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BY
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AALBORG UNIVERSITY
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ENGLISH SUMMARY

Differences in diet contribute to inequality in health and improvements in diet among the most vulnerable people may reduce the inequality. This PhD study comprises four studies, which were conducted to evaluate differences in dietary intake focusing on sociodemographic characteristics.

Study I is a cross-sectional study evaluating the dietary intake in 85,456 healthy Danish adults in a National Health Survey conducted in 2013 focusing on sociodemographic characteristics. We found that differences in dietary intake mirror differences in educational attainment and living arrangements. People with a high educational attainment had a higher intake of fruit/vegetables and a lower intake of red meat than people with a lower educational attainment. Compared to people who were living alone, people who were living with others had a higher intake of red meat and fruit/vegetables.

In Study II, we validated a food frequency questionnaire (HeartDiet) used in cardiac rehabilitation settings in Denmark and subsequent studies. HeartDiet was compared with a previously validated semi-quantitative 198-item food frequency questionnaire used in the Inter99 study. Besides, HeartDiet was compared with biomarkers for fish and fruit/vegetable intake. A total of 99 Danish healthy adults and 100 Danish patients with coronary heart disease were eligible for analysis. We found that HeartDiet was well aligned with the particular biomarkers and with the 198-item food frequency questionnaire used in the Inter99 study.

Study III and IV were designed to evaluate the longitudinal food intake among patients with ischaemic heart disease who were following a cardiac rehabilitation programme at Aalborg University Hospital between October 2015 and September 2018. A total of 186 patients were eligible for analyses before rehabilitation and post-rehabilitation, and at six month follow-up 157 patients were still eligible. In Study III, we investigated dietary changes in relation to sociodemographic characteristics. We found that unemployed women and retired women did not seem to benefit as much as employed women from the programme. In Study IV, we analysed the longitudinal changes in and maintenance of 19 food groups. We found a tendency towards that the quality of most foods were improved and an increase in the intake in almost all heart-healthy foods; however, the intake of e.g. wholegrain bread, cake and fast food remain unimproved.

DANSK RESUME

Kostmæssige forskelle er et væsentligt sundhedsproblem, og kostmæssige forbedringer hos de mest sårbare personer kan muligvis mindske uligheden i sundhed. Dette ph.d.-studie omfatter fire studier, hvori vi evaluerer forskelle i kostvaner med fokus på sociodemografiske karakteristika.

Vi har først vurderet kostvanerne hos 85.456 raske danskere med fokus på sociodemografiske karakteristika i en national befolkningsundersøgelse fra 2013. Vi fandt, at forskelle i kostvaner afspejlede forskelle i uddannelseslængde og om personerne boede alene eller ej. Personer med lang uddannelse havde et højere indtag af frugt/grøntsager samt et lavere indtag af rødt kød end personer med kortere uddannelse. Personer, der boede sammen med andre havde et højere indtag af frugt/grøntsager og rødt kød end personer, der boede alene.

Dernæst validerede vi HjerteKost, et fødevarefrekvensskema brugt i rehabiliteringssammenhæng i Danmark samt i de efterfølgende studier. HjerteKost blev sammenlignet med et tidligere valideret semikvantitativt fødevarefrekvensskema anvendt i Inter99-studiet. Desuden blev HjerteKost sammenlignet med biomarkører for fisk samt frugt/grøntsager. Valideringen inkluderede 99 raske danskere og 100 danske patienter med koronar hjertesygdom. Vi fandt, at resultater fra skemaet korrelerede godt med biomarkører samt med det semikvantitative fødevarefrekvensskema anvendt i Inter99-studiet.

Til sidst gennemførte vi et longitudinelt studie blandt patienter med iskæmisk hjertesygdom, der deltog i et hjerterehabiliteringsprogram på Aalborg Universitetshospital fra oktober 2015 til september 2018. 186 patienter udfyldte HjerteKost før og efter rehabiliteringen, og 157 patienter havde tilmed udfyldt skemaet ved opfølgningen efter seks måneder. Vi undersøgte først indflydelsen af sociodemografiske karakteristika på ændring af kostvaner. Vi fandt en tendens til, at kvinder udenfor arbejdsmarkedet samt pensionerede kvinder ikke havde så stor gavn af rehabiliteringsprogrammet, som kvinder i arbejde. Til sidst undersøgte vi kostændringer og vedligeholdelse heraf på fødevareniveau. Vi fandt en tendens til en forbedret kostmæssig kvalitet samt højere indtag af stort set alle hjertevenlige fødevarer - dog var indtaget af bl.a. fuldkornsbrød, kage og fast food uændret.

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Ulla Bach Laursen

February 2020

LIST OF PAPERS

This thesis is based on the following four papers:

Paper I

Laursen UB, Johansen MB, Joensen AM, Lau CJ, Overvad K, Larsen ML. Educational level and living arrangements are associated with dietary intake of red meat and fruit/vegetables: A Danish cross-sectional study. *Scand J Public Health* 2019; 47: 557-564 (1).

Paper II

Laursen UB, Rosenkilde LB, Haugaard AM, Obel T, Toft U, Larsen ML, Schmidt EB. Validation of HeartDiet: quick food frequency questionnaire in vascular disease prevention. *Dan Med J* 2018; 65: A5514 (2).

Paper III

Laursen UB, Johansen MB, Joensen AM, Overvad K, Larsen ML. Is cardiac rehabilitation equally effective in improving dietary intake in all patients with ischaemic heart disease? *Manuscript re-submitted* (3).

Paper IV

Laursen UB, Joensen AM, Johansen MB, Overvad K, Larsen ML. Heart-healthy dietary habits are improved and maintained six months after participation in a cardiac rehabilitation programme. *Topics in Clinical Nutrition*; Accepted, 3 January 2020 (4).

ABBREVIATIONS

CI	Confidence interval
CHD	Coronary heart disease
CVD	Cardiovascular disease
FFQ	Food frequency questionnaire
IHD	Ischaemic heart disease
MUFA	Monounsaturated fatty acids
PUFA	Polyunsaturated fatty acids
SFA	Saturated fatty acids

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CHAPTER 1. INTRODUCTION

Inequality in health is a major public health concern globally as well as in Denmark (5–7). Differences in dietary intake contribute to this inequality, suggesting that dietary improvements in vulnerable social groups may reduce inequality in health (8–11). To improve public health, continuous monitoring of dietary habits is essential to guide dietary interventions and campaigns in the future. Hence, identification of those with a challenging task according to diet may be reasonable.

Screening for the need of dietary intervention is highly relevant and properly validated dietary questionnaires are imperative to guide the dietetic assessment. In patients with ischaemic heart disease (IHD), only one disease-specific dietary screening tool (named HeartDiet) is applied in Denmark. HeartDiet has been recommended in national recommendations for years without a proper publication of the study (12, 13).

It has been proven difficult to promote persons to improve their dietary habits (14–17); nevertheless, dietary improvements have been reported in patients who were following a cardiac rehabilitation programme (18). However, it is unknown whether a standard cardiac rehabilitation programme aiming to alter dietary intake will be equally beneficial for all patients. It is therefore meaningful to identify those who will not benefit from the general programme. Moreover, identification of inadequate dietary intake and changes may help guide an appropriate dietary support performed by dieticians and other health professionals.

This thesis aimed to evaluate the dietary intake of healthy Danish adults and patients who were following a cardiac rehabilitation programme focusing on sociodemographic characteristics.

CHAPTER 2. BACKGROUND

2.1. HEART-HEALTHY DIET

Unhealthy diet was the second-leading risk factor for death accounting for 19% of total death globally in 2016 (10). For cardiovascular disease (CVD), unhealthy diet was the leading risk factor accounting for 52% of total death. Exploring the individually dietary risks, a diet low in wholegrain attributed to the largest number of death followed by a low intake of fruit and a high intake of sodium (10). These data emphasises the importance of a prudent diet in the prevention of diseases and death. National prevention strategies including dietary recommendations are therefore crucial. In Denmark, the official dietary recommendations are based on the Nordic Nutrition Recommendations (19–21). The recommendations are updated regularly according to the newest knowledge on dietary intake and health, and actual dietary intake of the Danish population. The essence of a healthy diet is to prevent lifestyle-related diseases including diabetes, cancer, obesity and IHD and to contribute to improved quality of life (10,19,20,22).

The Danish dietary recommendations prescribe 600 g of fruit and vegetables/day, of which minimum 300 g should be vegetables, 350 g of fish/week, of which 200 g should be oily fish, minimum 75 g of wholegrain/10MJ/day and choosing lean meat and lean cold meat (maximum 500 g unprocessed red meat and processed meat/week) (19,23). Also, dairy products should be low fat (¼-½ litre dairy product/day), maximum 10% of the total energy intake from saturated fatty acids (SFA) (including *trans* fatty acids) emphasising replacement of SFA with unsaturated fatty acids. Moreover, drinking water, maximum 10% of the total energy intake from added sugar and maximum 6 g of salt (sodium chloride)/day (19,20,23). Overall, it is recommended to consume a variety of foods, not too much and to be physically active (23). Finally, a moderate alcohol intake is recommended corresponding to maximum of 7 units/week for women and 14 units/week for men (19,20,23,24).

2.1.1. HEART-HEALTHY DIET IN PRIMARY PREVENTION OF ISCHAEMIC HEART DISEASE

A heart-healthy diet emphasises the Danish dietary recommendations in primary prevention of IHD (15, 19–21). A heart-healthy diet has been associated with reduction in total mortality and IHD. In large observational studies and randomised controlled trials heart-healthy diet has been associated with improved intermediate endpoints of IHD such as hypertension, glucose levels, and blood lipids (22–29).

Exploring the impact of single foods on IHD, intake of fruit and vegetables including nuts and legumes has been found to be inversely associated with blood pressure, blood lipids and glucose levels as well as clinical endpoints. The evidence is based on randomised controlled trials advising the participants to increase the intake of nuts or fruit and vegetables (28, 30, 31). Besides, evidence based on observational studies conclude that fruit, vegetables and nuts were associated with a reduction in risk of CVD and CVD mortality (28–30, 32). Fruit, vegetables and nuts have a high content of vitamins, minerals, fibre and bioactive compounds (28, 29). Also, nuts have a favourable fat content (28).

Intake of fish has been associated with lower risk of coronary heart disease (CHD) in prospective cohort studies emphasising a moderate intake (32–34), although not all studies have reported this (35–37). Fish consumption has been associated with beneficial effects on several intermediate markers such as blood pressure, triglyceride levels, electrophysiological effects and platelet aggregation. The cardioprotective effect has been associated to the content of marine n-3 PUFA including eicosapentaenoic acid, docosapentaenoic acid and docosahexaenoic acid, which is especially high in oily fish (34). n-3 PUFA supplementation is not recommended (38, 39).

The health benefits of wholegrain have been related to the content of fatty acids, fibre, micronutrients and other bioactive compounds comprised in the bran and germ (40, 41). In refined grain, these compounds are removed in the milling process. In prospective studies, wholegrain intake has been inversely associated with the risk of CHD, diabetes and cancer, among others (32, 40). The beneficial effect may be explained by the association between wholegrain products and lower concentration of total cholesterol and low density lipoprotein cholesterol, and improved glycaemic control (40). However, randomised controlled trials have not found the same association in follow-up periods between 12 to 16 weeks (42).

Red meat is unprocessed meat from four-legged animals, whereas processed meat has been transformed through smoking or salting, among others (43). Processed meat often consists of meat from four-legged animals but may also consist of poultry (43). Consumption of red meat has been associated with CVD mortality and risk of CHD and diabetes in prospective cohort studies (32, 44–46). Overall, studies have found a stronger association between processed meat, CVD risk and mortality compared with unprocessed red meat (44, 45).

Dietary fat mainly consists of fatty acids classified as SFA, monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) (47). Substitution of SFA with unsaturated fatty acids has been found to be associated with a lower incidence of CHD in prospective cohort studies and randomised controlled trials (48, 49); however, the evidence favour PUFA stronger than MUFA (48, 49). The cardioprotective effect has been strongly associated to reduction in low-density lipoprotein cholesterol (22, 49). Randomised controlled trials have found that replacement of SFA with PUFA, favoured the lipid profile more than replacement with MUFA or carbohydrates (47).

Trans fatty acids are unsaturated fatty acids containing at least one double bound in the *trans* configuration. Intake of *trans* fatty acids has been found to be associated with a higher risk of CHD (49); thus, in Denmark, industrially produced *trans* fatty acids was limited by law in 2004 (50).

As far as salt is concerned, health-related consequences of salt consumption are primarily associated to sodium content raising blood pressure in randomised controlled trials (51). In prospective cohort studies and some randomised controlled trials, a lower salt intake has been associated to decreased risk of CHD mortality; however, inconsistent results have been found in other randomised controlled trials (52, 53). It is recommended to restrict the salt intake primarily by reducing the intake of processed foods (19).

Few prospective cohort studies have analysed the association between consumption of added sugar, mainly sugar-sweetened beverages, and incident CHD (32, 54). A dose-dependent association has been identified; however, studies on consumption of added sugar are lacking (32, 54). Additionally, positive associations between intake of sugar-sweetened beverages and increased incidence of hypertension, type II diabetes and obesity have been explored (54–56). It is recommended that sugar intake should be restricted by reducing the intake of sugar-sweetened beverages and foods with added sugars such as candy and sugary breakfast cereals, etc. (19).

A J-shaped relation between alcohol and CHD mortality has been found in some prospective studies, meaning that abstainers and heavy drinkers have a higher risk than moderate drinkers (57). However, recently a combined analysis using large-scale prospective studies found a positive linear relationship between intake and risk of most cardiovascular disease subtypes (58). Intake of alcohol has been associated to e.g. increased blood pressure and increased levels of high-density lipoprotein cholesterol (59).

2.1.2. HEART-HEALHTY DIET IN SECONDARY PREVENTION OF ISCHAEMIC HEART DISEASE

In secondary prevention of IHD, a heart-healthy diet comprises the same overall recommendations as concerned in primary prevention (19, 23, 60–62). Few exemptions however exist. The current recommendations are primarily based on prospective cohort studies as well as few randomised controlled trials having IHD endpoints or intermediate endpoints (22, 63–66). A relative sparse number of trials have been conducted in patients with heart disease and those conducted have primarily investigated heart-healthy dietary patterns rather than isolated foods or nutrients (25, 64, 65, 67, 68). The Oslo Diet-Heart Study, a randomised trial in men with myocardial infarction, reported several cardioprotective effects on mortality and morbidity fifty years ago (65). Later, two minor randomised trials did not find any distinct differences in cause of death, major cardiovascular complications, lipid levels or blood pressure when comparing a heart-healthy diet with a low-fat diet or no dietary advices (67, 68). However, certain sources of bias have been stressed in one of the studies (25, 68). Twenty years ago, the Lyon Diet Heart Study, a large randomised secondary prevention trial compared a heart-healthy diet with usual care and found a reduced risk of CVD mortality and total mortality but no differences in blood pressure and lipids indicating that there may be other beneficial effects (64). In addition, prospective cohort studies have found an association between a heart-healthy pattern and mortality and cardiac complications (69, 70).

Only few studies have evaluated the cardioprotective effect focusing on the impact of single foods (22, 71). Three intervention studies have evaluated the effect of an improved fat composition and an increased intake of fish among patients with IHD (66, 72, 73). The DART study, a large randomised trial evaluated the effect of fish in men with previous myocardial infarction and found that those advised to eat oily fish had a substantial reduction in all-cause mortality (66). However, two other trials did not find the same promising results (72, 73). In secondary prevention, the recommendation is 350 g fish/week of which 300 g should be oily fish corresponding to 1 g of n-3 PUFA/day (23, 74, 75). n-3 PUFA supplementation has previously been recommended in secondary prevention (75, 76) but recently a meta-analysis including ten large randomised trials did not find any effect on major cardiovascular events in patients with prior CHD (39). n-3 PUFA supplementation is therefore not recommended anymore (22, 39, 74).

Concerning fat, maximum 7% of the total energy intake from SFA is recommended in secondary prevention (21, 22, 77). A reduction in LDL is associated with reduced risk of CVD and because of the beneficial effect on LDL by substituting SFA with unsaturated fatty acids, further SFA reduction seems efficient in patients with IHD (22, 47, 78).

2.2. SOCIODEMOGRAPHIC DIFFERENCES

Reducing health inequality according to various sociodemographic characteristics has been on the World Health Organization’s agenda for decades; however, wide disparities in health status remain within and between countries (5, 6). In the European Union, significant sociodemographic differences according to socioeconomic status, living arrangement, gender and ethnicity exists in hospitalisation, disease and mortality rates (5, 6, 79, 80). In a high-income country like Denmark, sociodemographic differences in health also exist regardless of the existence of a tax-financed healthcare system built on equal and easy access to treatment (7, 81, 82). Inequality in CVD mortality is particularly persistent. The risk of death from CVD has decreased, but differences between groups have widened as people with low socioeconomic status have not benefited from improved health behaviours and treatment as much as people with high socioeconomic status (6–8). Even the quality of treatment differs according to sociodemographic characteristics and seems to increase with some groups of patients receiving better treatment than others (83). In cardiac rehabilitation, sociodemographic differences have been found in relation to whom the programme was offered and in terms of attendance and adherence (84). Women, elderly, patients with low educational attainment and patients who were living alone were not offered participation and did not participate as much as men, younger patients, patients with higher educational attainment and patients who were living with others (12, 13, 84–87). Similar patterns were found for adherence (85, 86).

Sociodemographic differences in diet have been documented within and between countries and extensively focus have attended educational attainment, income and occupational status (88–94). Overall, a less healthy diet has been found among the most disadvantaged groups compared with the most advantaged groups in society, with the most pronounced results from the northern part of Europe (88–92, 95). In the southern part of Europe the cultural dietary traditions are more evident and differences are, therefore, not easily recognisable (92, 95). However, several other sociodemographic characteristics have been associated with dietary quality such as gender, ethnicity, age, living arrangement and marital status, among others (89, 92–94, 96, 97). Living alone has recently attracted more focus because the proportion of individuals living alone is rising (98). Living alone has, overall, been associated with a less healthy diet compared with living as a couple or living with others; however, according to intake of specific foods and variety the evidence is unambiguous (94, 99, 100). A sociodemographic gradient in diet has not only been found in healthy people; thus, differences in diet have likewise been found in patients suffering from IHD (101). Sociodemographic differences in health are mainly attributable to lifestyle, psychosocial and biological risk factors such as unhealthy diet which are more prevalent in socially vulnerable people (8–11). Meaning that uneven diet is responsible for some of the disparities in health. Hence, if unhealthy diet was addressed in the most vulnerable people, then inequality in health might narrow.

2.3. CARDIAC REHABILITATION PROGRAMME

2.3.1. ISCHAEMIC HEART DISEASE

IHD develops as a result of insufficient blood flow to the myocardial tissue and is most frequently due to coronary artery atherosclerosis or, less commonly, to obstruction of blood flow caused by an embolus (102). Manifestations of IHD include non-ST-elevation myocardial infarction, ST-elevation myocardial infarction, unstable angina and stable angina pectoris (102). In Denmark, IHD is the most common cardiovascular disease; in 2016, the incidence rate of IHD was 585 per 100,000 men and 410 per 100,000 women (81). The risk of mortality due to IHD is decreasing in Denmark and other Western countries (15, 103). Typical risk factors associated with development of coronary artery atherosclerosis include genetic predispositions, male sex, older age, smoking, hypertension, diabetes mellitus, abnormal blood lipid levels, low socioeconomic status, social isolation, stress, low mental health status and unhealthy lifestyle (15, 102).

2.3.2. RECOMMENDATIONS AND CLINICAL PRACTICE

Cardiac rehabilitation is an integrated part of secondary prevention of patients with IHD (12, 13, 15, 18, 104–106). A recent Cochrane review and meta-analysis of 63 randomised controlled trials conducted between 1970 to 2014 found that exercise-based cardiac rehabilitation reduced the risk of cardiovascular mortality and re-hospitalisation compared with conventional care (105). Other recently published studies have also found a reduction in all-cause mortality (18, 107, 108). In addition, an effect on quality of life and lifestyle has been found (18, 105). The main purpose of cardiac rehabilitation is to minimise the risk of disease progression and to improve the patient's physical, mental and social functional level in order to facilitate his or her return to normal life. Another aim is to eliminate or reduce symptoms and to improve quality of life (12).

Dietary support to eat a heart-healthy diet is one of several core components in secondary prevention of IHD (12, 13, 18). The remaining core components are patient education, physical training, support to smoking sensation, psychosocial support including screening for anxiety and depression, and optimised medical treatment (12). In Denmark, the programme is administered by a multi-disciplinary team consisting of a cardiologist, nurse, clinical dietician and physiotherapist. It is recommended that the individualised programme lasts a minimum of 12 weeks with at least two exercise sessions per week (12, 13). Provision of the cardiac rehabilitation programme is shared between hospitals and municipalities, whereas hospitals are responsible for the medical treatment (12, 13). To monitor the quality of cardiac rehabilitation, it is mandatory for Danish hospitals to register all patients in the Danish Cardiac Rehabilitation Database (109). The registration will soon be established in the municipalities too (110).

Screening for the need of dietary intervention is recommended in all patients with IHD (13). Screening is applied with the shortened food frequency questionnaire (FFQ), 'HeartDiet' (in Danish: 'HjerteKost'), which is self-administrated and consists of 19 questions to assess the quality and quantity of dietary intake (13, 111). Each question has three to five options corresponding to a given value. The values are summarised into a fat score and a fish-fruit-vegetable score. Both scores range from 0 to 100 points with higher scores indicating a more heart-healthy diet with respect to intake of saturated fat and a combination of fish, fruit, vegetables and wholegrain. HeartDiet has the ability to identify inappropriate dietary intake. Thus, a score of ≥ 75 points reflects a heart-healthy intake of saturated fat or fish, fruit, vegetables and wholegrain. An initial score of < 75 points reflects the need of dietary intervention, which may be performed as individual counselling or group-based sessions (13). Screening of unhealthy dietary intake may prevent future lifestyle-related diseases (112). However, consequences of screening include misclassification as false positive (low specificity). This misleading information may lead to financial cost for the hospital due to unnecessary dietetic intervention. Misclassification as false negative may lead to delay in dietary intervention and thereby possible health consequences (112). In 2015, dietary screening was established in 38% of the hospitals and 29% of the municipalities (113). Dietary interventions were delivered as individual counselling (94%) and/or group-based sessions (85%) in hospitals, whereas in municipalities, individual counselling accounted for 71% and/or group-based sessions for 67%. Execution of the intervention was predominantly performed by a clinical dietician (113).

In the North Jutland Region in 2014, 74% of the patients participated in cardiac rehabilitation in the municipality, 8% both at hospital and in municipality and 18% at hospital only (114). All patients receive an individual consultation with a rehabilitation nurse or cardiologist at the hospital before and after the rehabilitation programme. After the programme, the final status is sent to the general practitioner (114). All patients are offered a 12-week programme. At Aalborg University Hospital, patients are offered 4 weeks of cardiac rehabilitation including eight supervised exercise sessions of physical activity (1 hour each) and eight sessions to address the understanding of cardiac disease, medicine, risk factors, psychological themes, and dietary and lifestyle habits (75 minutes each) (115). The programme continues in the municipalities of the North Jutland region where an 8-week programme is offered (12 weeks if a municipality programme is offered only). All patients, regardless of the dietary screening, receive a dietary lecture performed by a clinical dietician at Aalborg University Hospital. No other dietary intervention is performed. The same procedure is performed in the municipalities in the North Jutland region; however, some municipalities offer additional individual dietary intervention (115). The dietary lectures emphasise a heart-healthy diet as described in 'Chapter 2.1.2. Heart-healthy diet in secondary prevention of ischaemic heart disease'.

2.4. NUTRITIONAL ASSESSMENT

Nutritional assessment methods include dietary assessment, assessment of body size and body composition, and clinical assessment (116–123).

Dietary assessment has been practiced for decades and is usually performed to assess nutritional status including overweight and malnutrition, associations between dietary intake and occurrence of diseases, changes in diet over time and differences in dietary intake by different sociodemographics (122). In Denmark, dietary intake was assessed recently in large national surveys assessing well-being, health and disease in adults (16, 17). In epidemiological studies, assessment of dietary intake is most commonly performed using an FFQ (124). The FFQ is used in studies designed to assess habitual diet. When self-administrated, the FFQ imposes a modest burden on the respondent, making it a relatively cheap and quick assessment tool (123, 124). An FFQ consists of a food list with all food items or a small selection of items depending on the focus of the survey being conducted. An FFQ also has a frequency response section where respondents indicate how often each food item is consumed. To allow analysis of between-person variation, the frequency response section usually has five to ten options - with more options when items are often or seldom consumed. Portion sizes may be specified in the questions, characterising a semi-quantitative FFQ. Usually, the frequency with which food items are consumed is converted into intake in grams, and the assigned portion size or a typical portion size is stated (123, 124). Limitations of FFQs include memory bias, non-exhaustive list of foods and interpretation of questions and perception of portion sizes. Other assessment methods include 24-hour dietary recall and food records, which are more time-consuming for both the respondent and the interviewer than the FFQ (125). The 24-hour dietary recall is an in-depth interview quantifying and qualifying what the respondent has eaten and drunk from midnight to midnight of the previous 24 hours. Limitations include memory bias, perception of portion sizes and the fact that the diet may vary from day to day (123, 125). The food record is a detailed listing of all meals, foods and drinks consumed on one or more days (123, 125). All foods should be listed as weighted or in household measures. Challenges include that the respondent may alter his or her eating behaviour; all foods may not be measured; and the diet may vary from day to day (125). Dietary biomarkers are often used as an objective supplement to the recorded dietary intake. Biomarkers can be used to assess nutritional status or the relationship between dietary intake and disease occurrence (126). Additionally, they are used as indicators to validate other dietary assessment methods. Dietary biomarkers often measure the concentration of a particular nutrient in plasma, serum, erythrocytes and in adipose tissue or other tissues (127). Biomarkers are useful in several ways. For instance, if a nutrient is found in several food groups, using a biomarker would capture total intake of that nutrient; if a nutrient is endogenously synthesised, a biomarker would better reflect the actual level in the body but will not reflect the dietary intake only (126). Also, combining the use of biomarkers with reported dietary intake may help reduce bias according to under-reporting or over-reporting (126). However, potential bias or confounding may still occur when using biomarkers; therefore, to reliably assess dietary intake, several factors should be considered, e.g. variation in dietary intake, specificity, bioavailability and metabolism, and type of specimen, among others (126).

Assessment of body size and body composition can be evaluated by anthropometric assessment methods. Weight and height are the most often used anthropometric measurements of body size (119). In hospitals, body size is often used as indicator for nutritional status and to monitor nutritional interventions (119, 128). The measurements are easy collected and may be self-reported. Body mass index (BMI) ($weight/height^2$) is often used to define overweight and obesity. BMI correlates with body fatness and therefore indirectly with body composition; however, elevated BMI may indicate muscularity, edema or adiposity (119, 121). BMI in combination with skinfold thickness or waist circumference may help to indicate the distribution of body fat (119, 129). Measurement of body composition is most often divided into two compartments to distinguish between fat mass and fat-free mass (i.e. skeleton, muscle and extracellular water) (117, 121, 130). Emphasis has particularly been on fat mass, especially visceral fat mass, due to the association between amount of fat and risk of CVD and cancer. Subcutaneous fat and/or visceral fat content are measured by e.g. skin thickness and waist circumference, both anthropometric measurement of body composition; however, skinfold thickness measurements may be hampered by measurement errors (117, 121, 129). Assessment of body composition can additionally be evaluated by more precise and accurate techniques requiring advanced equipment and technical expertise such as dual-energy X-ray absorptiometry and magnetic resonance imaging techniques (116, 120). These methods are ideal when assessing the effect of nutritional interventions or nutritional deprivations in e.g. malnourished patients on body composition (116, 120).

Finally, clinical assessment of nutritional status usually consists of a medical history, physical examination and functional test (118). A relatively new part of the clinical assessment is the functional test assessing the muscle strength, mobility, and immune and cognitive function. These tests may help detect malnutrition at a subclinical level due to the caused functional impairment (118, 120, 131). However, the tests may be hampered by large within-patient variation as well as limited practical use in some patient groups.

2.4.1. VALIDATION OF DIETARY ASSESSMENT METHODS

Validation of dietary assessment methods, for instances an FFQ, is crucial. The validation is performed to ascertain whether the FFQ measures the dietary aspect it was developed to measure in a specific population (127). First step is the selection of population (127). The population in the validation study should be a random sample of the population applied in the further work with the assessment method. Second step is to choose a standard for comparison and a gold standard would be advisable, but, unfortunately, such a standard does not exist for evaluating diet. In the choice of comparison method, it is crucial that the measurement errors are independent to avoid an artificial correlation (127). Comparison with a food record would usually represent an optimal method because measurement errors are almost independent. However, the correlation may be reduced due to altered food intake when carrying a food record, which may not influence the usual diet (124, 125, 127). Alternatively, comparison with a 24-hour recall is also reasonable and especially advisable in some people such as less motivated people and illiterate people (127). However, an FFQ and a 24-hour recall are encumbered with similar methodological errors including issues related to memory and perception of portion sizes and questions (125, 127). Comparing biomarkers is useful because measurement errors are obviously uncorrelated. However, reliable biomarkers do not exist for most food groups and biomarkers are affected by variation in bioavailability and metabolism, as well as potential technical errors (127). Third step is to consider an appropriate time frame of measurement (127). The comparison method should optimally reflect longer-time frame minimising the effect of day-to-day variation and seasonal variation. Fourth step is the sequence of the measurements because assessment of the first administration may influence the degree of detail in the second administration (127). If biomarkers are applied, especially short-term dietary indicators, at least two sample or a random collection over time is recommended. Fifth step is the number of appropriate participants involved (127). Too few participants would lead to a wide confidence interval (CI) and too many would raise the cost of the study and participants would be needlessly included. The number of participants is also influenced by the number of days of dietary intake; thus, if dietary measurement is largely replicated, the feasibility would probably be low. Validation studies including 100-200 participants seem reasonable. Finally, analysis of the relation between the FFQ and comparison method can be done in various manners and no single method features all information (127, 132). However, presentation of means and standard deviations of the methods and results on the association e.g. correlation coefficients are essential (127).

As part of evaluating a questionnaire, test of reproducibility is often conducted (127). Reproducibility, or test-retest reliability, refers to the consistency of a dietary method assessed across several administrations to the same participant. The precision relies on the true variation in daily intake and measurement error. Questionnaires with a high degree of reproducibility are appropriate in longitudinal research because risk of bias due to measurement error is low. Hence, the difference in performance pre- and post-intervention can be ascertained to the true change in diet (127, 133). Statistical analysis of reproducibility include degree of misclassification, mean and standard deviation of the difference, and correlation coefficients (133).

2.5. RATIONALE OF THE STUDIES

Study I

The association between several sociodemographic characteristics and dietary intake has attained extensive awareness in recent years (88–94). In Denmark, two large national surveys have lately evaluated the dietary intake (16, 17). They found apparent association between sociodemographics and quality of diet. Hence, participants with low educational attainment had an unhealthier diet compared to participants with a high educational attainment (16, 17).

Continuous monitoring of dietary intake is essential to guide future dietary interventions and campaigns aimed at improving public health (122). In this context, it is therefore relevant to evaluate the association between sociodemographic characteristics and specific food groups to ascertain possible challenging tasks. We have chosen to focus on the association between educational attainment and living arrangement, and the intake of fish, red meat, and fruit and vegetables for several reasons. First, low educational attainment is a well-established risk factor for health-related outcome and updated knowledge according to diet is relevant (5–8). Previous studies evaluating fish intake in Danish adults have found diverging results. Thus, studies using FFQs have not found an association between education attainment and fish intake (134–136); whereas, studies using a food record have found more consistent tendencies towards that those with higher educational attainment had a higher intake of fish than those with a lower educational attainment (137, 138). Studies have found a clear relationship between educational attainment, and fruit and vegetable intake; however, large variation in differences exists (92, 95, 134–138). The association between educational attainment and red meat has generally not been investigated and an updated picture therefore seem essential (92, 139). Second, living alone is an established risk factor for cardiovascular risk and mortality, and due to the increasing social tendency towards people living alone, this variable is highly relevant in relation to diet (79, 80, 98). Living alone has been associated with less healthy diet in Danish adults compared with people living with others; however, the literature is insufficient according to specific foods (134, 135, 138, 140). In addition, the association between living arrangement, and unprocessed red meat and processed meat has hardly been evaluated (139).

The specific choice of foods was also based on the possibility to quantitatively compare with the national guidelines (20). Overall, large dietary variation exists and the increasing focus on health and environment might enlarge the existing differences in diet.

Study II

In the clinic, systematic and accurate dietary assessment is relevant to evaluate dietary intake and to assist the provision of dietary advice (122, 141). Dietary assessment is likewise relevant when monitoring the impact of dietary interventions. Clinical dieticians often employ very detailed dietary information by e.g. 24-hour dietary recalls or food records; however, these tools are time-consuming for both the patients and the dieticians. Besides, a very detailed information is not always necessary to review and address concerns in the diet (141). Simple, quick to complete and disease-specific questionnaires are therefore essential.

Such a disease-specific dietary questionnaire is applied in Denmark (111, 142) (Appendix A) in patients with IHD undergoing cardiac rehabilitation. This questionnaire, HeartDiet was developed to measure the habitual diet of healthy people and patients with dyslipidaemia and/or CHD. Since 2013, it has been recommended to use HeartDiet to assess the individual's need for dietary intervention (12, 13); however, a validation has never been published.

Validation of this particular short, self-administrated questionnaire was therefore essential and was additionally needed for Study III and IV to evaluate the dietary intake in patients with IHD undergoing cardiac rehabilitation.

Study III

It has been proven difficult to promote persons to improve their dietary habits (14–17). Dietary habits are forged over a lifetime, and numerous barriers influence the process of changing diet: lacking financial resources and knowledge, partner's influence, available time, habits, motivation, previous experience and taste, among others (143–146). It has been speculated whether these barriers vary according to sociodemographic characteristics (16, 17, 144, 146) because differences in dietary intake is obvious in the general population (16, 17, 90, 94). Dietary support, on the other hand, is likely to motivate adults to change their diet (147). Dietary support is an integrated component in cardiac rehabilitation (12), and dietary improvements have been found in patients undergoing cardiac rehabilitation (18). In patients suffering from myocardial infarction, inequality in change of health-related outcomes has additionally been found (101, 148). Hence, patients with low socioeconomic status were less likely to change behaviour than patients with higher socioeconomic status. To further evaluate predictors of unhealthy diet in patients who were following a cardiac rehabilitation programme, a longitudinal study was conducted (149). The authors found that living alone, but not educational attainment, predicted unhealthy diet post-rehabilitation. However, it is unknown whether a standard cardiac rehabilitation programme aiming to alter diet will be equally beneficial for all patients. Identifying those who will not benefit from the general cardiac rehabilitation programme would be meaningful in order to future target the programme.

Study IV

Unhealthy diet is a major risk factor for several chronic diseases and low intake of healthy foods such as wholegrain, fruit and vegetables in particular contributes to the high risk (10). Dietary improvements therefore seem important, especially in patients with IHD due to the increased risk of recurrence (150). Dietary support is an integrated component in cardiac rehabilitation (12, 13), which is likely to motivate patients with IHD to change their diet (18, 147). To understand specific food behaviours in patients with IHD participating in cardiac rehabilitation may help optimising the dietary support. Hence, dietary focus may change if intake of some foods appeared unimproved during the programme or if improvements were not maintained at follow-up. Studies evaluating specific dietary changes in patients with IHD participating in cardiac rehabilitation are limited (151–153). One minor longitudinal study (n=47) examined dietary change focusing on few products namely change in dairy products, and bread and grain products only (153). Interpretation of the latter study is complicated due to a categorisation in good and poor responders. Two additional longitudinal studies (n=59, n=880) evaluated change in several food groups; however, important dietary knowledge was neglected regarding the intake of wholegrain products as well as the quality of fat (151, 152). Besides, the changes were measured by medians, which may not be a sensible measurement of change.

None of the previous studies reported the results by sex (151–153). An updated and further detailed description about dietary intake in patients undergoing cardiac rehabilitation is warranted to support dieticians and other health professionals with information about possible inadequate changes and to subsequently guide the patients.

CHAPTER 3. AIMS AND HYPOTHESES

This thesis aims to evaluate dietary intake of healthy Danish adults and patients who were following a cardiac rehabilitation programme in light of their sociodemographic characteristics. The specific aims of the four studies were:

Study I

The aim of the first study was to investigate the association between healthy Danish adults' educational attainment, living arrangements and their intake of fish, red meat and fruit/vegetables. In addition, to investigate the extent to which healthy Danish adults' diets were in agreement with current dietary recommendations for these food items (1).
Hypothesis: Participants with a high educational attainment have a healthier diet and adhere more to the recommendations than those with a low educational attainment. Compared with participants living alone, participants living with others have a higher intake of fish, red meat and fruit/vegetables. In addition, participants living with others adhere more to the recommendations in regard to fish and fruit/vegetables than participants living alone.

Study II

The aim of the second study was to validate the HeartDiet questionnaire by comparing it with biomarkers and with the validated semi-quantitative 198-item FFQ used in the Inter99 study (2).
Hypothesis: HeartDiet is well correlated with the 198-item FFQ used in the Inter99 study and with biomarkers.

Study III

The aim of the third study was to investigate the association between sociodemographic characteristics and changes in dietary intake in patients with IHD undergoing cardiac rehabilitation (3).
Hypothesis: Different sociodemographic groups do not have the same capacity to change their diet.

Study IV

The aim of the fourth study was to explore the longitudinal changes in and maintenance of specific food groups among patients with IHD who were following a cardiac rehabilitation programme (4).

Hypothesis: Dietary change differ according to food groups in patients who were following a cardiac rehabilitation programme.

CHAPTER 4. STUDIES

This thesis is based on four studies presented in four papers attached in the Appendix (1–4). The four studies are conducted to evaluate differences in dietary intake, focusing on sociodemographics. First, we evaluated the differences in dietary intake in healthy Danish adults. Second, we validated an FFQ used in cardiac rehabilitation settings in Denmark and in the subsequent studies. Third, we investigated the relation between sociodemographic characteristics and changes in diet among patients with IHD undergoing cardiac rehabilitation. Fourth, we evaluated the change in specific foods in patients with IHD undergoing cardiac rehabilitation.

This chapter provides a short overview of the study populations, design and aims of the studies (Table 1). Also, the four studies are presented including additional analyses not included in the papers.

4.1. STUDY POPULATIONS

Table 1. *Overview of the study populations, design and aims for Study I-IV.*

Study	Population (eligible for analysis)	Setting	Design	Dietary Assessment	Aim
I	85,456 healthy adults	Denmark, The Danish National Health Survey	Cross-sectional study	Four dietary questions covering nine items	To investigate the association between educational attainment, living arrangements and intake of fish, red meat and fruit/vegetables in healthy Danish adults. Besides, to investigate the extent to which healthy Danish adults' diets were in agreement with current dietary recommendations for these food items.
II	99 healthy adults + 100 patients with coronary heart disease (Biomarkers in 50 of the healthy adults)	The Lipid Clinic, Department of Cardiology, Aalborg University Hospital	Validation study	HeartDiet Inter99 Serum β-carotene Serum n-3 PUFA	To validate the HeartDiet questionnaire by comparing it with the validated semi-quantitative 198-item FFQ used in the Inter99 study, and with serum β-carotene and serum n-3 PUFA as biomarkers of dietary intake of fruit/vegetables and fish.
III	186 patients with ischaemic heart disease at T_1 and T_2 157 patients at all three assessments	Department of Cardiology, Aalborg University Hospital	Longitudinal study	HeartDiet	To investigate the association between sociodemographic characteristics and changes in dietary habits in patients with ischaemic heart disease undergoing cardiac rehabilitation.
IV	186 patients with ischaemic heart disease at T_1 and T_2 157 patients at all three assessments	Department of Cardiology, Aalborg University Hospital	Longitudinal study	HeartDiet	To explore changes in and maintenance of specific food groups among patients with ischaemic heart disease who were following a cardiac rehabilitation programme.

Inter99 indicates the 198-item food frequency questionnaire used in the Inter99 study; n-3 PUFA, marine n-3 polyunsaturated fatty acid; T_1 baseline/before rehabilitation; T_2 post rehabilitation; T_3 6 months after baseline.

4.2. STUDY I

To evaluate the dietary intake among different sociodemographic groups in Denmark, we used dietary data from the Danish National Health Survey (17, 154). The dietary questions were a slightly modified version of questions from a validated 48-item FFQ (155, 156). The survey was conducted on 300,450 Danish residents across all five Danish regions from February to May 2013 (17). A total of 162,283 respondents accepted the invitation, corresponding to 54% of those invited (17).

Aim

To investigate the association between educational attainment, living arrangements and intake of fish, red meat and fruit/vegetables in healthy Danish adults. Also, to investigate the extent to which healthy Danish adults' diets were in agreement with current dietary recommendations for these food items.

Key Methods

The study design was cross-sectional. Intake of fish, red meat (including both unprocessed red meat and processed meat) and fruit/vegetables was assessed from four questions covering nine items. Intake frequency was reported in five categories ranging from at least one time/day (vegetables, red meat as a main meal and fish as a main meal) or at least two times/day (fish and meat with sandwiches) to less/never. Intake of fruit was reported in eight categories ranging from at least six pieces/day to none. Intake was estimated by multiplying intake frequency by medium-sized portions inspired by standard portions in Denmark (157) and personal communication with the leading Danish expert in this field (Sisse Fagt, National Food Institute, Denmark, oral communication, 3 August 2017). The portions were 35 g for fish in sandwiches, 100 g for fish and red meat as a main meal, 23 g for meat in sandwiches, and 100 g for vegetables and fruit per portion. Educational attainment was reported as basic school, upper secondary school including vocational education, bachelor's degree or equivalent, and master's or PhD degree. Living arrangement was reported as living alone or living with others including children.

Simple linear regression was used to describe the association between educational attainment, living arrangements and dietary intake. Logistic regression was applied to describe the association between education, living arrangements and adherence to national dietary recommendations (20). Multiple linear regression models and multiple logistic regression analyses were employed to explore associations adjusted for age and mutually adjusted for education and living arrangements. Analyses were stratified by sex. As supplementary analyses, fish and red meat were separately analysed as fish/meat as a main meal and fish/meat with sandwiches. Also, fruit and vegetables were analysed separately.

Main Results

A total of 162,283 Danish adults participated in the national study; 60,076 participants were excluded because of self-reported lifestyle diseases; another 16,751 were excluded because they were below 25 years of age or enrolled in education and therefore could not be categorised according to the pre-specified categories. Thus, 85,456 healthy participants were eligible for analysis. Participants with a high educational attainment had a higher intake of fruit/vegetables and a lower intake of red meat than participants with a low educational attainment (Table 2). Furthermore, compared to participants living alone, participants living with others had a higher intake of red meat and fruit/vegetables. No clear associations were found regarding educational attainment, living arrangements and intake of fish. Educational attainment and living arrangement were significantly associated with adherence to the Danish dietary recommendations for red meat and fruit/vegetables.
We found similar associations when we separated fruit/vegetables into fruit and vegetables or red meat by meals. When separating fish intake as a main meal and fish with sandwiches, we found that women living with others had a higher intake of fish with sandwiches than those living alone (16g/week (95% CI 13; 19g/week).

Strengths and Limitations

Most important strengths of the study were that it has a very large number of participants and the possibility to stratify for gender. Also, we could analyse the intake of red meat as a specific outcome, which has rarely been done in other studies.

The study also had some limitations. It had a lower percentage of participants with a low educational attainment and a lower percentage of participants living alone than the general population. Selection bias might occur if those with the lowest educational attainment had the least healthy diet and a lower response than other participants. The study might also be affected by under-reporting as well as over-reporting. Under-reporting of unhealthy foods is common, especially among people with low socioeconomic status (158), so we may have underestimated the association between educational attainment and consumption of red meat. Given the cross-sectional study design, causality cannot be established. It was not possible to evaluate the intake of oily and lean fish separately due to the predefined questionnaire.

Main Conclusions

Higher educational attainment was positively associated with fruit/vegetable intake and negatively associated with red meat intake for both men and women. Living with others was positively associated with the intake of red meat and fruit/vegetables. Besides, educational attainment was positively associated with adherence to the recommendations for red meat and fruit/vegetables. Living alone was positively associated with adherence to the recommendations for fruit/vegetables and negatively associated with red meat.

Table 2. *Differences in dietary intake according to educational attainment and living arrangements.*

	Fish	**Red meat[a]**	**Fruit/vegetables**
	Differences in g/week (95% CI)	Differences in g/week (95% CI)	Differences in g/day (95% CI)
	Men		
Educational attainment			
Basic school	0 (ref)	0 (ref)	0 (ref)
Upper secondary school	-21 (-29; -13)	-71 (-81; -61)	18 (12; 25)
Bachelor degree	-6 (-14; 3)	-149 (-159; -138)	59 (53; 66)
Master or PhD degree	11 (1; 20)	-187 (-199; -175)	109 (102; 117)
Living arrangements			
Living alone	0 (ref)	0 (ref)	0 (ref)
Living with others	8 (0; 15)	40 (30; 49)	40 (34; 46)
	Women		
Educational attainment			
Basic school	0 (ref)	0 (ref)	0 (ref)
Upper secondary school	-8 (-16; -1)	-89 (-99; -80)	24 (17; 31)
Bachelor degree	1 (-6; 9)	-137 (-146; -128)	72 (65; 79)
Master or PhD degree	14 (5; 23)	-175 (-186; -164)	106 (97; 114)
Living arrangements			
Living alone	0 (ref)	0 (ref)	0 (ref)
Living with others	9 (3; 16)	110 (102; 118)	24 (18; 30)

Multiple linear regression was performed to explore associations adjusted for age and mutually adjusted for educational attainment and living arrangements.
CI indicates confidence interval.
[a] Unprocessed red meat and processed meat.

4.3. STUDY II

The conception of the shortened FFQ, HeartDiet and the acquisition of data were performed several years ago. In Study II, we analysed the data from this population (2). In the section below, we also present analyses of reproducibility, which were not included in Paper II. In the clinic and in longitudinal studies such as Study III & IV, it is important that repeated administrations of the FFQ reflect true dietary changes. Therefore, testing the reproducibility of the FFQ is essential.

A version of HeartDiet can be found online (111) and in Appendix A.

Aim

To validate the HeartDiet questionnaire by comparing it with the validated semi-quantitative 198-item FFQ used in the Inter99 study (155), and with serum β-carotene and serum n-3 PUFA as biomarkers of dietary intake of fruit/vegetables and fish.

Key Methods

In random order, 100 Danish healthy adults and 100 Danish patients with CHD completed the 198-item FFQ (159) and HeartDiet (111) based on their diet the previous four weeks. Data from HeartDiet were entered twice and verified, using EpiData (160). Intake of fish, fruit and vegetables was estimated by multiplying the frequencies of intake by standard portion sizes, which were 35 g for fish with sandwich, 125 g for fish as a main meal and 100 g per portion for fruit and vegetables (161, 162). The 198-item FFQ was scanned, and dietary intake of macro and micronutrients was calculated using FoodCalc software (163) based on Danish food composition tables and standard portion sizes (161, 162, 164). Extending the initial administration of HeartDiet (2), repeated administration was obtained after one month. HeartDiet was sent by mail to the 99 eligible healthy participants who all replied.

Biomarkers were analysed in a random subgroup of 50 healthy participants. The content of serum n-3 PUFA (the sum of eicosapentaenoic acid, docosapentaenoic acid and docosahexaenoic acid) reflected fish intake (34, 126), analysed by gas chromatography (Varian 3900) and a CP-sil 88 capillary column. Fatty acid methyl esters with 14 to 24 carbon atoms and separation of several *trans* fatty acids were quantified as weight percentages of total fatty acids. The content of serum levels of β-carotene reflected intake of fruit and vegetables (126), which was assessed using standard high-performance liquid chromatography. All methods have been described in detail previously (165, 166).

Comparison of data was presented in several ways namely by means and standard deviations of the questionnaire, correlation coefficients and graphic illustration by scatter plots and Bland Altman plots (167). In detail, HeartDiet was compared with the 198-item FFQ regarding intake of fish, fruit and vegetables using correlation coefficients and graphic illustration. Correlation coefficients and scatter plots were applied when comparing fish and fruit/vegetable intakes in HeartDiet with the biomarkers serum β-carotene and serum n-3 PUFA. Additionally, correlation coefficients and scatter plots were employed in the comparison between the fat score in HeartDiet and the intake of SFA in the 198-item FFQ. Correlation analyses were performed using Spearman's rank correlation coefficient with 95% CI calculation using Fisher's z-transformation.

To identify inappropriate dietary intake, a cut-off point at 75 points was chosen. To evaluate this cut-off point, a heart-healthy diet based on HeartDiet (both dietary scores ≥ 75 points) was compared with the national dietary recommendations and with the 198-item FFQ (155, 168).

To test reproducibility, Pearson correlation coefficient was estimated with 95% CI calculated using Fisher's z-transformation.

Main Results

A total of 199 participants were eligible for analysis. Intake of fish, fruit and vegetables and the fat score were statistically significantly correlated with the 198-item FFQ and with biomarkers (Table 3). The result were not different between sub-groups (men/women, healthy adults/patients with CHD, young/old). By graphical inspection of Bland Altman plot, we found no obvious variation in fish intake below 50 g/day, whereas higher intakes induced systematic differences (Figure 1). The interpretation regarding fruit and vegetables was hampered due to the very few categories in HeartDiet but the variation tended to increase in intake above 200 g/day. In general, HeartDiet tended to underestimate the intake compared with the 198-item FFQ.

HeartDiet's ability to correctly identify those with a need of dietary intervention was 92% (sensitivity), whereas HeartDiet's ability to classify those without a need was 41% (specificity). The overall proportion of corrects test results (accuracy) was 80%.

Testing the reproducibility, we found a highly significant correlation for both dietary scores and specific food groups. Pearson correlation coefficient, r (95% CI), was 0.77 (0.67; 0.84) for the fat score and 0.85 (0.78; 0.90) for the fish-fruit-vegetable score. Additionally, correlations for fish, fruit and vegetables ranged between 0.72-0.82.

Strengths and Limitations

The study had several strengths. HeartDiet was validated in several ways including comparison with a semi-quantitative 198-item FFQ used in the Inter99 study (155) and use of biomarkers. Besides, several methods were employed including graphical illustration. Moreover, participants comprised both healthy adults and patients with CHD. Reproducibility was tested.

Some limitations must be acknowledged. HeartDiet might have been validated by other means. For further discussion of study limitations, please refer to 'Chapter 5.2. Methodological strengths and limitations'. HeartDiet is not able to distinguish between oily and lean fish, which may reduce the validity of the comparison. Administration was repeated after one month only, which could induce participants to remember their previous answers (127). Longer periods between administrations are typical (127); nevertheless, we expect limited bias due to seasonal variation and limited influence by a true change in diet.

Main Conclusions

HeartDiet was well aligned with the 198-item FFQ used in the Inter99 study and with biomarkers. Furthermore, a high reproducibility was found for both dietary scores and specific food groups.

Table 3. *Comparison of HeartDiet with the 198-item food frequency questionnaire in the Inter99 study and with biomarkers.*

HeartDiet	**Comparison (Inter99 and Biomarkers)**	**HeartDiet Mean ± s.d. (gram)**	**Inter99 Mean ± s.d. (gram)**	**Spearman's ρ (95% CI)**	**n**
Fish intake	Inter99, fish intake	31 ± 18	45 ± 34	0.75 (0.68; 0.81)	199
	Inter99, n-3 PUFA			0.74 (0.67; 0.80)	199
	Biomarker, n-3 PUFA			0.45 (0.19; 0.65)	50
Fruit intake	Inter99, fruit intake	198 ± 91	322 ± 198	0.70 (0.62; 0.76)	199
Vegetable intake	Inter99, vegetable	132 ± 79	173 ± 112	0.54 (0.44; 0.64)	199
Fruit/vegetable	Biomarker, β-carotene	-	-	0.59 (0.37; 0.74)	50
Fat score[a]	Inter99, SFA (g/day)	-	-	−0.51 (−0.61; −0.40)	199
	Inter99, SFA (E%)			−0.61 (−0.69; −0.51)	199

Intakes in g/day. n-3 PUFA (biomarker) in weight as percentage of total fatty acids and β-carotene in µmol/l. Inter99 indicates the 198-item FFQ used in the Inter99 study; CI, confidence interval; n-3 PUFA, marine n-3 polyunsaturated fatty acids; SFA, saturated fatty acids; E%, energy percentage from saturated fatty acids (without alcohol).

[a] The fat score ranged from 0 to 100, with higher scores indicating a more heart-healthy diet with respect to saturated fat.

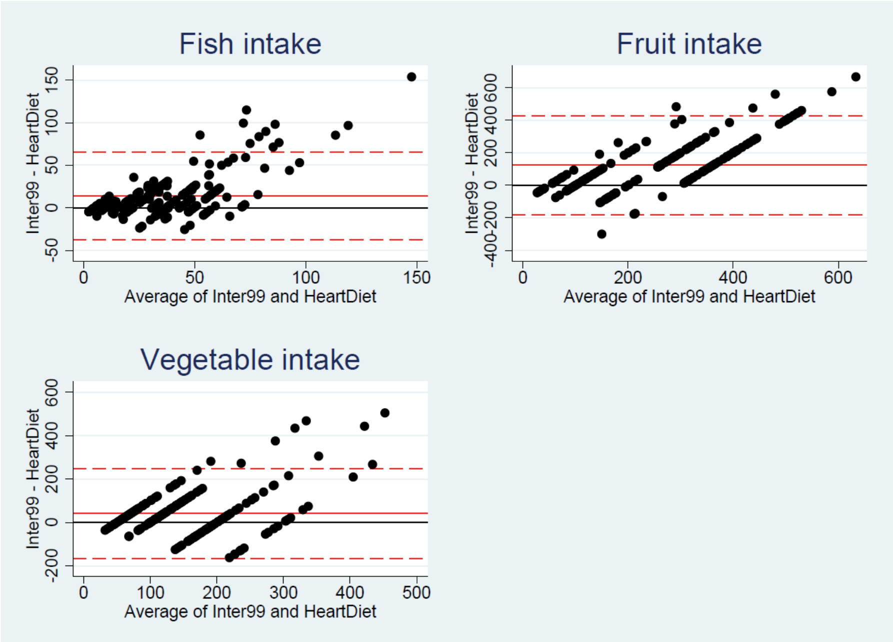

Figure 1. *Bland Altman plots.*

Evaluation of the variation in intake between Inter99 and HeartDiet according to fish, fruit and vegetable intake.

Y axis represents the difference between Inter99 and HeartDiet and X axis represents the average of these questionnaires. The solid red line represent the average of the differences and the dotted red lines the limits of agreement.

Inter99 indicates the 198-item FFQ used in the Inter99 study.

4.4. STUDY III

Aim

To investigate the association between sociodemographic characteristics and changes in diet in patients with IHD undergoing cardiac rehabilitation.

Key Methods

A longitudinal study was conducted between October 2015 and September 2018. The inclusion criteria were adult patients with non-ST-elevation myocardial infarction, ST-elevation myocardial infarction, unstable angina or stable angina pectoris, and participation in cardiac rehabilitation at Aalborg University Hospital, Denmark. Exclusion criteria were earlier participation in rehabilitation programmes. All patients gave written informed consent and the study was registered at the Danish Data Protection Agency. Dropout was defined as attending less than 50% of the rehabilitation programme.

The cardiac rehabilitation programme was performed as illustrated in 'Chapter 2.3.2. Recommendations and clinical practice'. Diet was assessed using the validated FFQ, HeartDiet (2) at baseline/before rehabilitation (T_1), post rehabilitation (T_2), and 6 months after baseline (T_3). Sociodemographic characteristics were assessed at T_1 from the Danish Cardiac Rehabilitation Database (109) and included marital status, living arrangements, educational attainment and employment status.

A paired t-test was applied to compare differences in fat score and fish-fruit-vegetable score between the administrations. Multiple linear regression was used to describe the association between sociodemographic characteristics and change in diet. The analyses were mutually adjusted for education and living arrangements and further adjusted for age. All analyses were stratified by sex. Associations were assessed by absolute differences to allow an intuitive interpretation, which otherwise may be further complicated by the upper limit of the dietary scores. As supplementary analyses, analyses were employed according to attendance of the dietary lecture and according to dietary scores at T_1.

Main Results

A total of 332 patients with IHD attended cardiac rehabilitation in the study period during which 186 participants provided data on food intake at time T_1 and T_2, and

157 participants provided data in all three administrations, see flowchart (Figure 2). Eighty-nine percent of the patients participated in the dietary lecture at the hospital.

Patients statistically significantly increased their fat and fish-fruit-vegetable scores from T_1 to T_2. These improvements were maintained at T_3. In Table 4 & 5, the association between sociodemographics and changes in diet was explored. The increase in fat score was lower in male pensioners than in employed men (-11 (95% CI -17; -5)). The fish-fruit-vegetable score was less increased in men with a bachelor degree (-8 (95% CI -13; -3)) and female pensioners (-18 (95% CI -32; -4)) than in men with a vocational education and employed women (adjusted analyses). Overall, there was a trend towards a lower increase in both dietary scores among retired women and unemployed women compared to employed women. Besides, a trend towards that participants who were married or living with others had a lower increase in dietary scores compared with participants who were unmarried or living alone. Moreover, no trend was seen according to educational attainment.

As supplementary analyses, we found that patients not attending the dietary lecture had a lower fat and fish-fruit-vegetable score at T_1 compared with patients attending the lecture. Similar trends as in the main analysis were found according to sociodemographic characteristics. In the stratified analyses according to dietary scores at T_1 (<75 or ≥ 75 points), patients still statistically significantly increased their fat and fish-fruit-vegetable scores. Patients with a fat score ≥ 75 points at T_1 had a lower increase in fat score compared with those having scores < 75 points. In the same patients, differences in dietary change according to living arrangement and marital status were more obvious compared with those having scores < 75 points at T_1. In patients with scores < 75 points at T_1, differences in dietary change according to employment status were more obvious compared with patients having dietary scores ≥ 75 points.

Strengths and Limitations

The strengths of the study were its longitudinal design with dietary assessment at three administrations, and the application of a validated FFQ (155). We considered change in sociodemographic characteristics albeit similar results were found when excluding participants who changed status regarding marital status and living arrangements. In addition, educational attainment rarely changes late in life. The internal and external validity were explored (4). We found only few differences between participants with complete dietary data and those with incomplete data, and between the total study cohort and patients who declined to participate or missed the study invitation.

Some limitations must be acknowledged. The study might be underpowered, especially among women. Repeating the study in larger scale may be considered. In such a study, it would be recommended that the primary investigator solely perform the handout of the questionnaires, possibly inducing fewer patients to miss the invitation and fewer patients to decline participation. In addition, the timeline may be reconsidered, and a longer follow-up period may be used to evaluate the long-term consequences of dietary change.

Main Conclusions

Patients undergoing cardiac rehabilitation statistically significantly improved their dietary intake. The improvements remained statistically significant during follow-up. Differences in dietary improvements exist according to marital status, living arrangements and employment status. Thus, unemployed women and retired women did not seem to benefit as much as employed women from the programme. In the future, targeted interventions to improve dietary intake over time may become relevant.

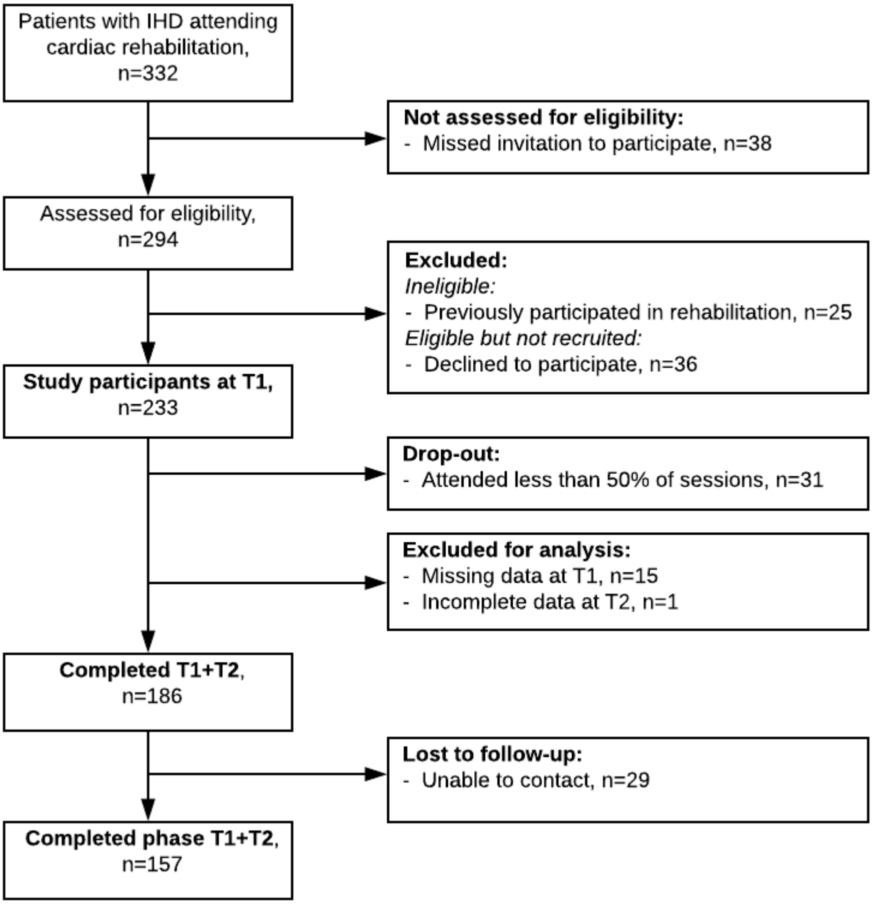

Figure 2. *Flow chart of the study participants in Study III & IV.*
IHD indicates ischaemic heart disease (non-ST-elevation myocardial infarction, ST-elevation myocardial infarction, unstable angina and stable angina pectoris); T_1 , baseline/before rehabilitation; T_2 , post rehabilitation; T_3 , 6 months after baseline.

Table 4. *Change in dietary scores according to sociodemographic characteristics for men.*

Men	**Fat score**			**Fish-fruit-vegetable score**		
	T_1	Δ (T_2- T_1)	Δ (T_3- T_1)	T_1	Δ (T_2- T_1)	Δ (T_3- T_1)
	Mean score[a]	Δ (95% CI)[b]		Mean score[a]	Δ (95% CI)[b]	
Marital status						
Married	70	0 (ref)	0 (ref)	78	0 (ref)	0 (ref)
Unmarried	66	-3 (-7; 2)	3 (-3; 9)	70	1 (-4; 5)	6 (0; 11)
Living arrangements						
Living with others	70	0 (ref)	0 (ref)	77	0 (ref)	0 (ref)
Living alone	65	-4 (-8; 1)	2 (-5; 8)	67	0 (-5; 4)	5 (-2; 11)
Educational attainment						
Basic school	63	-3 (-9; 3)	1 (-7; 9)	63	-6 (-12; 0)	1 (-7; 9)
Vocational education	68	0 (ref)	0 (ref)	81	0 (ref)	0 (ref)
Bachelor degree	70	-3 (-8; 2)	-3 (-10; 4)	74	-8 (-13; -3)*	-6 (-12; 0)
Master or PhD degree	77	-1 (-9; 7)	0 (-11; 10)	79	7 (-1; 15)	8 (-1; 18)
Employment status						
Employed	69	0 (ref)	0 (ref)	75	0 (ref)	0 (ref)
Unemployed	54	2 (-7; 12)	4 (-10; 18)	74	-5 (-15; 5)	-11 (-25; 3)
Pensioners	69	11 (5; 17)*	3 (-6; 12)	73	2 (-5; 9)	-1 (-10; 7)

Multiple linear regression was used to describe the association between sociodemographic characteristics and dietary change. The analyses were mutually adjusted for education and living arrangements and further adjusted for age.

CI indicates confidence interval; T_1 , baseline/before rehabilitation; T_2 , post rehabilitation; T_3 , 6 months after baseline.

[a] Mean score at T_1 ranging from 0 to 100, higher scores indicating a more heart-healthy diet with respect to intake of saturated fat and a combination of fruit, vegetable, fish and wholegrain intake.

[b] Differences in score from T_1 to T_2 or T_1 to T_3 compared to the reference.

*$P<0.05$

Table 5. *Change in dietary scores according to sociodemographic characteristics for women.*

Women	Fat score			Fish-fruit-vegetable score		
	T_1	Δ (T_2- T_1)	Δ (T_3- T_1)	T_1	Δ (T_2- T_1)	Δ (T_3- T_1)
	Mean score[a]	Δ (95% CI)[b]		Mean score[a]	Δ (95% CI)[b]	
Marital status						
Married	78	0 (ref)	0 (ref)	57	0 (ref)	0 (ref)
Unmarried	70	0 (-8; 7)	2 (-6; 11)	47	2 (-6; 11)	2 (-8; 12)
Living arrangements						
Living with others	77	0 (ref)	0 (ref)	56	0 (ref)	0 (ref)
Living alone	67	1 (-7; 9)	4 (-5; 13)	49	1 (-8; 10)	0 (-11; 11)
Educational attainment						
Basic school	63	8 (-2; 18)	6 (-5; 16)	48	5 (-6; 17)	-1 (-14; 11)
Vocational education	81	0 (ref)	0 (ref)	57	0 (ref)	0 (ref)
Bachelor degree	74	4 (-5; 13)	-2 (-13; 8)	54	6 (-4; 16)	3 (-9; 16)
Master or PhD degree	79	-1 (-15; 13)	-9 (-25; 7)	53	2 (-14; 18)	2 (-16; 20)
Employment status						
Employed	75	0 (ref)	0 (ref)	51	0 (ref)	0 (ref)
Unemployed	74	-3 (-14; 8)	4 (-10; 18)	53	-9 (-21; 3)	-5 (-19; 10)
Pensioners	73	-5 (-17; 7)	-9 (-22; 4)	56	-8 (-21; 5)	-18 (-32; -4)*

Multiple linear regression was used to describe the association between sociodemographic characteristics and dietary change. The analyses were mutually adjusted for education and living arrangements and further adjusted for age.

CI indicates confidence interval; T_1 , baseline/before rehabilitation; T_2 , post rehabilitation; T_3 , 6 months after baseline.

[a] Mean score at T_1 ranging from 0 to 100, higher scores indicating a more heart-healthy diet with respect to intake of saturated fat and a combination of fruit, vegetable, fish and wholegrain intake.

[b] Differences in score from T_1 to T_2 or T_1 to T_3 compared to the reference.

*$P<0.05$

4.5. STUDY IV

Aim

To explore changes in and maintenance of specific food groups among patients with IHD who were following a cardiac rehabilitation programme.

Key Methods

The study design has been described previously; please refer to 'Chapter 4.4. Study III'. Intake of the 19 specific food groups was presented as percentages and frequencies based on 186 participants between T_1 and T_2, and 157 participants between T_1 and T_3. All analyses were stratified by sex.

Main Results

Potential differences in dietary change by food groups were explored. The general tendency was that the intake of most foods had improved at T_2 and these improvements were maintained at T_3. A few food groups were; however, almost stable in intake. For men these include cake/chocolate/ice cream, fast food/chips, sugar/jam/sweetened beverages and wholegrain bread. The same food groups seemed stable for women as well as intake of milk/yogurt and fat used for cooking. From T_1 to T_3, 32% of the men and 42% of the women increased their fruit intake. At T_3, an intake ≤ 1 portion of fruit/day was found among 59% of the men and among 32% of the women (Table 6). Similar results were found for vegetables, apart from women who also had a low intake of vegetables at T_3. From T_1 to T_3, 36% of the men and 35% of the women increased their intake of fish. Still, 50% of the men and 52% of the women had fish as a main meal ≤ 2 times/month at T_3.

Strengths and Limitations

The study had some strengths. We had the opportunity to evaluate potential differences in change within 19 food groups. Besides, the intakes were presented in a very detailed manner. A validated FFQ was applied (155). The results were presented for men and women both separately and combined.

The study also had limitations. Given the study design without a control group, we cannot be sure that the observed dietary change was caused solely by the cardiac rehabilitation programme. For further discussion of the applied methods, please refer to 'Chapter 5.2. Methodological strengths and limitations'. Under-reporting and over-reporting are common (158); however, the FFQ was validated with a good correlation between biomarkers and the validated semi-quantitative 198-item FFQ used in the Inter99 study (155).

Main Conclusions

A tendency towards that the quality of most foods were improved and more heart-healthy foods were consumed in patients with IHD undergoing cardiac rehabilitation. Improvements were maintained 6 months after baseline. However, the quantity and quality of some foods did not seem to improve, among these intake of wholegrain bread. Besides, the intake of cake, fast food, sugar and to some extent candy did not seem to decrease.

Table 6. *Intake reported before rehabilitation, post rehabilitation and 6 months after baseline.*

Food groups	**Men, % (n)**			**Women, % (n)**		
	T_1 (n=137)	T_2 (n=137)	T_3 (n=114)	T_1 (n=49)	T_2 (n=49)	T_3 (n=43)
Vegetables/legumes[a]						
< 1 portion/day	43 (59)	24 (33)	29 (33)	22 (11)	8 (4)	7 (3)
1 portion/day	36 (49)	51 (70)	41 (47)	39 (19)	53 (26)	58 (25)
2 portions/day	18 (25)	19 (26)	23 (26)	27 (13)	29 (14)	21 (9)
3 portions/day	3 (4)	6 (8)	7 (8)	12 (6)	10 (5)	14 (6)
Fruit/berries[a]						
< 1 portion/day	28 (38)	15 (21)	14 (16)	18 (9)	6 (3)	9 (4)
1 portion/day	42 (58)	41 (56)	45 (51)	37 (18)	31 (15)	23 (10)
2 portions/day	22 (30)	32 (44)	27 (31)	31 (15)	45 (22)	40 (17)
3 portions/day	8 (11)	12 (16)	14 (16)	14 (7)	18 (9)	28 (12)
Fish (as a main meal)						
0-1 times/month	36 (50)	26 (35)	25 (29)	35 (17)	29 (14)	19 (8)
2 times/month	31 (42)	23 (32)	25 (28)	20 (10)	18 (9)	33 (14)
3-4 times/month	26 (36)	34 (47)	36 (41)	24 (12)	29 (14)	26 (11)
2 times/week	7 (9)	15 (20)	12 (14)	18 (9)	18 (9)	16 (7)
≥ 3 times/week	0 (0)	2 (3)	2 (2)	2 (1)	6 (3)	7 (3)
Wholegrain bread						
< 1 slice/day	7 (9)	4 (6)	1 (1)	2 (1)	2 (1)	2 (1)
1 slice/day	7 (10)	11 (15)	9 (10)	20 (10)	27 (13)	12 (5)
2 slices/day	47 (64)	47 (64)	47 (54)	49 (24)	57 (28)	65 (28)
≥ 3 slices/day	39 (54)	38 (52)	43 (49)	29 (14)	14 (7)	21 (9)

T_1 indicates baseline/before rehabilitation; T_2 , post rehabilitation; T_3 , 6 months after baseline.

[a] One portion of fruit or vegetables corresponds to 100 g/1 dl.

CHAPTER 5. DISCUSSION

This section discusses the findings of the studies performed in order to evaluate sociodemographic differences in diet and in changes of diet. This is followed by a discussion of the methodological strengths and limitations. Further discussion concerning design in relation to study limitations can be found in 'Chapter 4. Studies' and in the papers included in the appendices.

5.1. DISCUSSION OF STUDY RESULTS

The overall aim was to evaluate the dietary intake among healthy Danish adults and patients participating in a cardiac rehabilitation programme in light of their sociodemographic characteristics. First, we evaluated dietary intake in healthy adults (Study I). We found an association between educational attainment and intake of fruit/vegetables and an inverse association between educational attainment and intake of red meat. We also found that people living alone had a lower intake of fruit/vegetables and red meat than people living with others. Next, we validated the FFQ, HeartDiet (Study II). We found that the shortened FFQ was well aligned with a validated semi-quantitative 198-item FFQ used in the Inter99 study and with biomarkers. Finally, we conducted a longitudinal study among patients with IHD participating in a cardiac rehabilitation programme (Study III & IV). In Study III, we investigated the relationship between sociodemographic characteristics and changes in diet. The data indicated that differences in dietary improvements exist and were associated with marital status, living arrangements and employment status. In Study IV, we explored the changes in specific food groups. The intake of most food groups seemed to improve; however, change in some foods seemed inadequate.

5.1.1. EVALUATING DIETARY DIFFERENCES IN DANISH ADULTS

Unhealthy diet is a major risk factor for several chronic diseases and low intake of healthy foods such as wholegrain, fruit and vegetables in particular contributes to the high risk (10). In 2011, 20% of Danish adults were found to consume an unhealthy diet consisting of a low intake of fruit, vegetables, fish and wholegrain bread and a high intake of saturated fat and added sugar, whereas 15% were found to consume a healthy diet (134). In between, a medium healthy diet was found among 65% of Danish adults. A large social gradient persists in dietary intake (134, 136) and in Study I, we evaluated the association between sociodemographics and specific foods to ascertain possible challenging tasks (1). In consistence with previous findings (92, 134–138), we found that Danish adults with a high educational attainment had a higher intake of fruit/vegetables than adults with a lower educational attainment (1). No clear associations were found for fish intake, which confirms the results of earlier studies using FFQs (134–136). Even though our analyses were stratified by sex there was no clear indication of an association between educational attainment and fish. A more detailed assessment by e.g. food records may have found a difference in intake as presented in other studies (137, 138). Only few studies have evaluated the association between educational attainment, and unprocessed red meat and processed meat. However, a Danish study found that educational attainment was inversely associated with intake of unprocessed red meat/processed meat (92). Another Danish study found that adults with a low intake of red meat or processed meat were most often adults with a high educational attainment compared with those with a low educational attainment (139). Our study confirmed this association, which was apparent for both men and women.

Few studies have analysed the association between living arrangements and dietary intake of fish, fruit and vegetables, and results have been diverging (134, 135, 138). We did not find a distinct association according to fish, which confirmed results evaluated by two previous Danish studies (134, 138). However, evaluating fish intake separately as fish as a main meal and fish with sandwiches may capture a possible difference according to educational attainment. A study that evaluated the dietary intake by an FFQ found a tendency towards a higher intake of fish as a main meal in adults living with others compared with adults living alone (135). We found some, albeit modest, differences in fish with sandwiches among women but not in fish as a main meal. The results indicate that differences in fish intake focusing on living arrangement currently are minor regardless of whether fish is considered in different meals or by sex.

A previous Danish study found that adults living with others had a higher intake of fruit compared with adults living alone (135). Non-significant differences were found for vegetables presented as cooked vegetables and salad/shredded vegetables; however, the study might be too small to capture potential differences in the detailed presentation of data. Another study did not find an association according to fruit or vegetable intake; however, this may be due to the questionnaire used to evaluate the frequency of intake and not the amount (134). We found a significant higher intake of fruit/vegetables among men and women living with others compared with those living alone. When separating fruit and vegetables, we found similar associations.

According to red meat, another Danish study found that adults with a low intake of unprocessed red meat or processed meat were most often adults living with others compared with those living alone (139). We found that both men and women living with others had a significant higher intake of unprocessed red meat and processed meat than those living alone. Further, the differences were most obvious in women.

5.1.2. SOCIODEMOGRAPHICS AND CHANGE IN DIET

In Study III, we found differences in dietary improvements according to living arrangements, marital status and employment status (3). Employment status has previously been associated with dietary quality; thus, it has been most often found that unemployed adults have less healthy diet compared with those who were employed (169–172). In a Danish longitudinal study in healthy adults, unemployment influenced diet as a consequence of reduced income and this influence varied with the duration of unemployment (170). Additionally, a large Danish National Health Survey evaluated respondents' motivation to eat healthier. Among those with an unhealthy diet, people who were not in the working force less often replied that they wanted to eat healthier than people who were employed (16). This suggests that people not in the working force may be less motivated for and less likely to change diet. In a clinical setting, our study confirmed this trend even though dietary support and behaviour change techniques were applied in the cardiac rehabilitation programme. Thus, women who were unemployed or retired improved their diet less than employed women. In men, the same trend was found for the fish-fruit-vegetable score but not for the fat score.

It is generally confirmed that people with a low educational attainment have a less healthy diet compared with those with higher educational attainment, which also was found in Study I (1, 90, 134, 136). Several studies have sought to explore possible barriers to eat healthy in people with low educational attainment. Some studies have found that nutritional knowledge was lower in people with low educational attainment (146, 173, 174), which may affect the choice of diet. A Danish study has investigated whether food prices may be a barrier to eat low-fat food to prevent a hypothetical heart disease (144). The authors found that participants having a low household income, low educational attainment or who were not in the working force were more prone to report high cost of low-fat foods as a barrier to eat healthier than participants with a higher household income, higher educational attainment and participants in the working force (144). In primary prevention, studies have

evaluated the impact of dietary and health interventions to promote healthy eating (175). Most studies evaluating individual-based and group-based education have found a greater impact in healthy people with a high educational attainment compared with those with a lower educational attainment (175). In our study, we did not find any clear trend in dietary change according to educational attainment and the programme may therefore have been equally beneficial in relation to educational attainment.
People living alone have generally a less healthy diet compared with people living with others (94). This was also evident in a longitudinal study among patients undergoing cardiac rehabilitation, which found that living alone predicted poor diet at 1 year follow-up (149). Barriers to eat healthy among people living alone include financial difficulties when shopping for one, motivation to eat alone and inadequate cooking skills (94). In our study, we did not find a tendency towards a further increase in gap between people living alone and people living with others. Instead, we found a marginal tendency that married patients and patients living with others improved their diet less than unmarried patients and patients living alone. This tendency may be due to the lower potential to improve the diet in those with the highest baseline scores; thus, patients living with others and married patients had a more healthy diet at baseline. However, patients with higher baseline scores still significantly improved both scores indicating that patients seemed to benefit from the programme in spite of different starting point.

Based on the present study, differences in dietary change clearly seem to exist. In the future, targeted cardiac rehabilitation programmes may become relevant to decrease differences in diet and other health-related outcomes in socially vulnerable groups, but further research is needed.

5.1.3. CHANGE IN DIET

In Study IV, we aimed to explore potential differences in change by food groups (4). We found a tendency that participants improved the qualitative and quantitative intake of most food groups, including the fat quality and intake of fish, fruit, vegetables and nuts. However, change of some food groups seemed inadequate. Few studies have analysed change in diet by food groups (151–153). In line with our results, three longitudinal studies found improved fat quality according to fat spread on bread post rehabilitation (151–153). We found an increased intake of fish, fruit and vegetables, which supports the findings by Roca-Rodríguez et al (152). Contrary to our results, Twardella et al did not find an increase in fruit intake (151). This could be due to the applied assessment by median intake, which may not be the most sensible way to report changes. In contrast to the two former mentioned studies, the improvements in fish, fruit and vegetables intake remained at follow-up in our study; nevertheless, attention should be drawn to the low intakes at follow-up. Attention should especially be paid to the inadequate dietary change for some food groups. Hence, a dietary aspect not previously explored was the intake of wholegrain bread, which did not seem to change during the programme in neither men nor women. Most participants consumed a few slices of wholegrain bread per day and the recommended 75 grams of wholegrain/10MJ/day therefore seemed infeasible to reach (19, 20). Additionally, the quantitative intake of cake, fast food, sugar and to some extent candy did not seem to decrease in many participants. However, most participants had a fairly low intake of these foods but focus could be intensified. At baseline, the intake of milk/yogurt and fat used for cooking was reasonable in women and did not particularly change, whereas the intake was less healthy in men and seemed to improve during the programme.

Overall, it seemed harder to establish a healthy food quantity than a healthy food quality. This detailed information on dietary change and maintenance may be useful by clinical dieticians and other health professionals seeking a more precise clinical focus. In the future, health professionals may choose to tailor the dietary lecture differently due to the potential differences according to food group. Nevertheless, we found that the intake was improved for most food groups, although the intake of wholegrain bread was stable. Besides, in spite of the increase in the consumption of fruit, vegetable and fish among others, we still saw a very low intake in most patients, which may emphasis a greater attention or different focus in future dietary lectures. Further studies should explore how to improve the specific food groups even more.

5.1.4. VALIDATING HEARTDIET

In Study II, we validated the FFQ, HeartDiet (2). All correlations coefficients studied were between 0.45 and 0.75, which are typical or even stronger coefficients compared to what is typically seen in the literature, thus indicating good relationship (127). Further, the coefficients were, in general, stronger than results presented in other studies comparing short FFQs with full-length FFQs (141, 176–178). In detail, coefficients for fish, marine n-3 PUFA and fruit were at least 0.70. We found lower coefficients for vegetables but similar results were additionally found in other studies (176, 177, 179). The fat intake has likewise been evaluated in previous studies and relatively low coefficients have been found (177, 178, 180). We found a good relation between the fat score and intake of SFA evaluated by the 198-item FFQ (155). Correlation coefficients may be able to determine the agreement between methods but shed no light on the reasons for any lack of agreement and other methods were presented including the mean of the difference in intake and Bland Altman plots (167). Both methods found that HeartDiet underestimated the intake compared with the 198-item FFQ. Further, the conducted Bland Altman plots illustrates that the underestimation was increased at higher mean intakes. This is probably due to the lower maximum intake of fish, fruit and vegetables in HeartDiet, whereas an assessment of a much higher intake was available in the 198-item FFQ. In addition, we also compared results from HeartDiet with biomarkers. In other studies, coefficients at 0.28 for beta-carotene have been observed (127) but stronger correlations have been reported (176). We found a strong correlation at 0.59 for beta-carotene. The correlation between fish intake and biomarker for n-3 PUFA was similar to most previously demonstrated coefficients (127, 181, 182); however, the validity of the n-3 biomarker may be reduced because HeartDiet do not distinguish between oily and lean fish. Nevertheless, a stronger correlation is expected if HeartDiet could estimate the intake of oily fish as found in a recent study that compared three methods of assessing fish intake (183). This also applies to the comparison between fish intake in HeartDiet and n-3 intake in Inter99. HeartDiet's ability to correctly identify patients as having a heart-healthy diet or not was additionally evaluated. A high sensitivity was calculated. Thus, only few patients with an unhealthy diet will not be identified. The specificity was rather low probably due to HeartDiet's tendency to underestimate the intake compared with the 198-item FFQ. HeartDiet will therefore incorrectly identify some patients with a heart-healthy diet as having an unhealthy diet. Nevertheless, the potential psychological consequences would be negligible, contrary to if the test aimed to identify diseases. Reproducibility was tested and correlations fitted well with previously reported values (127, 133).

5.2. METHODOLOGICAL STRENGTHS AND LIMITATIONS

Validating HeartDiet

In Study II, HeartDiet was validated against a validated semi-quantitative 198-item FFQ used in the Inter99 study (155) and against biomarkers. Comparison with a food record is usually recommended as the gold standard; however, such an evaluation would be costly and might be hampered by requiring many recording days to ensure reasonable dietary variation (124, 125, 127). Likewise, it is very time-consuming for the participants and the interviewer. The 24-hour recall would also be costly and similar methodological errors exists when comparing the FFQ and a 24-hour recall (125, 127). Nevertheless, comparison of two FFQs may rise methodological issues because sources of error are likely to be replicated. In theory, dependent errors may occur when validating an FFQ against another retrospective method, as earlier described (125, 127). In practice, comparison of methods e.g. FFQs and food records has shown minor differences in food groups and nutrients in some studies (184–189). Besides, to validate HeartDiet at the level of foods, comparison of FFQs with food records may be challenged (127). This is due to the very detailed information in the food record that need to correspond to the FFQ. Moreover, day-to-day variation in intake is large (127). The validation of HeartDiet could have been performed by other means; however, the 198-item FFQ was judged to be superior and other methods would have caused logistical problems. To improve the study design, we further compared the estimated intake of fish, fruit and vegetables with plasma biomarkers. Biomarkers are used as a surrogate for food intake and we used β-carotene as the biomarker for fruit and vegetables. Carotenoids are mainly obtained from fruit and vegetables and are therefore a relatively specific fruit and vegetable biomarker (126). To assess the total amount of fruit and vegetables, different carotenoids could have been used; nevertheless, β-carotene is often preferred as it is one of the major carotenoids in fruit and vegetables (126). As biomarker for fish intake, we used marine n-3 PUFA in serum. n-3 PUFA is a relatively specific biomarker for fish intake because it is predominately obtained from fish and can only to a limited extent be endogenously synthesised (126). The correlation between carotenoids, n-3 PUFA and dietary intake varies due to e.g. dietary assessment method, potential confounders and bioavailability (126, 182). Besides, choice of carotenoids is crucial because numerous carotenoids exist and the amount of these differs in fruit and vegetables. The concentration of the biomarker likewise varies in different foods and food composition databases may not capture seasonal variation in concentration (126).

Longitudinal study design

In Study III & IV, we conducted a longitudinal study. Due to the study design without a control group, we cannot be sure that the cardiac rehabilitation programme solely caused the change in dietary intake and other circumstances might have influenced this change. Thus, a diagnosis of a chronic disease may influence life-changing decisions including change in lifestyle in all patients with IHD (190). It could also be hypothesised that the attendees in the cardiac rehabilitation were a selective group likely to collaborate and follow advice in general and dietary advice in particular. However, the effect of a cardiac rehabilitation programme is already well-established (18), and our primary aim was not to prove its effect. Nevertheless, if the effect of a cardiac rehabilitation programme needed to be confirmed in a new setting, e.g. in the municipality, other study designs could have been used, for instance a randomised controlled trial, randomising patients to cardiac rehabilitation or no intervention. This would, however, not have been practicable in Denmark where cardiac rehabilitation is recommended to all patients with IHD (12, 13). Moreover, it would have been ethically improper to randomise patients out of rehabilitation. A prospective study design could also have been chosen, comparing attendees with non-attendees in cardiac rehabilitation (191). However, selection bias is likely as significant sociodemographic and clinical differences persist among attendees and non-attendees (12, 13, 84, 85), which may affect the dietary change. Propensity score matching may minimise this problem, matching attendees with non-attendees in cardiac rehabilitation on different patient or clinical characteristics (192). However, we find that to evaluate the dietary change among attendees in cardiac rehabilitation, the performed longitudinal study design seemed sufficient.

CHAPTER 6. CONCLUSIONS AND PERSPECTIVES

First, we found that compared with people with a lower educational attainment, people with a high educational attainment had a higher intake of fruit/vegetables and a lower intake of red meat. In addition, people who were living with others had a higher intake of fruit/vegetables and red meat than people who were living alone. No clear tendencies were found for educational attainment, living arrangements and intake of fish. Overall, our findings have contributed to and updated the existing literature about differences in specific foods among the Danish population. Thus, interventions targeted adults living alone and adults with a lower educational attainment may be effective. To future guide dietary interventions, national health surveys are continuously needed.

Next, we contributed to accomplish the validation of the shortened FFQ, HeartDiet. HeartDiet was used in the subsequent studies and in cardiac rehabilitation settings in Denmark. We found that HeartDiet was well aligned with a validated semi-quantitative 198-item FFQ used in the Inter99 study and with biomarkers. Besides, a high reproducibility was found. Our contribution to publication of HeartDiet was urgent because HeartDiet has been recommended in national recommendations for years without a proper publication of the study (12, 13). In the future, modified and updated dietary assessment methods may be needed due to the constant change in Danes' diet.

Finally, we conducted a longitudinal study among patients with IHD attending a cardiac rehabilitation programme. We investigated the association between sociodemographic characteristics and change in diet. We found differences in dietary improvements according to living arrangements, marital status and employment status. Thus, unemployed women and retired women did not seem to benefit as much as employed women from the programme. We also examined the change in specific food groups and found a tendency towards an improved and maintained intake of most food groups. However, the intake of wholegrain bread, cake, fast food, sugar and to some extent candy seemed stable.

Our findings suggest that change in diet may differ according to sociodemographic characteristics in attendees in a cardiac rehabilitation programme. However, further investigations and large prospective studies are needed to reject or confirm our findings. Additionally, qualitative studies would bring new insight to the field evaluating socially vulnerable patients' perspectives on dietary support in the context of a rehabilitation programme. Also, an intervention study randomising socially vulnerable patients to a socially differentiated programme or a standard programme would clarify the effect of an extended programme. The contents of the socially differentiated programme should take the patients' suggestions into consideration as well as the experiences derived from previous studies (193). Besides, health professionals' experiences may be relevant. Health professionals have previously emphasised that socially vulnerable patients would benefit from a more flexible and individualised programme (194) fitting the idea of placing the patient at the centre of rehabilitation (195).

In this thesis, we focused on diet only. Cardiac rehabilitation has several core components (12, 13); when evaluating cardiac rehabilitation according to sociodemographic characteristics, other lifestyle and health-related outcomes should also be considered. Further studies may focus on investigating whether a cardiac rehabilitation programme has the potential to decrease inequality in health. Eliminating inequality in health is a global, national and regional challenge (8, 196) that cannot be solved by a rehabilitation programme only. However, a rehabilitation programme may positively contribute to narrow the wide differences in health by improving health mainly in the least healthy patients.

Outpatient cardiac rehabilitation in Denmark became a responsibility shared between hospitals and municipalities in 2007 (12, 13, 197). In the recent phase of the restructuring of the entire programme, procedures and quality may have changed. However, most of our current knowledge on cardiac rehabilitation is hospital-based and the recent restructuring leaves a gap in evidence. Research is therefore needed evaluating the cardiac rehabilitation programme in the municipality setting.

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APPENDICES

Appendix A. HeartDiet: Food Frequency Questionnaire

Appendix B. Paper I

Appendix C. Paper II

Appendix D. Paper III

Appendix E. Paper IV

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