary habits [16].

Together with our results, this small set of studies reveals the relevance of ethnic specific dietary patterns and underscores persisting adherence to traditional dietary patterns among ethnic minority groups. The papers presented in the current thesis are the first to examine differences in dietary patterns across and within different ethnic groups in a European context. This thesis adds to the current knowledge evidence that major comparable dietary patterns are present across ethnic groups, at least within the Netherlands, but that ethnic specific foods take an important role in dietary patterns derived in a multi-ethnic population. Independent of the methodology used, ethnic differences in dietary patterns were illustrated both in behaviour-based as well as biomarker-derived dietary patterns, and were also observed both in pooled and in ethnicity stratified analyses. The importance of such ethnic specific dietary patterns is underscored by the finding that irrespective of SES and level of acculturation or acculturation strategy, ethnic minority populations (i.e. Surinamese) greatly adhered to a dietary pattern that was characterized by traditional foods.

Comparable dietary patterns describe dietary behaviour across ethnic groups, but different elements in the diet are associated with HbA1c and fasting glucose concentrations

According to our results, a comparable Western dietary pattern described dietary intake to a large extent in ethnic minority groups in the. It is commonly thought that the
Westernization of the diet following migration is one of the reasons of the observed risk escalation of cardiovascular diseases and T2DM within migrant origin groups [17-19]. However, we showed that such a Westernized dietary pattern (i.e. “meat and snack” pattern) is not necessarily associated with T2DM among ethnic minority groups [20]. More research is required to understand the role of this dietary pattern in the prediction of other chronic diseases, but the absence of an association with T2DM may be related to the continued inclusion of ethnic specific foods within the diet of ethnic minority populations. More specifically, the Western dietary patterns of ethnic minority groups may be more diverse than the stereotypical Western diet observed within non-migrant populations. Some of the foods characterizing this Western dietary pattern among ethnic minority groups were clearly ethnic specific (e.g. roti and couscous). For example, among South Asian origin Surinamese the “meat and snack” dietary pattern was, besides typical Western foods (e.g. meat, snacks, sugar sweetened beverages), also characterized by high consumption of legumes and organ meat. Among the Turkish, olive oil was highly correlated to the foods consumed in this pattern, and among the Moroccan origin population high intakes of low fat dairy products appeared important in the characterization of this dietary pattern. Such food groups are presumably “healthier” and the high consumption of such foods may have diluted the effect of the overall “meat and snack” dietary pattern. For example, the consumption of low fat dairy products among Moroccan participants may lower the risk for T2DM [21]. Consequently the “Western-ness” of the diet may have different meanings across ethnic groups.

Ethnic differences in the subtypes of fats consumed may be one explanation for the observation that different elements in the diet were associated with HbA1c and fasting glucose concentration across ethnic groups. While a typical Western diet seems to be associated with HbA1c and fasting glucose concentrations among participants of Dutch origin, the subtle differences in foods characterizing dietary behaviour may be the reason for the observation that other elements of the diet among migrant origin groups describe a T2DM specific dietary pattern. Arguments in favour of this explanation may be that the nutrient composition of the diet substantially differs across ethnic groups. For example, there is strong biological evidence from a study among more than 12,000 cases of incident T2DM across eight European countries that SFAs – repeatedly associated with negative health consequences [22, 23] - are not homogenous in their effects [24]. Ethnic differences in the intake of sub-types of SFAs may have led to differences in foods that are associated with HbA1c and fasting glucose concentrations. While red meat (high in SFA) typically described the T2DM related dietary pattern within those of Dutch origin, the consumption of different types of red meat, with therefore also a different nutrient composition and possibly composed of different types of SFA may be the reason why high intakes of red meat seems to be inversely associated with HbA1c and fasting glucose concentrations among South Asian origin Surinamese. In the Multi-ethnic
Cohort, established in Hawaii and Los Angeles, it has previously been observed that lean beef was the most commonly consumed red meat for all ethnic-sex groups, except for Native Hawaiian and Japanese American men, and Japanese American women whose top contributor was lamb and pork, respectively [25]. Such subtle differences in dietary behaviour should be assessed in future studies, as it may increase our understanding on the link between diet and disease across ethnic groups.

There are large ethnic differences in nutrient composition in foods consumed [26]. Among the micronutrients studied, Sharma et al observed great ethnic variation in foods consumed as sources of vitamin A, C and E [26]. This implies that the biological impact of diet on disease may differ on the basis of the foods ethnic groups consume. The subtypes of SFA derived from dietary consumption, and the mediating role of ethnicity in the association between fats and disease outcomes should therefore be further investigated in ethnically diverse populations.

**Conceptualization of socio-economic status and acculturation in studies assessing the role of diet in multi-ethnic populations**

Indicators of SES seemed to influence dietary patterns differently across ethnic groups, and we observed only weak association between acculturation and dietary patterns.

**Socio-economic status**

While among non-migrant populations a positive association between SES and diet quality has commonly been observed [27-32], such an association was not clearly observed within the Surinamese population included in the HELIUS-Dietary Patterns Study (chapter 5). Surinamese did not show a lower adherence to the “meat and snack” pattern, which could be construed as less healthy, with increasing SES, whereas Dutch origin participants did show decreasing adherence to this pattern with increasing SES. There seems to be a selective change in dietary patterns among ethnic minority groups, presumably a move towards more vegetables and fruits with higher SES but still fidelity to the traditional diet.

This selective adoption may be explained by the value that is given to foods, as described by the model of Koctürk-Runefors [33]. Staple foods (i.e. rice and bread) are strongly associated with cultural identity, values and norms and the intake of such foods may be the last to change. In contrast, accessory foods (i.e. vegetables, meat and chicken) or “extras” (i.e. fruits, sweets and nuts) are less valued and change in their use seems more related to external factors, such SES. Sharma et al reported that African Caribbean adults in Britain, despite low incomes, spent more on traditional foods like yams than on potatoes, thereby maintaining cultural food preferences [34]. Together with our results, the continued adherence to traditional foods and dietary patterns demonstrates the importance given to some aspects of diet among ethnic minority populations. Thus the
promotion of healthy diets should be based on existing (ethnic specific) dietary patterns, respecting the value assigned to these patterns. However, as in the host population, promotion of fruit and vegetable intake is particularly relevant for low socio-economic groups.

**Acculturation**

The results from chapter 6 indicate inconsistent associations between dietary patterns and acculturation regardless of the operationalization of acculturation. Overall we could not conclude that the adherence to dietary patterns differed largely with respect to different levels of acculturation or acculturation strategies within Surinamese but also compared to those of Dutch origin. The absence of an association is likely not due to the fact that the acculturation models were not able to describe acculturation within this population. Flannery et al. compared the unidimensional and bidimensional models of acculturation in a sample of 291 Asian Americans [35]. Both models performed equally well, predicting many criteria with excellent validity. They concluded that the use of a specific acculturation model is dependent on the research topic and the research population [35]. Some models may be better to predict acculturation in specific populations than others. This idea is supported by the authors of an elaborate review of the literature on the Mexican health paradox (referring to initially favourable health outcomes among Mexican immigrants to the US). They suggested that there is a need to develop scales for specific groups and health outcomes [36].

Potential explanations for our observation that Surinamese origin respondents maintained a traditional dietary pattern without adapting to a Westernized dietary pattern with acculturation are twofold. First, it may just be that the traditional dietary pattern in this group is very robust. This idea is supported the results from chapter 5 showing that a socio-economic gradient in the adherence to this traditional dietary pattern was not present among Surinamese origin participants. A second, potential explanation is that the reality may be more complex than we have managed to capture in this analysis. For example, socio-demographic variables may influence dietary patterns. A migrant who migrated to the host country at a young age may still not adopt dietary patterns of the host country because he or she lives with parents or grandparents who prefer a traditional diet [11, 37]. Additionally, evidence shows that many migrants change the breakfast and lunch pattern towards patterns observed in the host population, the preferences for dinner together with the family are often continued from the traditional food culture [38]. Other factors, such as the value assigned to traditional foods and taste preference as described in the dietary acculturation model of Satia-Abouta [39], may also influence dietary patterns. This model presumes that there is a complex and dynamic relation between socio-economic, demographic and cultural factors with exposure to the host culture, which may better predict to what extent new migrants change their
attitudes about food, taste preferences, and food preparation. Such factors may all be relevant for the degree of adaptation to the dietary patterns of the host culture [39]. While the unidimensional and bidimensional models of acculturation are relatively quick and convenient in their use, and may inform us on attitudes, behaviours or cultural orientation, the model of Satia-Abouta [39] may help us to study which other relevant factors are important in the understanding of the adherence to specific dietary patterns.

Reflections on dietary pattern analysis
Experimental, clinical, and epidemiological nutrition research has traditionally strived to identify the specific mechanisms and health effects of single nutrients. However, because each food item contains energy, essential nutrients, and a multitude of bioactive substances that interact with each other and the surrounding food matrix in complex ways, the search for associations between single food factors and chronic disease may be difficult and confusing [40-42]. It is argued that nutrition studies choosing a traditional nutrient specific approach may underestimate the total health impact of natural foods, and could lead to inaccurate interpretations of study outcomes resulting in the formulation of erroneous dietary advice [40-42]. Therefore, dietary pattern analysis, generally divided into two main categories i.e. data-driven methods and hypothesis driven methods, has emerged as an alternative and complementary approach to examining the relationship between determinants of diet and the link between diet and the risk of chronic diseases.

The best dietary patterning method depends on the research question at hand
We were primarily interested in characterising dietary patterns based on food intake frequencies and their intercorrelations, instead of focusing on selected aspects of diet. This is an exploratory approach of dietary pattern analysis, which fits the explorative nature of the studies included in this thesis. This approach ignores prior knowledge completely. Several exploratory, i.e. data-driven dietary pattern methods were applied to derive (ethnic specific) dietary patterns in one or more populations. While cluster analysis, PCA and RRR are all empirical dietary pattern methods that have their advantages and disadvantages; they all seem to answer different questions with respect to the study of dietary patterns. Cluster analysis has the potential to be used within nutritional education interventions to, for example provide people with more tailored advice on dietary change. However, this may only be the case when: 1) distinctive and reproducible clusters of dietary patterns are derived from the data [43]; 2) cluster membership is stable [44]; and 3) when it is predictable which type of people belong to a certain cluster [45-48]. We showed that while reproducible clusters were observed over time, distinctive
in their representation of clusters of people consuming high vs low fiber bread, cluster membership was not stable over time. A practical limitation of cluster analysis is that it creates groups of people. Consequently, the power to detect associations with outcomes of interest may be lower if the sample size is not large enough. This may be further complicated when studying dietary clusters within an ethnically diverse population. The chance that clusters of ethnic groups will be derived from the data is likely to happen and may therefore be not applicable when studying the link between different clusters and disease outcomes.

Principal component analysis provides an informative picture of the correlation between types of foods consumed within a population. Such insight may aid the development of nutritional intervention programs because it generates clear behavioural based dietary patterns commonly consumed within population; dietary change may be more readily achieved when recommended foods are compatible with existing patterns of food consumption. However, the interpretation of the derived dietary patterns using PCA is rather difficult (e.g. individuals can greatly adhere to more than one dietary pattern) and subjective decisions may highly influence the conclusions derived from the analysis. Also, PCA aims to explain as much variation in dietary intake data. Therefore it may not be the optimal method to examine the elements in the dietary pattern that should be targeted by T2DM prevention programs. In various previous applications of PCA used to obtain dietary risk factors, the odds ratios for the first principal components or factors were not significantly different from 1 [49-52]. A possible reason for these disappointing results is that explaining as much variation in food intake as possible does not mean that much variation in disease specific intermediate risk factors will be explained.

Reduced rank regression derives disease specific dietary patterns, which have considerable potential for testing new hypotheses on diet–disease relationships through specific biological pathways [53]. In contrast to PCA, RRR does not describe naturally occurring patterns of the population under study but instead explains variation in biologically important intermediate risk factors for specific disease outcomes. Our results imply that a diabetes specific dietary pattern is meaningful in different populations, sharing the same ethnic origin and culture, but living in different geographical settings.

The field of dietary pattern analysis is moving forward. The first priority is to determine which questions we would like to answer. The second is to ascertain whether any of the commonly used methods will answer these questions. If not, we may need to turn to other disciplines. For example, human genome research offers an opportunity to study complex patterns using data mining methods such as neural networks or decision trees [54].

At present, patterns of dietary intake are studied on a food-by-food basis, given that the usual unit of analysis is food intake measured over a whole day. Although the
use of individual foods for the study of dietary patterns has been useful, it remains possible that parallel analysis using the nutritional composition of meals could increase our ability to study diet-disease patterns. The concept of analysing food combinations at the meal level is not entirely new [54]. The examination of food combinations at the meal level provides an approach to deal with the complexity and unpredictability of the diet and aims to overcome the limitations of the study of nutrients and foods in isolation [54]. Such analysis may also potentially provide more insight into ethnic differences in dietary patterns, on the basis of meal composition, and how such meal based patterns may affect ethnic differences in disease risk profiles. Coding systems in such analysis may be rather complex [54], and traditional dietary pattern methods may be insufficient here. The use of other methods should be explored such as neural networks, in which a larger number of coefficients can be utilized and take into account complex non-linear relations that exist within the data [54] and decision trees, which, in contrast to regression methods, assume that the effect of a variable in the subset is unrelated to the effect of the variable in other subsets [54].

The role of decision making in dietary pattern analysis in ethnically diverse populations

The main common characteristic of all aforementioned data-driven dietary patterning methods is that they are based on conventional statistical analyses. Their main disadvantage, in relation to their ability to reveal the dietary patterns from a set of data, is that they make the decisions and assumptions made by the researcher [41]. In the following sections I will therefore focus on how specific subjective decisions may have affected the findings in the studies performed from a multi-ethnic perspective.

Food groupings

Food groups are most frequently used as dietary input variables in dietary pattern analysis. An advantage of this is that together they can represent the total dietary intake, accounting for interactions between nutrients and other components within the groups. With regard to multi-ethnic comparison studies, foods groupings highly affect the dietary patterns derived from the data, as well as the conclusions that can be drawn from such analysis. Fruit and vegetable intake might serve as an example as there are large cultural differences in such foods consumed. While Surinamese for example still strongly adhere to a traditional dietary pattern, characterized by high intakes of Surinamese vegetables, while the consumption of these vegetables is not common among those of Dutch origin (chapter 5). Commonly consumed foods within ethnic groups may have a different nutrient composition and therefore their biological impact on measured blood glucose or other biomarkers may differ. If only assessing the behaviour role of fruit and vegetable intake in the association with disease outcomes,
an important biological link between such ethnic specific foods could be missed. For example, if Surinamese vegetables were coded as an individual group, which was done with food such as roti and pom, Surinamese vegetables, may find strong intercorrelations with the other Surinamese foods, which increases the chance of generating a separate dietary pattern. Therefore, food group coding decisions must be carefully based on the populations and the objective of the analysis.

**Within and between population dietary pattern analysis**

As observed from the results in chapter 5 and 8, the decision to pool all ethnic groups or conduct ethnic specific analysis influences the patterns of dietary intake that are derived using PCA from the data at hand. One explanation is that the variation in food intake is different in pooled versus ethnic specific dietary pattern analyses. A PCA models the variation in a set of variables in terms of a smaller number of independent linear combinations (i.e. dietary patterns) of those variables. The variation in the intake of ethnic specific foods may be greater when the population is more diverse (pooled analysis). This way, the chance of modelling an ethnic specific dietary pattern may be higher as the explained variance of a linear combination of such ethnic specific foods has increased.

Stratified analysis based on ethnic origin may be more applicable in the assessment of similarities in dietary patterns across ethnic groups. Dietary patterns derived from the pooled analysis may complement our understanding on the relevance of traditional dietary patterns and a pooled approach should be applied when aiming to understand whether e.g. ethnic differences in disease risk can be explained by ethnic differences in the adherence to patterns of dietary intake.

**Implications and recommendations for future research**

**There is a need for interventions that take ethnic differences in dietary pattern into account**

The high adherence to a traditional dietary pattern among Surinamese migrant groups indicates the importance that should be given to traditional foods in T2DM prevention programs. Additionally, although the dietary patterns among ethnic minority groups do compare with the Westernized diet observed among those of Dutch origin, the dietary patterns of ethnic minority groups appear to be still characterized by ethnic specific foods or dietary behaviour. Diet is deeply rooted in cultural values and personal identity and may therefore be difficult to change [55, 56], especially when interventions fail to meet the specific needs of ethnic minority groups. Therefore, changing diet in interventions for T2DM risk reduction should take into account what foods are eaten among ethnic minority groups. However, assessment of the effectiveness of such interventions should
carefully be assessed. Current knowledge about the effectiveness of cultural adaptations is limited [56]. Therefore, future research needs to be conducted among ethnic minority groups with different migration histories and local circumstances.

**Prospective data**

While cross-sectional studies are valuable to explore new areas of interest, such as ethnic differences in dietary patterns, they are unable to make causal inferences. We observed large under-reporting of energy intake, possible due to residual confounding, and therefore, to acquire evidence on the causality of dietary patterns and disease relations, it may be important to repeat the analysis using prospective data. The continuation of the HELIUS study and the dietary assessment among the ethnic groups described in this thesis is therefore of utmost importance as it will eventually allow understanding of the influence of ethnic differences in dietary patterns on the observed ethnic inequalities in health. Also, longitudinal data will allow for the assessment of dietary trajectories. While dietary patterns within a population may not change so readily over time, individuals do change their diet over time. Changes in diet over time as observed in the Doetinchem Cohort Study may affect diet-disease association.

**Operationalization of determinants of diet in multi-ethnic populations**

It is important to improve our understanding on how determinants such as SES and acculturation act within different ethnic minority groups. It is therefore suggested that researchers should systematically explore the effect of their choice of socio-economic and acculturation indicators prior to data analysis, to demonstrate their cross-ethnic group validity.

With regard to the study of the effect of acculturation on diet, it seems worthwhile that researchers should carefully select the acculturation model that best matches their research topic and their population. In some cases, the unidimensional model of acculturation will be sufficient, while in other cases; the bidimensional model will be optimal. Or, when aiming to understand what factors are related to differences in the adherence to specific dietary patterns, the dietary acculturation model of Satia-Abouta [11] might be preferred. With respect to the specific assessment of dietary acculturation, development of a dietary acculturation instrument which could be used in various population groups would help to stimulate cross-cultural exchange and discussion as well as promote the development of new tools and help improve existing research efforts.
Implications for policy and practice  
National food composition surveys should include the main migrants groups in the Netherlands

The aim of the Dutch policy on health and diet is to facilitate a healthy lifestyle in society. Monitoring of food consumption forms the basis of nutrition and food policy. Currently, national food composition surveys do not provide insight into food consumption among ethnic minority populations in the Netherlands. Do results of this thesis show that inclusion of these groups is necessary to be able to assess dietary habits for the whole population, given large differences in diet between ethnic groups. Data in these groups could inform Dutch policy for developing dietary recommendations applicable to a broader public, while this data could also be used to update FFQs in order to capture all relevant foods available on the market. The latter is important because dietary intake changes over time, not only because of the constant introduction of new foods that are being introduced on the market, but also because of migration. While migrants are influenced by the food culture of the host population leading to changes in their dietary habits, they also contribute to widening the spectrum of new foods in the diet of the host population.

Currently, together with the National Institute of Public Health and the Environment, we are analysing the habitual dietary intake data assessed within the HELIUS-Dietary Patterns study in order to provide insight into food intake across ethnic groups. This will aid our understanding on the ethnic differences in macro and micronutrient consumption, and food group intake, in addition to the differences in dietary patterns, as shown in this thesis. Preliminary results suggest that also at the food and nutrient level large ethnic differences in dietary intake are present. For example, compared to Dutch origin participants, South Asian origin Surinamese, and Moroccans seem to consume less vegetables, while Turkish women consume significantly more (but still less than the recommended daily intake). The Turkish population has the highest fruit consumption, and seems to be the only group that meets the daily-recommended intake. Cakes and cookie consumption was highest in the Moroccan population and the consumption among Moroccan men significantly higher from those of Dutch origin. African origin Surinamese, Turkish and Moroccan had a significantly higher meat and meat products consumption (including chicken) than those of Dutch origin. At the nutrient level the results suggest there were large ethnic differences in total energy intake, and Turkish and Moroccans seem to have more favourable fat intake compared to those of Dutch origin.

When including ethnic minority groups into the National Food Composition Surveys adaptation in the assessment methods is necessary. While the newly developed ethnic specific FFQ, as part of the HELIUS-Dietary Patterns study, could be used to rank individuals according to dietary intake, quantifying absolute intakes may be hampered
by factors such as over-reporting and the relative rough assessment of the portion sizes. Currently food composition data is collected using specifically designed software, EPIC-SOFT on a multiple 24-hour recall basis. Applying dietary assessment using 24-hour recalls generates data that can be used to estimate mean intakes on a population level, which is the aim of national consumption surveys. However, the software is not yet adapted to assess the dietary habits among ethnic minorities. Therefore, it is of utmost importance that this software is updated with ethnic specific foods, that coloured photos of ethnic specific foods are included and that there is a possibility for the participants to be assisted by culturally matched trained interviewers.

**National dietary recommendations should be adapted to address dietary behaviour in ethnic minority populations**

We observed that the ethnic differences in dietary patterns were rather robust. With increasing SES, and different acculturation strategies, no significant changes were observed with respect to the high adherence to a dietary pattern characterized by foods typically consumed in a traditional Surinamese diet among Surinamese living in Amsterdam. National dietary recommendations should take such differences in dietary behaviour across ethnic groups into account. Nevertheless, current recommendations only include few examples of ethnic specific foods. For example, couscous is the only example of a suggested grain that is not commonly consumed in a typical Dutch dietary pattern. In the USDA’s myplate, the examples in the grain section are much more ethnically diverse and include e.g. quinoa, noodles, pitas, bulgur (cracked wheat), and whole wheat tortillas [57]. Therefore, the USDA’s myplate may be more applicable to inform individuals on healthy dietary choices in ethnically diverse populations than the tools currently employed in the Netherlands (i.e. “schijf van vijf”).

At the end of 2015, the Dutch health council will present new recommendations for a healthy diet in which they aim to shift the focus from nutrients to foods. These new recommendations based on foods should recognize the ethnic differences in foods consumed. By adapting the currently employed Dutch recommendations for a healthy diet, paying attention to the dietary diversity which is illustrated by this thesis, such recommendations may be more relevant to the usual diet of ethnic minority populations.

Hypothetically, the shift from nutrients to foods may produce dietary recommendations that have shifted from a focus on the reduction of saturated fatty acid intake (of which the intake is now recommended to reduce to maximally 10% of total energy intake) [58] to specific foods, such as red meat. But, the intake of red meat seems of lesser relevance among Surinamese. Among Surinamese, dietary recommendations on the consumption of traditional foods, such as roti and rice and noodles dishes, may be more applicable to disease risks. Dietary change could only be promoted if recommendations are relevant to people’s usual diets.
General conclusion

This thesis has contributed to the scientific basis of dietary analysis within an ethnically diverse population in the Netherlands. It has provided insight into the dietary patterns of five different ethnic groups, recognizing the idea that people do not eat isolated nutrients. Instead, people eat meals consisting of a variety of foods with complex combinations of nutrients that are likely to be interactive or synergistic. The studies described in this thesis provide insight into the determinants of ethnic specific dietary patterns, how such dietary patterns are associated with T2DM, and several methodological approaches of studying dietary patterns. The following main conclusions can be drawn from this thesis:

1. Dietary assessment in a multi-ethnic population using ethnic specific FFQs is feasible and has provided a basis for a better understanding of the patterns that describe dietary intake among the main migrant groups in the Netherlands. We found evidence to suggest that comparable dietary patterns across ethnic groups described dietary behaviour, but the adherence to dietary patterns may be different across ethnic groups. Independent of ethnic origin, the promotion of a dietary pattern characterized by fruit and vegetable intake seems particularly relevant for low socio-economic groups. Simultaneously, among ethnic minority groups, it appears important to recognize the value that is given to ethnic specific foods due to the continued adherence to a traditional dietary pattern.

2. The continued adherence to a traditional dietary pattern, independent of SES and acculturation, may affect the way in which dietary patterns are associated with disease across ethnic groups. We found evidence that a Western dietary pattern (characterized by high consumption of red meat, processed meat, sugar and sweets, snacks, etc.) may find different associations with T2DM among ethnic minority populations compared to those of Dutch origin. Therefore, results emphasize the need for a better understanding of the Westernization of the dietary patterns among ethnic minority groups – of which typically is assumed to be at the detriment of health and at the cost of the presumably “healthier” traditional diet. The subtle differences in dietary behaviour across ethnic groups may be illustrative of the continued diversity of foods typically consumed in different ethnic groups.

3. Ethnic differences observed in dietary patterns derived on the basis of the prerequisite to be associated with biomarkers of disease, emphasizes the need to shift our focus from commonly recognized foods predictive for disease, to an exploration of different – ethnic specific – elements of the diet within ethnic groups that may be relevant to the occurrence of disease. Not only because we are obliged to do so due to the increasing ethnic diversity in many Western countries, but also because such ethnic specific elements in the diet may consistently be associated with diseases across populations.
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