

# Healthy eating at worksites

Effectiveness of a Canteen Take Away concept in promoting healthy eating among employees



Anne Dahl Lassen  
PhD Thesis  
2010

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PhD Thesis by Anne Dahl Lassen

National Food Institute  
Technical University of Denmark  
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PhD Thesis by Anne Dahl Lassen

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## Preface

My main research interest is on how healthy eating can be increased at a community level. The foundation is the idea that the promotion of healthy eating should not focus only on downstream individual behaviour but should have a strong upstream orientation that creates and maintains health equalities. To me, the challenge is to assist consumers in making healthful dietary selections whilst maintaining enjoyment of eating and freedom of choice.

The aim of this PhD study was to contribute to the evidence of effective healthy eating promotion initiatives at the worksites and to improve our understanding of the role of availability and convenience as effective tools in promoting healthy eating habits. This thesis deals with the context of real life settings rather than isolated foods or laboratory environments.

The PhD study is based on work carried out at the Division of Nutrition, National Food Institute, Technical University of Denmark through August 2007 to August 2010. The project is a part of a bigger cooperative research network 'Canteen Take Away - Dissemination and Sustainability of Healthy Eating Promoted by Workplaces', here referred to as The Canteen take away Partnership. The partnership includes three research institutions and a number of public, private and civil organizations. Although a collaborative research partnership like this possesses many challenges in terms of conflicting interests and differences in perspectives amongst network members it also offers a lot of benefits and synergies resulting from the collaboration. The project has been innovative in both the type of health promotion activity being evaluated and in the methodology that was employed i.e. introducing a novel concept for evaluating the nutritional quality of individual meal and using a digital photographic method for dietary assessment. This work would not have been possible without the support and commitment from the partners and worksites participating in the project. They have provided valuable feedback and insight thereby contributing to the practical and strategic relevance of the work. Hopefully, this will help facilitate future implementation of the results.

My background is in the area of nutrition and food science. However, eating is more than just food and nutrition. I have great respect for the canteen staff that puts much efforts in creating healthy and enjoyable meals. Furthermore, although physical activity is an important determinant of several lifestyle diseases, along with nutrition, physical activity will not be addressed in the present thesis.

The project was performed in accordance with the ethical standards of the Helsinki Declaration of 1975, as revised in 2008. I hope you will enjoy reading this thesis.

Anne Dahl Lassen, September 2010

*"Happy eating makes for happy family life; sit down and eat together and talk;  
treasure family taste and home cooking" (Japanese dietary advice)*

## Acknowledgements

During the years that I have worked with this thesis, I have had the opportunity to work with quite a large number of people to whom I would like to express my deepest gratitude to for their support, expert advice and numerous fruitful discussions.

I am especially thankful to my dedicated and knowledgeable supervisors Dr. Inge Tetens, Head of the Nutrition Division and Work Package Responsible of the Canteen takeaway Partnership, MSc Nutritionist Anja Biloft-Jensen and Associate Professor Klaus Kaae Andersen, and my former supervisor Senior Advisor Ole Hels, until determination of employment, for their support, guidance and encouragement which helped me take the journey of writing this thesis.

I would like to extend my sincere gratitude to Dr. Gitte Laub Hansen, Project Coordinator of The Canteen take away Partnership, Danish Cancer Society, for her important contributions to the research project and for her great commitment in coordinating the entire research project and bringing the results into practice in corporation with the many project partners.

Also, I would like to thank Dr. Lars Ovesen from Slagelse Hospital as Scientific Manager of The Canteen take away Partnership and Morten Strunge Meyer as the Director of The Canteen take away Partnership for providing valuable feedback and adding new dimensions of thinking to the research project.

A special thanks to Sanne Poulsen and Lotte Ernst who did their master thesis work at The Danish Cancer Society under supervision of The University of Copenhagen and The Canteen take away Partnership. Their excellent work laid the foundation for Paper II and IV in this thesis.

I appreciate my very good colleagues from DTU National Food Institute, Division of Nutrition, including MSc Nutritionist Tue Christensen, Dietician Karin Hess Ygil, Post doc Vibeke K Knudsen, Research assistant Maj-Britt Gille, PhD student Marianne Sabinsky and PhD student Nina Lyng for their advice, assistance and manuscript review. Also, I appreciate my very good colleague PhD student Anne Vibeke Thorsen for many inspiring discussions on the topic of promoting sustainable healthy eating habits at worksites, and for reading and correcting the English text of the completed manuscript.

The PhD study is part of The Canteen take away Partnership funded by the Danish Council for Strategic Research, programme for health, food and welfare. I am especially grateful to all the worksites, canteen staff, employees and members of the partnership who generously shared their time, expertise and experience to contribute to the completion of the present research projects.

Last, but not least, I am grateful to my family and friends, and especially to my husband, Søren, and our children, Sofus and Luisa, for all the support and love that I have been privileged to enjoy also during this PhD journey.

## Abbreviations

BMI: Body Mass Index

BMR: Basal metabolic rate

CTA: Canteen Take Away

DDG 2005: Danish dietary guidelines 2005

E%: Percentage of total energy

g: gram

HMI: Healthy Meal Index

kJ: Kilojoule

MJ: Megajoule

NNR 2004: Nordic Nutrition Recommendations 2004

## List of papers

This PhD thesis is based on the following four papers (Paper I-IV), referred to in the text by their roman numbers:

- I: Evaluation of a new digital method for assessing food intake at workplace canteens.  
Lassen AD, Andersen KK, Biloft-Jensen A, Christensen T, Gille M-B, Tetens I  
*Resubmitted 2010*
  
- II: Evaluation of a digital method to assess evening meal intake in a free-living adult population  
Lassen AD, Poulsen S, Ernst L, Andersen KK, Biloft-Jensen A, Tetens I  
*Food & Nutrition Research*, 2010, **54**(5311), DOI: 10.3402/fnr.v54i0.5311
  
- III: Development and validation of a new simple Healthy Meal Index for canteen meals.  
Lassen AD, Biloft-Jensen A, Hansen GL, Hels O, Tetens I.  
*Public Health Nutrition*, 2010, **13**(10), 1559-1565
  
- IV: Effectiveness of a Canteen Take Away concept in promoting healthy eating pattern among employees  
Lassen AD, Ernst L, Poulsen S, Andersen KK, Hansen GL, Biloft-Jensen A, Tetens I  
*Submitted 2010*

## Summary

### *Background*

The promotion of a healthy balanced diet is a key element for the prevention of overweight, obesity and several chronic diseases. The focus has shifted from considering food behaviour as a mainly private issue to recognizing the responsibility of the society, including the worksites, in creating environments and conditions that support and promote healthy eating habits and an active lifestyle. Besides improving dietary intake at work, worksite health promotion initiatives may also lead to improvements in the lifestyles of employees and their families outside of the worksite. A direct way of reaching the families is to provide employees with so-called Canteen Take Away (CTA), i.e. healthy ready-to-heat meals, offered by the worksite to bring home at subsidized or market prices.

### *Aim*

The overall aim of the present PhD study was to contribute to the evidence base of effective healthy eating promotion initiatives at the worksites. The objectives were to evaluate the digital photographic method for assessing food intake both at worksite canteens offering a variety of meals (Paper I) and for assessing home evening meal intake in an adult 'free-living' population (Paper II), to develop a Healthy Meal Index to assist caterers in making healthy meal offers without using nutrient-calculation software (Paper III) and to evaluate the effectiveness of a recently introduced health promotion strategy – the Canteen Take Away concept – in improving the diets of the employees (Paper IV).

### *Paper I and II*

Two variants of the digital photographic method for assessing food intake at worksite canteens were evaluated using digital images of weighed duplicate plates of customers' self-selected canteen meals ( $n=100$ ). High correlation coefficients between actual and estimated weights were found for both methods for all food categories (0.89 to 0.96). Bland Altman plots and linear regression analysis revealed that the precision of the method was improved by weighing the dishes before and after eating and hereby obtaining an estimate of total weight of food eaten. A third variant of the digital photographic method assessing evening meals intake among free-living individuals was evaluated against weighed records of participants' usual evening meals for five consecutive days ( $n=88$ ). The method was found to be valid with regard to the estimation of macronutrient distribution, energy density and energy-adjusted food contents (correlation coefficients 0.87 to 0.97). Furthermore, the method was found to be feasible for recording weekday evening meal intake during a period of three weeks or more (28 participants).

### *Paper III*

The simple Healthy Meal Index (HMI) was developed and validated following the nutrient profiling approach. Furthermore, the Plate Model together with the Danish and American Dietary Guidelines provided the background for the development. Three key score components were prioritized to be included in the simple HMI (1: Fruit and vegetable content, 2: Fat content and quality, and 3: Wholegrain/

potato content) with three levels of scores (0, 1 and 2). The HMI was validated against weighted and chemically analysed food and nutrient content of a representative sample of canteen meals ( $n=180$ ). The sample was split into four categories according to the total index score and compared across categories. Average energy density decreased significantly across categories (from 876 kJ/100 g to 537 kJ/100 g,  $p<0.001$ ). Also, content of total and saturated fat, carbohydrate and fruit and vegetables varied across categories with higher score values being closer to dietary guidelines ( $p<0.001$ ).

#### *Paper IV*

The effectiveness of a CTA-concept was tested under real-life conditions in a financial worksite setting offering CTA twice a week. Twenty-seven employees were included and their dietary intake on weekdays receiving CTA was compared with weekdays not receiving CTA. Four non-consecutive 24-h dietary recalls were applied to assess dietary intake on a daily basis. Moreover, a digital photographic method was used to assess evening meal intake for three consecutive weeks. Nutritional improvements were seen on days receiving CTA compared to days not receiving CTA with regard to both evening meal intake and on a daily basis. Especially, an increase of vegetable intake by about 109 g on CTA-days seems to be promising, as it is considered more difficult to increase vegetable intake compared with fruit intake.

#### *Conclusions and perspectives*

The present thesis has provided novel insight into: Digital photographic methods for assessing food intake, the development of the HMI to evaluate the nutritional quality of individual meals and finally the effectiveness of a canteen take away concept. The HMI may provide a valuable tool to caterers and dieticians who wish to evaluate nutritional quality of meals in line with the recommendations for healthy eating without the use of nutrition calculation programs. Moreover, the results from the present PhD study reinforce the importance of availability, accessibility and convenience as effective tools in promoting healthy eating habits. It provides evidence to support further action in worksites in enabling and promoting healthy eating pattern among employees even across the contexts of worksite and family. Over time, this type of dietary change program has the potential for considerable access into communities and thereby to contribute significantly to larger public health goals of reducing incidences of dietary related diseases.

## Sammendrag (Danish summary)

### *Baggrund*

Fremme af sunde kostvaner er et vigtigt element i forebyggelse af overvægt, fedme og en række kroniske sygdomme. Fra at betragte sundhed og sunde kostvaner som primært den enkeltes eget ansvar, er fokus nu i højere grad rettet mod, hvordan vi kan påvirke omgivelserne, så det bliver både nemmere og mere fristende for den enkelte at spise og leve sundt. Her har arbejdspladsen en central plads i den voksne befolkning. Arbejdspladsen kan være med til at påvirke medarbejderens kostvaner indirekte ved at påvirke normer og holdninger for sund mad og mere direkte ved at gøre den sunde mad mere tilgængelig både i arbejdstiden og uden for arbejdet. I de senere år har et nyt sundhedsfremmende tiltag i stigende grad vundet indpas – såkaldt Kantine take away (KTA) – hvor virksomheden sælger færdiglavede måltider til at bringe med hjem og spise til aftensmad til en reduceret pris eller på markedsvilkår.

### *Formål*

Det overordnede formål med dette ph.d. projekt har været at øge viden om, hvordan tilgængelighed af sund mad på arbejdspladserne kan tilskynde medarbejderne til i højere grad at træffe sunde valg både på og uden for arbejdet. De specifikke formål har været at evaluere brugen af fotometoder som værktøj til at estimere indtaget dels i forbindelse med frokostmåltiderne i arbejdspladskantinerne (artikel I) dels i relation til voksne personers aftensmåltider (artikel II), at udvikle et redskab, der kan støtte kantinepersonalet i at servere sunde måltider, herunder KTA måltider (artikel III), samt at evaluere effekten af KTA ved at sammenligne medarbejdernes indtag på hverdage henholdsvis med og uden KTA (artikel IV).

### *Artikel I og II*

To varianter af fotometoden til at måle fødevarerindtaget på arbejdspladskantiner blev evalueret og sammenlignet med vejet registrering af dobbeltportioner fra kunders frokostmåltider ( $n=100$ ). Der blev fundet høje korrelationskoefficienter mellem faktiske og estimerede vægte for begge metoder for alle fødevarer-kategorier (0,89 til 0,96). Bland Altman plots og lineær regression analyse viste, at præcisionen af estimaterne kunne forbedres ved at veje tallerkenerne i forbindelse med fotograferingen før og efter endt indtag for derigennem at få et estimat af det samlede fødevarerindtag. En tredje variant af fotometoden til måling af voksne personers indtag til aftensmåltider blev evalueret op imod vejet registrering af deltagernes sædvanlige aftensmåltider over 5 dage ( $n=88$ ). Metoden blev fundet at være valid i henhold til estimering af makronæringsstoffordeling, energidensitet og energi-justeret fødevarerindhold (korrelationskoefficienter 0,87 til 0,97). Desuden fandt deltagere, at metoden var brugbar til registrering af aftensmåltidet i tre uger eller mere (28 deltagere).

### *Artikel III*

Et simpelt Måltids-Index blev udviklet og valideret i henhold til principperne for ernæringsprofilering. Udgangspunktet for udviklingen var dels Y-tallerkenen dels de danske og amerikanske ernærings-anbefalinger. Tre komponenter blev inkluderet i indexet (1: Indhold af frugt og grønt, 2: Fedtindhold og kvalitet samt 3: Fuldkorns/kartoffelindhold) med mulighed for tildeling af point på tre niveauer (0, 1 og 2). Indexet blev valideret op imod et repræsentativt udsnit af kantinemåltider, hvor indholdet var vejjet og analyseret for næringsindhold ( $n=180$ ). Opdeling skete i fire kategorier afhængigt af den samlede indeks score og sammenlignet på tværs af kategorier. Den gennemsnitlige energitæthed faldt signifikant hen over kategorierne (fra 876 kJ/100g til 537 kJ/100 g,  $p<0,001$ ). Også indholdet af total og mættet fedt, kulhydrat og frugt og grøntsager varierede mellem kategorierne, således at højere scores gav værdier, som var tættere på de aktuelle kostråd ( $p<0,001$ ).

### *Artikel IV*

Kantine take away som sundhedsfremmende tiltag blev undersøgt i en finansiel virksomhed, der gennem nogle år havde tilbudt KTA til deres medarbejdere to gange om ugen. I alt 27 medarbejdere indgik i undersøgelsen og deres kostindtag på hverdage, hvor de modtog KTA, blev sammenlignet med kostindtaget på hverdage, hvor de ikke modtog KTA. Fire gange 24 timers kostinterview blev anvendt til at vurdere kostindtag på daglig basis. Desuden blev fotometoden anvendt til at vurdere aftensmandens næringsstofindhold over tre uger. Maden på dage med KTA havde en bedre ernæringsmæssig sammensætning end maden på dage uden KTA både med hensyn til aftensmadens indhold samt madens indhold set over den samlede dag. Især en forskel i indtaget af grøntsager på gennemsnitlig 109 g per dag synes at være lovende, da det anses for vanskeligere at øge grøntsagsindtaget sammenlignet med frugtindtag.

### *Konklusioner og perspektiver*

Ph.d. afhandlingen giver ny viden inden for tre forskellige forskningsområder: Fotometoder til vurdering af fødevarer- og næringsindtagelse, udvikling af et måltids-index til vurdering af den ernæringsmæssige kvalitet af enkelte måltider samt effekten af et Kantine take away koncept i relation til medarbejdernes indtag. HMI kan potentielt bruges både af professionelle, f.eks. cateringfirmaer og diætister, og den brede offentlighed, der ønsker at vurdere den ernæringsmæssige kvalitet af måltider i tråd med anbefalingerne for sund kost uden brug af programmer til ernærings-beregning. Resultaterne fra afhandlingen støtter derudover betydningen af tilgængelighed som et effektivt tiltag i forhold til fremme af sunde madvaner. Sund Kantine take away kan med fordel indgå som element i en samlet sundhedsfremme strategi på arbejdspladserne. Yderligere forskning bør fokusere på innovative strategier der tager afsæt i at øge tilgængeligheden af sund mad og samtidig styrke den sociale opbakning, herunder i familien, således at den enkeltes mulighed for at etablere sunde kostvaner styrkes.

# 1. Background

## 1.1. Dietary recommendations and food choice influences

### *Dietary intake and recommendations*

Eating a healthy balanced diet and maintaining an active lifestyle throughout infancy and adulthood are considered key elements for the prevention of overweight, obesity and several chronic diseases (WHO, 2003). However, the populations in Denmark and other Western countries generally do not meet the dietary guidelines. It has been argued that even small beneficial changes in food intake at the population level, maintained over a longer period of time could have a large impact on public health (Steyn *et al.*, 2009).

Table 1.1 outlines population nutrient goals proposed by the Institute of Medicine (Institute of Medicine, 2005; Institute of Medicine, 2004) and the Nordic Council of Ministers (Nordic Council of Ministers, 2004a), respectively, together with data on the average diet consumed by the adult Danish population (Petersen *et al.*, 2010). Compared to the official recommendations for dietary intake the average diet of the adult Danish population contains too much sugar, salt and fat, especially saturated fat (Petersen *et al.*, 2010). The average diet of the adult Danish population provides 35% energy from fat (15 E% from saturated fat), when the contribution from alcohol is excluded from the calculations, whereas the population goal recommended by the Nordic Nutrition Recommendations 2004 is 30% energy (10 E% from saturated plus trans fatty acids). Furthermore, the content of dietary fibre is too low compared to the recommended intake of 25 to 35 g a day.

**Table 1.1.** Population nutrient goals for adults in United States and the Nordic countries compared with the actual diet of the Danish population

Nutrients	United States <sup>1</sup>	Nordic countries <sup>2</sup>	Average diet of the adult Danish population 2003-2008 <sup>3</sup>
Total fat (E%)	20-35	25-35 (30)	35 <sup>4</sup>
Saturated fat (E%)	As low as possible	<10	15 <sup>4</sup>
Protein (E%)	10-35	10-20 (15)	15
Total carbohydrate (E%)	45-65	50-60 (55)	50
Added sugars (E%)	≤25	0-10 (<10)	10
Dietary fibre (g/day)	25-38	25-35	21
Sodium chloride (g/day)	< 6	< 5-6	8.5 <sup>5</sup>

<sup>1</sup> Dietary Reference Intakes (Institute of Medicine, 2005; Institute of Medicine, 2004), <sup>2</sup> Nordic Nutrition Recommendations (Nordic Council of Ministers, 2004a); figures in brackets are population goals, <sup>3</sup> (Petersen *et al.*, 2010), <sup>4</sup> Calculated without energy from alcohol, <sup>5</sup> Salt added at the table is not included

The dietary guidelines represent the translation of the nutrient recommendations for food intake into dietary advice aimed at the general population or specific population groups. In 2005, the 6<sup>th</sup> edition of the Dietary Guidelines for Americans was released (US Department of Health and Human Services, 2005), and MyPyramid, shown in Figure 1.1, was developed and issued by the United States Department of Agriculture (USDA) to illustrate recommendations found in the guidelines. At the reference 10 MJ level (2400 cal) 5 cup equivalents of fruit and vegetables is recommended and 8 ounce equivalent of grains, including 4 ounce equivalent of whole grains<sup>1,2</sup>. Also, in 2005 the dietary guidelines for overall healthy dietary patterns communicated to the population in Denmark was published. The principles of the Danish Dietary Guidelines apply to all healthy people over the age of 2 years and include eight key messages (Astrup *et al.*, 2005). The Danish Food Compass shown in Figure 1.1 communicates these guidelines. Moreover, Danish Canteen Nutrition Guidelines (in Danish: <http://www.altomkost.dk>) have been released based on the Danish Dietary Guidelines.

With regard to fruit and vegetables, the Danish Dietary Guidelines recommend a daily intake of 600 g equalling 3 servings of vegetables and 3 servings of fruits per day. The actual average daily intake of vegetables is 162 g for the Danes aged 18-75 years. The intake of vegetables seems to have stagnated from 2000-2002 to 2003-2008 whereas the intake of fruit has increased. The estimated average intake of fruit and juice is 283 g a day for the Danes aged 18-75 years. With regard to wholegrain intake it is estimated that Danes eat approximately half of the recommended intake of minimum 75 g wholegrain per 10 MJ (Mejborn *et al.*, 2008)<sup>3</sup>.

The dietary guidelines communicated to the population in United States and Denmark are generally in good agreement. Guidelines include key messages aimed at *increasing the population's intake of fruit and vegetables and fish, eating whole grains (and potatoes) and limiting the intake of sugar-rich foods and fat, especially animal fat*, and to incorporate physical activity into a healthy eating plan. Moreover, the Danish dietary guidelines for canteens emphasise the need for reducing the salt intake of canteen food, as salt content in canteen meals has been found to be high – on average 3.5 g per meal equivalent to 15 g per 10 MJ (Rasmussen *et al.*, 2010).

Another pictorial model, the Plate Model, originally promoted by the Swedish Diabetic Association, has the advantage of being simple and easy to employ. It has been found to be the preferred educational nutrition model by both professionals and the public (Hunt *et al.*, 1994), and meal components may be selected to match a range of different meal types and preferences. Figure 1.1 c illustrates a plate following the Nordic version of the Plate Model. The plate is divided into three sections (like a 'Y'). The smallest sector, about one-fifth of the total area is for meat, fish, eggs or cheese (and fats). The remaining four-fifth is divided

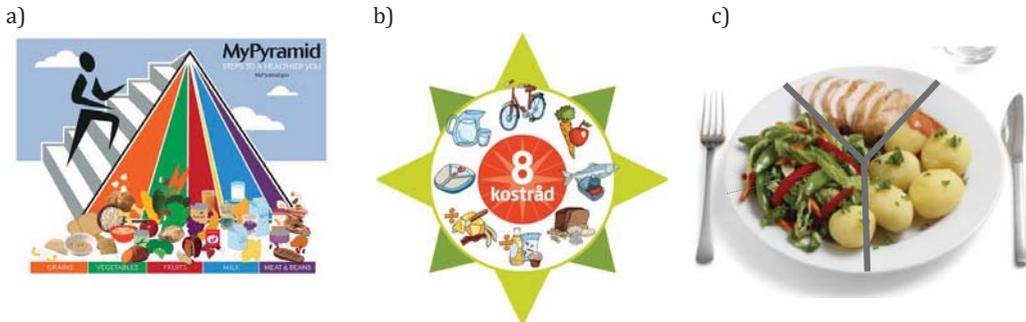
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<sup>1</sup> 1 cup equivalent fruit and vegetables is 2 cups raw leafy vegetables or 1 cup other raw or cooked fruits and vegetables (corresponding to about 150 g). 1 ounce equivalent grain is ½ cup cooked rice/pasta or 1 slice bread (corresponding to about 50 to 75 g).

<sup>2</sup> Intake amounts in the USDA Food Patterns encompassed by the 2010 Dietary Guidelines Advisory Committee remain unchanged from 2005 with the exception of the vegetable subgroups (2010 DGAC Membership, 2010).

<sup>3</sup> 75 g wholegrain corresponds to almost 250 g wholegrain foods, e.g. cooked wholegrain pasta/ rice or wholegrain bread. Calculated from Mejborn *et al.* (Mejborn *et al.*, 2008).

approximately equally with two-fifth for the staple food (rice, pasta, bread, potatoes etc) and two-fifth for fruit and vegetables.



**Figure 1.1.** The American MyPyramid (a) and the Danish Food Compass (b) illustrating the food and dietary guidelines of the respective countries and the Plate model (c) illustrating recommended proportion of foods

### ***Food choice influences***

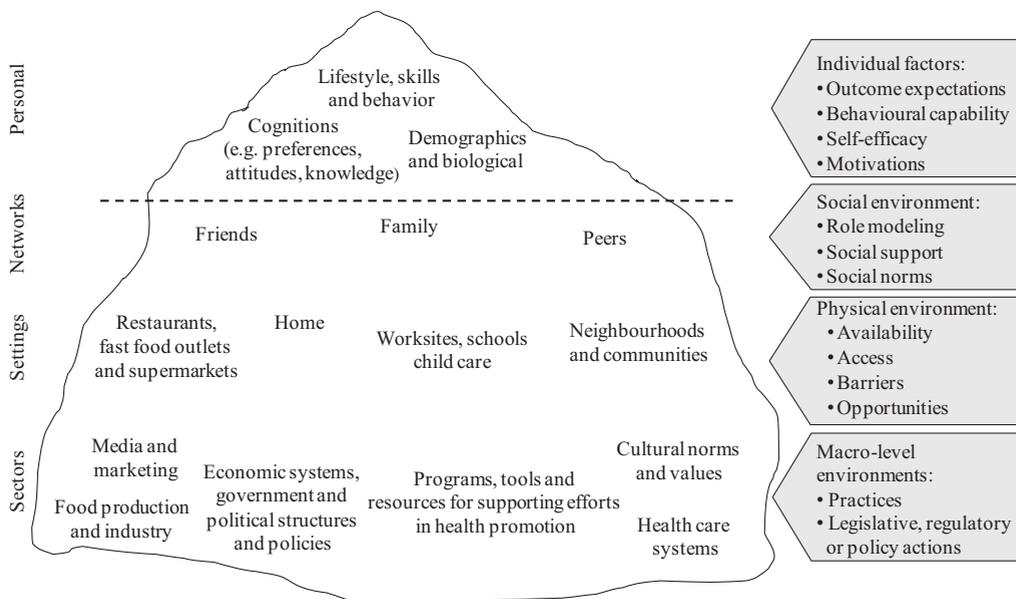
What and how much we choose to eat is influenced by a complex, interrelated set of factors across different levels extending from the individual to the broader macro-level environments. Figure 1.2 shows the range of factors using an iceberg as a metaphor analogy to illustrate that the individual factors depicted above the waterline most likely account for only a smaller part of the total range of factors influencing food choice and behaviour.

Individual level factors include demographic and biological factors as well as characteristics such as preferences, attitudes and knowledge, skills and behaviours (Story *et al.*, 2008). Also, lifestyle factors including habits and lack of time to prepare healthy meals are frequently reported individual level barriers for not following nutritional recommendations, especially for those who intend to eat healthily but do not do so (Groth *et al.*, 2009). Accordingly, Blanck *et al.* (Blanck *et al.*, 2009) found convenience followed by taste, cost and finally health to be the most important factor for lunch food choices among U.S. adults working outside home. Education and behavioural intervention strategies strongly focus on individual level factors to increase likelihood of conscious behaviour change towards more healthy diets (Brug *et al.*, 2006), and there is good evidence that individual counselling may promote moderate positive changes in the dietary intake of individuals with a high risk of disease (Research Centre for Prevention and Health, 2010). The long term effect is however unclear, and both Holsten (Holsten, 2009) and Brown and colleagues (Brown *et al.*, 2007) conclude that interventions targeting individual activity and dietary behaviours generally have had limited effectiveness. Powerful and repeated mass campaigns seem to have some effect on the dietary intake in the population but need to be combined with other strategies to be effective (Research Centre for Prevention and Health, 2010).

Below the waterline are the factors in the environment related to eating behaviours. First proposed by McLeroy and colleagues (1988), the social ecological models aim to focus on both individual and environmental level components in health promotion interventions. It emphasizes that individuals interact with their environments and that characteristics of the environment influence their health behaviours (Giskes *et al.*, 2010). It has been suggested that it may be difficult to prioritize good nutrition in the context of contemporary lifestyles that include increased time spent outside home (Welch *et al.*, 2009). This perspective shifts the focus of behaviour change from the individual to the social and physical environment in which the individual lives (Dorfman *et al.*, 2007; Elinder *et al.*, 2009; WHO Regional Office for Europe, 2007). The social environment includes interaction with family, friends, peers and others in the community and may impact food choices through mechanisms such as role modelling, social support and social norms (Story *et al.*, 2008).

The physical environment includes the settings where people buy foods, produce and eat foods and meals such as home, worksites, schools, supermarkets and restaurants (Story *et al.*, 2008). These settings may influence food choices both through the availability and accessibility of healthy foods and by affecting opportunities and barriers for healthy eating. There is a wide variety of factors in the physical environment that may encourage a positive energy balance, sometimes labelled as the 'obesogenic environment' (Elinder *et al.*, 2009). The intake of fast foods, convenience or ready-prepared foods has been associated with less healthful diets (Jabs *et al.*, 2006), and energy-dense products are increasingly marketed in large portions, that 'unnoticed' tempt us to eat more (Matthiessen *et al.*, 2003). For example busy parents may rely on convenience foods, prepared foods, or eating take out or restaurant food, all of which are associated with higher calorie density (Kumanyika *et al.*, 2008). Continuous efforts towards the physical food environment are therefore greatly needed.

Story and colleagues (Story *et al.*, 2009) suggest that the more restricted the physical environment is with regard to availability and accessibility of healthy inexpensive options, the more influence the environment may have with regard to food choices that are made – in contrast to that of the individual factors and social influence. However, the communities and settings need to be empowered to enable them to build their capacity to develop and sustain improvements in their social and physical environments. The macro-environment includes the broader infrastructure that may support or hinder health behaviours among individuals and in the different settings (Brug *et al.*, 2006). It employs a wide range of sectors such as the food production, manufacturing and media as well as food and agriculture policies, economics and health care systems. Moreover, it includes culture-specific eating patterns and tools and resources to use for health promotion (Goetzal *et al.*, 2008). Finally, ongoing research may offer new solutions and knowledge in relation to health promotion.



**Figure 1.2.** A 'Healthy eating promotion iceberg' illustrating from an ecological approach the multiple influences on what people eat as well as the possible mechanism for food choice influences (right charts). Modified from Story *et al.* (Story *et al.*, 2008)

**Summary: Dietary recommendations and food choice influences**

The actual behaviour of consumers in relation to food choice and intake is obviously in mismatch with nutrient recommendations and dietary guidelines. To support improvements in dietary intakes, we need to know more about the determinants of food behaviour and choices. Focus has shifted from considering food behaviour, obesity and health as mainly a private issue to recognizing the responsibility of the society in creating environments and conditions that support and promote population-wide healthy eating habits.

## 1.2. The worksite arena

### *Calls for action to be taken at the worksites*

The potential of the worksites for promoting healthy eating has received increasing attention in recent years and several policy papers call for action to be taken at the worksites (European Commission, 2007; Nordic Council of Ministers, 2006). Also many companies are showing interest in investing in health promoting activities to protect and develop their human resources (Heinen *et al.*, 2009). The worksites provide a natural social context. Most employees eat one or more meals during the workday and it has the potential to reach a large number of people, including many who would otherwise be unlikely to engage in preventive health behaviour. Besides improving dietary intake at work, worksite interventions may also lead to secondary improvements in lifestyles of employees and their families outside of the worksite (Ni Mhurchu *et al.*, 2010) and may in the long term influence social norms around food choice and psychical activity.

The Nordic Council of Ministers adopted in 2006 a Nordic Plan of Action on better health and quality of life through diet and physical activity (Nordic Council of Ministers, 2006). This plan highlights the worksite as an important setting for promoting a healthy lifestyle, both among employees and in society as a whole: “In the coming years, the Nordic countries will give priority to initiatives directed at inspiring workplaces to invest in initiatives to promote a healthy diet and physical activity among their employees”.

One year later the Second WHO European Action Plan for Food and Nutrition Policy 2007–2012 (WHO Regional Office for Europe, 2007) was adopted stating that: “Actions should be designed at both national and local levels, with particular attention paid to community interventions and the health-promoting potential of arenas or settings such as [...] workplaces”.

Moreover, the WHO’s Global Plan of Action for Workers’ Health 2008–2017, states in Point 14 that: “Health promotion and prevention of noncommunicable diseases should be further stimulated in the workplace, in particular by advocating healthy diet and physical activity among workers, and promoting mental and family health at work” (WHO, 2007).

### *An overview of the effectiveness of worksite healthy eating initiatives on dietary outcomes*

Soler *et al.* (Soler *et al.*, 2010) evaluated the effectiveness of interventions in worksites that included health-risk assessment with feedback to employees either alone or as part of a broader worksite health promotion program. With regard to dietary behaviours the authors concluded that the body of evidence from a total of 11 studies was generally positive, however the magnitudes for the effect estimates were small. Thorogood and colleagues (Thorogood *et al.*, 2007) likewise found small effect size when summarizing the results of eight randomized controlled worksite trials on changes in fruit and vegetable consumption in a meta-analysis. The increase in consumption of fruit and vegetables was close to 0.2 servings per day. Buttriss and colleagues (Buttriss *et al.*, 2004) drew special attention to one of these studies, the Treatwell 5-a-Day Study, showing that involving family members could be a promising

strategy to increase fruit and vegetable intake (Sorensen *et al.*, 1999) with potential benefits for the whole family (Brekke *et al.*, 2004). In terms of reduction of fat intake, two of the largest worksite intervention evaluations, the Working Well Trial (Sorensen *et al.*, 1996) and the Next Stop Trial (Tilley *et al.*, 1999) reported a net reduction in percentage of energy obtained from fat of 0.4 and 1 percentage, respectively (Thorogood *et al.*, 2007).

Mhurchu *et al.* (Ni Mhurchu *et al.*, 2010) included in a review 16 health promotion studies with dietary outcomes. They suggested based on the review that future programmes to improve employee dietary habits should move beyond individual education and aim to intervene at multiple levels of the worksite environment. Other authors likewise have argued that environmental strategies should at least be incorporated in traditional worksite health promotion programs to achieve greater behavioural changes and to reach a wider audience (Engbers *et al.*, 2006; Institute of Preventive Medicine Environmental and Occupational Health, 2008). Elinder and Jansson (Elinder *et al.*, 2009) points out that establishing causal relationships between environmental factors and population diet or obesity pose great challenges because randomised controlled trials are not always possible or feasible to conduct and because the dynamic interactions between individual and societal levels complicate the interpretation of results. Moreover, more reliable indicators of environmental determinants are needed in order to explore the interactions between the environmental factors and individual eating pattern.

### ***Effectiveness of worksite healthy eating initiatives targeting the physical environment***

The worksites have a wide range of possibilities to increase the availability and accessibility of healthy food at the worksite, e.g. provide free fresh fruit, offer healthy food and beverages at the canteen, at meetings and vending machines, organize employees healthy lunch clubs and breaking structural barriers for healthy eating (providing staff refrigerator and microwaves in kitchens etc.).

Table 1.2. and Table 1.3 summarize peer-reviewed English language articles since 1994 on worksite intervention studies in healthy populations focussing on changes in the physical food environment alone or as part of multi-component intervention strategies <sup>4</sup>. Only studies with output data related to the environmental intervention component are included. Eight studies were identified that included data on changes in dietary intake measured or calculated per employee (Table 1.2). Moreover, six studies were identified that included relative changes in sales data (Table 1.3).

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<sup>4</sup> *Literature search strategy:* The following electronic databases were searched up to august 2010: DADL, Web of Science and MEDLINE using the following search terms: worksite, workplace, occupational health, diet, nutrition policy, food services, cafeteria(s). Besides, the reference lists of relevant studies and review articles were searched by hand.

**Table 1.2.** Studies reporting changes in dietary intake in relation to the environmental intervention component in worksite intervention studies targeting the food environment alone or as part of a multi-component intervention strategy

Study, author and country	Study design	Measurement method (environmental component)	Intervention effect: Changes in dietary intake (environmental component)
(Dubois <i>et al.</i> , 1996)	Non-randomised intervention study at 1 intervention and 2 control worksite canteens. Increased availability of foods lower in fat	24-hour dietary recalls of 160 employees at pretest and 93 at posttest	+3 percentage of energy obtained from saturated fat for regular clients at the intervention cafeteria (p<0.05). No changes were found in the control group
Seattle 5 a Day Worksite Program (Beresford <i>et al.</i> , 2001) United States	Randomised intervention study at 14 intervention and 14 control worksites all with canteens. Multi-component intervention, targeting both individual and environment levels	Plate observations of canteen meal selections at one lunch hour at each site.	+0.4 servings fruit and vegetables per lunch meal served in the intervention worksites and +0.2 at the control worksites. No significant differences between groups.
(Steenhuis <i>et al.</i> , 2004b; Steenhuis <i>et al.</i> , 2004a) The Netherlands	Randomised intervention study at 17 worksite canteens. One control group and three intervention conditions: 1) education only, 2) education and healthy food supply in six product categories and 3) education and labelling	Food Frequency Questionnaire among 621 regular visitors and sales data for targeted products	No significant effects on intake data for any of the conditions. Regarding sales data only the labelling on desserts showed a significant effect
Heartbeat award (HBA) (Holdsworth <i>et al.</i> , 2004) England	Non-randomised intervention study at 4 intervention and 2 control worksite canteens (sites applying for but not receiving the award). Change menus to >1/3 healthy choices	Food Frequency Questionnaire among 577 employees (lunch)	Positive changes were found in four out of 20 foods consumed by employees in HBA-holding premises: Increase in consumption of fruit, reduction in consumption of fried foods and sweet puddings and change to lower fat milks

The 6 a Day Canteen Study (Lassen <i>et al.</i> , 2004; Thorsen <i>et al.</i> , 2010) Denmark	Intervention study at 5 worksite canteens. Increased availability of canteen fruit and vegetables based on participatory approach and goal setting	Weighing of all fruit and vegetable consumed at the canteens and customer counting for three weeks	+95 g fruit and vegetables consumed per lunch meal. Significant increases in all 5 worksites. The effect size was sustained 5 y after the intervention in 4 of the worksites (p<0.001)
Food at Work (Lassen <i>et al.</i> , 2010) Denmark	Randomised intervention study at 5 intervention (3 with canteens) and 3 control worksites (2 with canteens). Multi-component intervention targeting both individual and environment levels based on a participatory approach and goal setting	Chemical analysis of canteen customers duplicate plates at two different days at each site (144 plates)	-11 percentage of energy obtained from fat in lunch meals consumed at the intervention worksites with canteens (p<0.001). No significant changes were found in the control group
(Lowe <i>et al.</i> , 2010) United States	Intervention study at 2 worksite canteens and randomly assignment of participants into one of the two intervention conditions: 1) 10 new low-energy-density foods and labelling. 2) plus education and pricing incentives	Cash register to quantify 96 regular canteen customers lunch purchases	Percentage of energy from fat in purchased lunches showed a main effect during the intervention period (from 45E% to 39E%). Changes in both conditions were similar
ISAFRUIT project (Alinia <i>et al.</i> , 2010) Denmark	Non-randomised intervention study at 5 intervention and 3 control worksites. Providing a daily piece of free fruit at work	Two times 24-hour dietary recalls of 124 employees	+112 g fruit and vegetables consumed per employee on a daily basis in the intervention group (p=0.002). No significant changes were found in the control group

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**Table 1.3.** Studies with output measures on relative changes in sale figures in worksite intervention studies targeting the food environment alone or as part of a multi-component intervention strategy

Study, author and country	Design and intervention	Measurement method (environmental component)	Intervention effect: Changes in sale figures (environmental component)
(Jeffery <i>et al.</i> , 1994) United States	Intervention study at one worksite canteen. Increased variety and reduced price of fruit and salad	Canteen cash register receipts	Fruit and salad purchases increased threefold in the intervention period
(Levin, 1996) United States	Non-randomised intervention study at one worksite and one control worksite canteen. A heart symbol next to three low-fat entrées	Canteen sales analysis	Increased sales of targeted low-fat entrees at the experimental cafeteria. No change in sales at control site.
(Perlmutter <i>et al.</i> , 1997) United States	Intervention study at one worksite canteen (5 phases). Modification of entrees to include less sodium and fat and marketing of modified entrees	Canteen sales analysis	No significant differences in sales figures for the modified dishes
(French <i>et al.</i> , 1997) United States	Nine vending machines at four locations. Three time periods. 50% price reduction on low-fat snack options	Sales analysis on vending machines	The percentage of low-fat snacks sold increased about 80% during the low-price intervention from 26% to 46% of total sales.
The CHIPS study (French <i>et al.</i> , 2001a) United States	Intervention study at 12 worksites and 12 secondary schools. Sites were assigned randomized sequence of treatment conditions. Price reduction on low-fat snack options from vending machines	Sales analysis on vending machines	Increases in low-fat snack sales by 9%, 39%, and 93% at price reductions of 10%, 25%, and 50% respectively. Promotional signage was weakly associated with increases in low-fat snack sales.
(French <i>et al.</i> , 2010) United States	Non-randomised intervention study at two intervention and two control worksites (bus garages). Increased availability and price reduction of healthy items from vending machines	Sales analysis of healthy items on vending machines	Increasing availability by 50% and reducing price by averagely 31% resulted in 10% to 42% higher sales of the healthy items

The methodologies used in the studies vary widely, and there seems to be a number of shortcomings both with regard to study design (e.g. no control group), intervention description and implementation (e.g. not tailored to the specific worksite) and the measurement method used (e.g. collection of data from one day only despite large day-to-day variation in canteen offering). Yet, the outcomes from the studies suggest some promising results in influencing employees to consume more healthy foods. This includes studies focussing on *increasing the accessibility of healthy choices*. Both the 6 a Day Canteen Study and the Food at Work used participatory approach and goal setting to motivate canteen staff to increase healthy food options as well as reducing the availability of more unhealthy foods. The 6 a Day Canteen Study focusing specifically on fruit and vegetable consumption in five selected worksite canteens in Denmark, showed significant increases in the total consumption of fruits and vegetables for all worksite canteens from baseline to short-term follow-up; 95 g per customer on average per meal corresponding to 1 serving. A long-term follow-up data collection 5 years after the beginning of the intervention (Thorsen *et al.*, 2010) revealed that four out of five worksite canteens were able to either maintain the results of the intervention or even increase the fruit and vegetable consumption. The Seattle 5 a Day Worksite Program likewise focusing on changes in fruit and vegetable consumption in a wide range of worksite types all with cafeterias revealed an average increase of 0.4 servings in the intervention worksites from plate observation at cafeteria checkout lines (Beresford *et al.*, 2001).

In the Food at Work study a favourable change in the nutritional composition of the meals was demonstrated, showing a median fat reduction of 11 E% of the lunch selected by the employees in the intervention group (Lassen *et al.*, 2010). There was no change in neither energy intake nor fruit and vegetable content during intervention. Duboi *et al.* (Dubois *et al.*, 1996) found significant reduction of saturated fat of 3 E% among regular clients at the intervention worksite based on 24-hour dietary recalls. A range of changes in availability was applied, including modified recipes, increased availability of lower-fat dairy and meat products, decreased portion sizes and using unsaturated fats for sauces, salad dressings and cooking. Lowe *et al.* (Lowe *et al.*, 2010) found that introduction of 10 new low-energy density foods, providing nutrition label and financial discounts for purchasing low-energy density food items was associated with decreased energy from fat in the purchased lunches. On the other hand the study by Steenhuis *et al.* (Steenhuis *et al.*, 2004b) based on changes in six product categories showed no significant effects on intake data.

*Food pricing* has been suggested to be an effective tool to affect food choices, and large effects of price reduction on sales of fresh fruits and vegetables at a worksite canteen have been demonstrated (Jeffery *et al.*, 1994). This is in line with a study comparing nutritional intake among customers having lunch at worksite canteens serving buffet style with those having lunch at canteens with à la carte style serving, i.e. worksite canteens with a fixed price for a varied number of dishes. On average, employees having lunch at buffet style canteens consumed 76 g more fruit and vegetables per lunch than those having an à la carte lunch (Lassen *et al.*, 2007b). Thus, more customers were encouraged to combine different options, including salad, fruits and snack vegetables, when these options were included in the buffet price.

Price reduction as well as increased availability of healthy options at *vending machines* was also found to increase sale of healthy items in three studies by French and colleagues (French *et al.*, 2001a; French *et al.*,

2010; French *et al.*, 2001b; French *et al.*, 1997). Employees were mostly price responsive for snack purchases (French *et al.*, 2010).

Worksite *fruit programs* where employees receive a free piece of fruit every working day have been shown to be another effective approach in increasing employees' daily fruit intake; 112 g on average per day compared to baseline in the intervention group. No significant difference in intake was seen in the control group. In Denmark worksite fruit programs have gained increasing popularity, and in 2008 a questionnaire among 1800 Danish companies revealed that close to half of the companies had a fruit program (Sundhedsstyrelsen, 2008). This is a fine example of how a fairly simple health promotion approach aiming at providing fruit at breaks can result in significant changes in employees' daily intake.

Other studies have been less positive in outcome. This include studies promoting 'healthier' menu items through *nutrition labelling and/or health education* (Stubenitsky *et al.*, 2000; University of Crete School of Medicine, 2000). Although some positive effects have been shown, providing nutritional information to consumers at the point of purchase does not have strong research support (French *et al.*, 2001a; Steenhuis *et al.*, 2004b). Levin (Levin, 1996) however found an increase in low-fat entrees labelled with heart symbols.

Providing healthy *Canteen Take Away* is a more recent worksite initiative that seems to be growing in popularity in the Western countries (Wanjek, 2005). However, to our knowledge the effectiveness of this health promoting concept in improving employees' dietary habits has not been described in the scientific literature until now. Possible nutritional health benefits may include improvement of the nutritional quality of the diet of employees and their families directly by provision of healthy meals that may substitute less healthy meals, including other types of ready meals and fast-food (Jeffery *et al.*, 2006) and in the long term influence the norms for healthy eating (Winston *et al.*, 2008). From the perspective of the employee another important argument for supplying CTA meals is a way of tackling the work-family conflict (Roos *et al.*, 2007). CTA meals may reduce the time needed for shopping, cooking and cleaning at home thereby supporting the employees in their daily life to balance work demands with personal and family commitments (Carnethon *et al.*, 2009).

### ***Implementation of healthy eating initiatives at worksites***

The successful implementation of health promotion initiatives depends on the enthusiasm of many stakeholders at the worksites who have the power to contribute to, or hamper an implementation of the initiatives. Thorsen stresses that in order to be successful the health promotion initiatives need to be tailored to local cultural and dietary realities of the particular worksite environment in which it is implemented (Thorsen *et al.*, 2010). Other important conditions that may increase sustainable worksite healthy promotion initiatives are anchoring the initiatives at both top and bottom levels of a worksites organisation. This includes linking the initiatives to organizational objectives, support from top management, stakeholders' participation, motivation and ownership in all phases of the program development and implementation (Larsen *et al.*, 2008; Lassen *et al.*, 2007a).

At the 'bottom' level the canteen staff is often those most directly involved in implementing the programmes. It is well recognized that improving the nutritional quality of food served can be challenging, and efforts to change the food selection and content may be met with resistance by both the canteen staff and the customers (Glanz *et al.*, 2007; Pope *et al.*, 1995; Steenhuis *et al.*, 2004a). In order to support the ongoing progress towards healthier menu meals, key actors including food service professionals need to be motivated and prepared to implement the program. The development of an assessment tool directed at the worksite canteens would be valuable for providing self-evaluation and setting targets for the work.

Moreover getting a positive attitude among employees is crucial. Obstacles in relation to the promotion of healthy eating may include a range of structural barriers, for example time to participate, production conflicts and shift work (Sorensen *et al.*, 2004; Wandel *et al.*, 2005), as well as aspects like resistance to breaking old habits, a perception that wellness programs are contrary to their work culture (the 'macho' factor) or scepticism about management's commitment to improve worker's health (Canadian Labour and Business Centre, 2003; Roos *et al.*, 2001). Additionally, many people perceive food intake and their overall health as a personal issue (Steptoe *et al.*, 2004; Taylor *et al.*, 2004). Nevertheless, it has been shown that under given conditions, employees at both white and blue-collar worksites have a positive attitude towards the worksite promoting and implementing healthy eating at the worksites (Lassen *et al.*, 2007a). The use of participatory strategies is important to assure that programs are responsive to employees' needs and priorities. Participation (involvement) is mentioned as one of the most important principles of the health promotion concept of WHO (Chu *et al.*, 1994). Employees and others are requested to participate in the development, implementation and evaluation of health promotion programs directly affecting their living and working conditions.

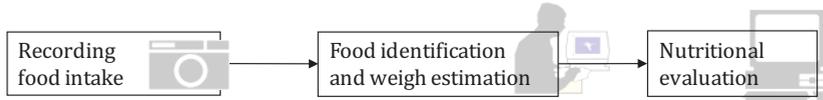
### ***Summary: The worksite arena***

The potential of the worksites for promoting healthy eating among the adult working population has received increasing attention in recent years. Research does not provide definitive guidance toward the optimal work-site strategies for promoting healthy eating. Very promising, however, seems to be studies aimed at increasing the availability and accessibility of healthy food at the worksite either in conjunction with individually directed educational programs or as stand-alone interventions. Importantly, initiatives need to be tailored to the needs of the particular worksite environment in which it is implemented. Also price strategies have shown to be effective in influencing eating behaviours. Health promoting initiatives across the settings of the worksite and home environments provide another opportunity for enabling and promoting healthy eating pattern. More research is warranted on solution-oriented, real-life setting research that also takes into consideration the motivation and empowerment of the stakeholders in the environments to provide sustainable improvements in dietary intakes in the population as a whole.

### 1.3. Digital methods for dietary assessment

Achieving accuracy and precision in assessing dietary intakes is always a challenge. There is no 'one-size-fits-all' dietary assessment tool appropriate for all research conditions, and there is always a trade-off with the choice of any diet assessment methodology. Several methods are available that possess both strengths and limitations. The choice of method will ultimately be influenced by several factors including response rates, accuracy and costs. Traditional methods for assessing dietary intake such as 24-hour dietary recalls, diet records and food frequency questionnaires depend largely on the participants' memory and/or ability to estimate portion sizes. Weighed records are often regarded as a 'gold standard' method for individual level dietary assessment, but this method is time-consuming and demanding for the participants (Gibson, 2005). Also, meal observations are considered a reliable method for collecting dietary intake data, but there are limits regarding the number of observers who can be included and trained, and the number of persons who can be observed simultaneously (Burgess-Champoux *et al.*, 2008).

In recent years new applications of digital technologies, including photographs and visual imaging, to capture dietary behaviour in real-time have been explored. Different digital methods are examined in order to improve estimation precision and refine the method for use in various settings with various purposes. A schematic illustration of the different steps in the digital method is given in Figure 1.2.



**Figure 1.2.** A schematic illustration of the different steps in the digital method

Depending on the specific context and the target group the *recording* of the actual food intake can be accomplished by a research team or by the participants themselves. Recording involves both taking the images of the food before and after consumption of the meals and getting information on product types, recipes etc. Different camera technologies have been used including both disposable cameras and mobile phones or personal digital assistants with camera. Next step involves *food identification and portion size estimation* of the recorded foods, which so far mostly have been done by human labour on basis of either specific reference meals or a general reference data base. Finally, data collected on weight estimates need to be further converted to measures of *nutritional quality*. This can be done by simple counts of food servings as suggested by Swanson (Swanson, 2008) or by using a food based index or food checklists as done by Mitchell *et al.* (Mitchell *et al.*, 2009). Other studies have coupled the estimated food intake weights to nutrient databases (Higgins *et al.*, 2009; Small *et al.*, 2009).

#### **Digital methods for assessing food intake away from home**

The use of digital photographic technologies have been used in various out-of-home facilities including laboratory facilities (Martin *et al.*, 2009; Williamson *et al.*, 2003) and dining facilities at universities (Williamson *et al.*, 2004), nursing homes (Simmons *et al.*, 2000) and elementary schools (Martin *et al.*,

2007; Mitchell *et al.*, 2009; Swanson, 2008). The advantages of using the digital method are that it captures images in real-time and does not rely on participants' literacy, motivation or ability to recall portion size. Also, when using the digital method in canteen settings the food and the nutrient intake data can be collected from a large group with minor interaction with the participants, thereby decreasing response burden. This may be especially important when carrying out studies in workplaces, where the study population can be expected to have little time to devote to assessment due to job demands etc. (Glasgow *et al.*, 1996). The digital method could thereby be useful for research on evaluating the impact of different intervention programs and experiments to improve understanding of food environments and their impact on dietary behaviours (Mitchell *et al.*, 2009; Story *et al.*, 2009).

The methodology generally involves taking images of participants' food selection and plate waste by a research team using a standardized procedure. Reference dishes from the dining facility with known weights of individual foods within the meals can be used to estimate the weights of participants' individual food intake.

Swanson and colleagues (2008) demonstrated the utility of a digital method at two elementary schools over two days serving 6-7 different meal options each day. Each food tray was reported to take less than 5 seconds to set up and photograph (Swanson, 2008), thereby causing minimum disruption to the participant's normal behaviour and respondent burden. Mitchell and colleagues evaluated the School Food Checklist based on digital analysis, and found it to be a reliable method for measuring the food contained in children's packed lunches in five school settings (Mitchell *et al.*, 2009). Finally, Williamson and colleagues found the digital method to be valid when compared to weighed measures of six different test menus (Williamson *et al.*, 2003). They also demonstrated the validity of a digital method by comparing it to direct visual estimation of food consumption among college students in a single cafeteria setting on one day (Williamson *et al.*, 2004).

To our knowledge, none of the published studies use the digital method at workplace canteens offering greater variety of menu options, including buffet meal options. Neither have any of the published studies evaluated the possibility of improving the estimation precision of the digital method by weighing the participants' plates before and after consumption of the meals to get the total weights of the food consumed. The weighing can be done easily and quickly with practically no extra burden to the participants.

### ***Digital methods for assessing food intake among free-living individuals***

With regard to assessing the food intake of free-living individuals several issues complicate the usability of the digital method. First, it requires that the participants take images themselves thereby introducing greater participant burden and potentially lower photo quality and compliance, which may also lead to increased estimation errors. Second, it is not possible to take images of reference dishes directly related to the food eaten and the dinner services used. Instead, a database with reference images of commonly eaten foods on standardized plates etc. must be applied which may increase estimation error. Especially estimation of the beverages served in non-transparent drinking glasses may be problematic.

Nevertheless, recent validation studies have shown promising results among both children (Higgins *et al.*, 2009; Small *et al.*, 2009) and adults (Kikunaga *et al.*, 2007; Martin *et al.*, 2009) using different camera technologies including both disposable cameras and mobile phones or personal digital assistants with camera. Kikunaga and colleagues (Kikunaga *et al.*, 2007) compared a handheld digital assistant with camera and mobile phone with weighed diet record as the reference method among college students, and found median nutrient intakes to be comparable. Martin and colleagues (Martin *et al.*, 2009) tested the digital method using a camera-enabled cell phone for total energy estimation among a free-living adult population receiving pre-weighed evening meals to eat at home. Results indicated that the digital method produced reliable estimates of energy intake of the dinner meals. However, as the food was provided by the researchers the variety of meals was limited and not necessarily representative of the habitual diet.

The digital method used among free-living individuals may have a broad range of applications including studies that require a long recording period. Multiple days of recording may be required to capture individuals' usual intake under free-living conditions as day-to-day variability in diet is known to be high (Basiotis *et al.*, 1987). Dietary surveys usually have a maximum duration of 7 days at the most, because participant fatigue otherwise may result in less accurate reporting by the end of the recording period (Lillegaard *et al.*, 2007).

Wang *et al.* (Wang *et al.*, 2006) asked participants how long they would be willing to continue recording their diet using the so-called Wellnavi instrument – a hand held personal digital assistant with camera. About half of the participants were willing to do so for about one month. Higgins and colleagues (Higgins *et al.*, 2009) concluded that the digital method they tested was more convenient and less burdensome for children and their families compared to the traditional food diary method, and Boushey *et al.* (Boushey *et al.*, 2009) found that dietary assessment methods using technology, e.g. a personal digital assistant or a camera, were preferred among adolescents compared with the pen and paper record.

The food images may in addition be used qualitatively to gain more insight into the food behaviour of the target population (Keller *et al.*, 2008).

### **Summary: Digital methods for dietary assessment**

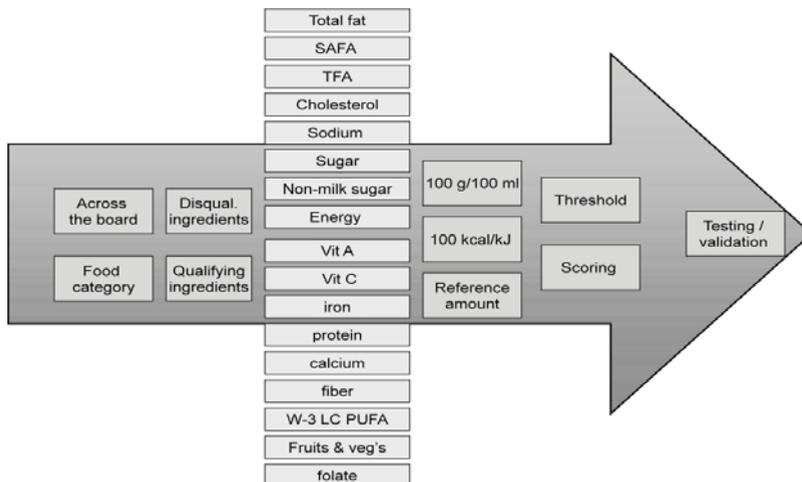
To evaluate the effectiveness of the various strategies for improvement of the food and eating environment, simple and valid monitoring tools are needed. New applications of digital technologies, including photographs and visual imaging, to capture dietary behaviour in real-time have been explored in recent years. The digital photographic method involves different steps from taking the images of the food eaten to subsequent portion size estimation and evaluation of the nutritional quality. Different methods have been used in different context both for assessing food intake away from home and for assessing meal intake among free-living individuals. However, more work is needed to improve the accuracy and precision of the methods including in worksite canteens offering a great variety of menu options and buffet meal selection. Also, using the method among free-living population the precision and accuracy of the method to estimate participants' habitual diets needs to be established in addition to the feasibility of the method in terms of participants' satisfaction and willingness to recording their meal intake.

## 1.4. Evaluation of overall nutrient quality of foods and diets

### Food and diet quality scores

Evaluation of overall nutrient quality of foods and diets is increasingly in focus as an alternative or supplement to the traditional approach of investigating the effect of single dietary components (2010 DGAC Membership, 2010; Toft *et al.*, 2007). Two major methods are used to reduce complex dietary data, either predefined measures at the food or whole diet levels, or statistical approaches such as principal component analysis or factor and cluster analysis to characterize dietary patterns using collected dietary information.

Composing of predefined measures in terms of index or scores is a complex matter with a large degree of subjectivity. The main advantage of these scores is that they all present one joint measure of different dietary aspects instead of several independent measures (Kaluza *et al.*, 2007). A variety of indexes and scores have been developed to evaluate overall diet quality, including a simple dietary quality index based on the intake of dietary fibre and saturated fat (Biltoft-Jensen *et al.*, 2008), a Food Intake Patterns for the MyPyramid Food Guidance System (Britten *et al.*, 2006) and the Healthy Eating Index-2005 to conform to the Dietary Guidelines for Americans 2005 (Guenther *et al.*, 2008). Also, efforts have been carried out to evaluate overall nutrient quality of individual food items using the nutrient profiling approach (University of Crete School of Medicine, 2000; Drewnowski *et al.*, 2009; Drewnowski *et al.*, 2008; Tetens *et al.*, 2007; Mejborn *et al.*, 2009). Nutrient profiling is the science of ranking foods based on nutrient composition. Nutrient profiles can be used for different purposes, including food labelling and marketing control.



**Figure 1.3.** A visual model to compare existing nutrient profiling schemes; basic figure (Verhagen *et al.*, 2008)

Verhagen and van den Berg (Verhagen *et al.*, 2008) have presented a simple visual model shown in Figure 1.3 where the various choices that can be made are indicated allowing for easy comparison of existing

schemes. In no particular order the following choices are possible; a choice between a system based on food categories or 'across the board', a choice between qualifying (e.g. fibre,  $\omega$ -3 PUFA, fruits and vegetables) and/or disqualifying ingredients (e.g. salt, sugar, saturated fat and energy), a choice for the reference base, which can be per 100g, 100 kJ, and/or per reference quantity/serving, and a choice between a scoring system or a threshold system. When all the individual choices have been made and agreed upon, the system of choices needs to be validated and tested.

With regard to indicators of nutrient quality of whole meals research remains limited. Recommendations and evaluations referring to the whole diet or individual food items may be difficult to translate by caterers and consumers into daily meal planning and practice. Moreover the commonly used dietary scores are based on nutrients and/or nutritional indicators in contrast to food products and may therefore be difficult in direct communication with a general public (Kaluza *et al.*, 2007).

### ***Energy density***

Energy density has been shown to be inversely connected to overall diet quality and increased nutrient density (Schroder *et al.*, 2008; Patterson *et al.*, 2010). Moreover, energy dense foods are regarded as convincing determinants in relation to the obesity epidemic (WHO, 2003). The Second Expert Report from the World Cancer Research Fund and the American Institute for Cancer Research recommend the average energy density of diets to be lowered from the current around 770 KJ per 100 g (185 kcal) (Ledikwe *et al.*, 2005) towards 520 kJ (125 kcal) per 100 g excluding drinks (World Cancer Research Fund / American Institute for Cancer Research, 2007). Low energy density is associated with low-fat and/or water-rich foods such as fruit, vegetables and wholegrain products (Astrup, 2008).

The energy density of a food or a diet is a measure of the amount of energy provided per unit weight. Different methods are used in the literature to calculate energy density including food only or including all food and drinks. Johnson *et al.* (2009) suggest that food and drinks should be treated separately as they have differing effects on satiety and energy intake. Also, the exclusion of beverages in the calculation of energy density increases comparability with other studies (Johnson *et al.*, 2009; Rolls, 2009).

### ***Summary: Evaluation of overall nutrient quality of foods and diets***

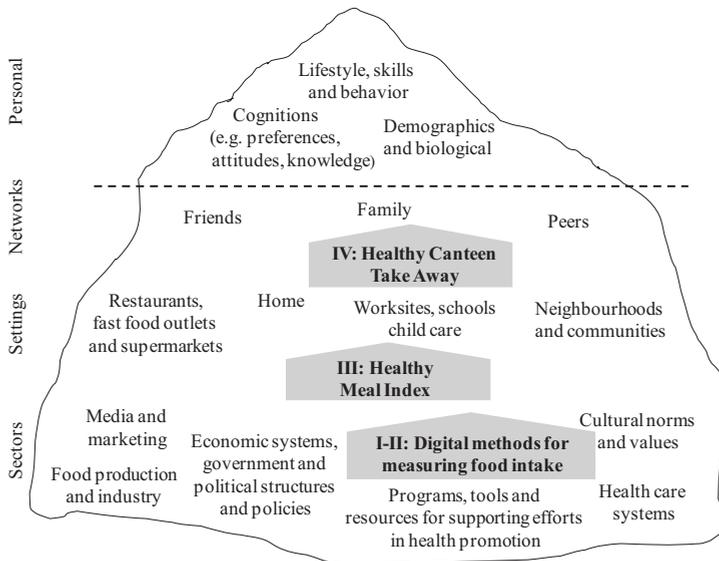
A range of scores, indexes and nutrient profiling systems has been developed in order to evaluate overall nutrient quality of diets or foods, whereas research with regard to the nutrient quality of whole meals, including canteen meals, remains limited. Also, energy density has been shown to be a good indicator of diet quality. The main advantage of using scores or index systems is that they all present one joint measure of different dietary aspects instead of several independent measures. However, composing of a predefined index or a score is a complex matter with a large degree of subjectivity. Different aspects need to be considered including qualifying and/or disqualifying ingredients, a choice for the reference base and a choice between a scoring or a threshold system.

## 2. Aim of the PhD study

The overall aim of the present PhD study was to contribute to the evidence base of effective healthy eating promotion initiatives at the worksite. The objectives of the four papers included in the present thesis were the following:

- To evaluate digital methods for assessing food intake at worksite canteens offering a variety of meals (Paper I) and assessing home evening meal intake in an adult population (Paper II).
- To develop and validate a simple Healthy Meal Index reflecting the nutritional profile of individual canteen meals (Paper III). The index was developed both for scientific purposes and to assist caterers in making healthy meal offers without having to use nutrient-calculation software.
- To investigate the effectiveness of the canteen take away concept in promoting healthy eating by evaluating the nutritional quality of employees' evening dinner meal intake and their total daily intake on weekdays receiving CTA compared to other weekdays not receiving CTA (Paper IV).

Figure 2.1 illustrates the range of factors influencing food choice and behaviour, as described in Chapter 1.1, showing the objectives of the present thesis. The digital method for assessing home evening meal intake and the Healthy Meal Index was used to evaluate the nutritional quality of employees' evening meals in Paper IV.

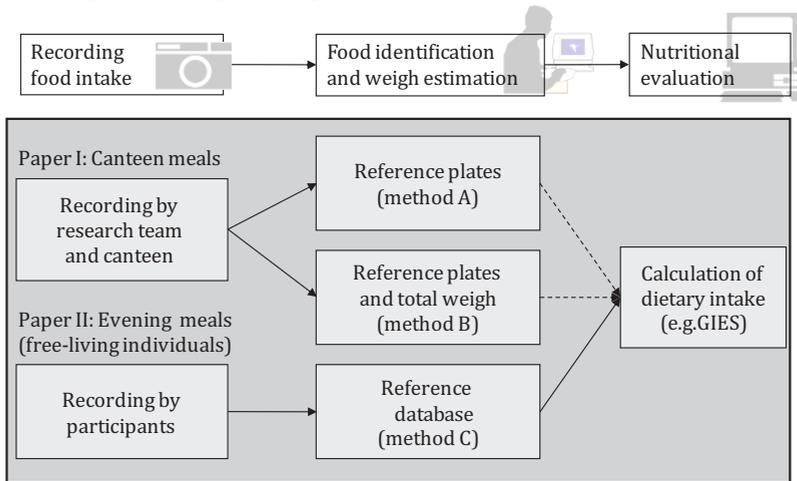


**Figure 2.1.** An illustration of the multiple influences on what people eat showing focus points of the present thesis in grey boxes

### 3. Methods

#### 3.1. Digital methods for dietary assessment (Paper I-II)

Three variants of the digital photographic method were evaluated as illustrated in Figure 3.1, here named method A and B (Paper I) evaluating canteen food intake, and method C (Paper II) evaluating evening meal intake among a free-living adult population.



**Figure 3.1.** A schematic illustration of the steps involved in the three variants of the digital method evaluated in the present thesis (method A, B and C, respectively)

#### ***Comparing the validity of two variants of the digital method for assessing canteen meal intake (Paper I)***

The digital methods A and B for assessing canteen meal intake were evaluated using digital images of weighed duplicate plates of customers' self-selected canteen meals. The exact same methodology was applied to the two methods except for providing the image analyst with the total weight of the meals with regard to method B. It was therefore possible to compare directly the two digital methods with regard to precision of the weight estimations of the individual foods within the meals.

Briefly, the study included 19 workplaces with in-house canteens (Lassen *et al.*, 2007b; Lassen *et al.*, 2007a). The duplicate plate method was used to collect customers' self-selected meals. *Recording* and collection of reference portions were accomplished by laboratory technicians. Individual foods on the duplicate plates excluding food left unconsumed, were identified and weighed using a digital balance weight. One hundred meals were included in the present study to comprise a great variety of meals from different worksite canteens. The one hundred meals were stratified by meal type and randomly assigned

to one of two groups in order to evaluate the estimation accuracy of the two different digital methods providing either no reference information for the image analysts on weights (digital method A, 50 meals) or providing the image analysts with the total weight of the meals (digital method B, 50 meals). *Weight estimation* was done by two trained image analysts independently. For more details and description of the estimation procedure see Paper I.

### ***Validity and feasibility of the digital method for assessing evening meal intake in a free-living adult population (Paper II)***

The digital method C, evaluating the evening meal intake among a healthy adult population, was compared against weighed records of 19 participants' usual evening meals for five consecutive days. This method differed from method A and B in several ways. First, as the *recording* took place in peoples' own homes, the recording was accomplished by the participants themselves. This method included taking pictures of the food before eating and again after they had finished eating, including possible leftovers. Second, it is not possible to take images of reference dishes directly related to the food eaten. Instead a database with reference images of commonly eaten foods was developed. The weights of the individual foods excluding leftovers were recorded by two trained image analysts independently. Furthermore, 28 participants recorded their evening meals on weekdays for three consecutive weeks (the Canteen Take Away study) were interviewed individually at the end of the registration period to get their perspective on the feasibility of the method. For more details and description of the estimation and interview procedure please see Paper II.

### ***Data analysis (Paper I-II)***

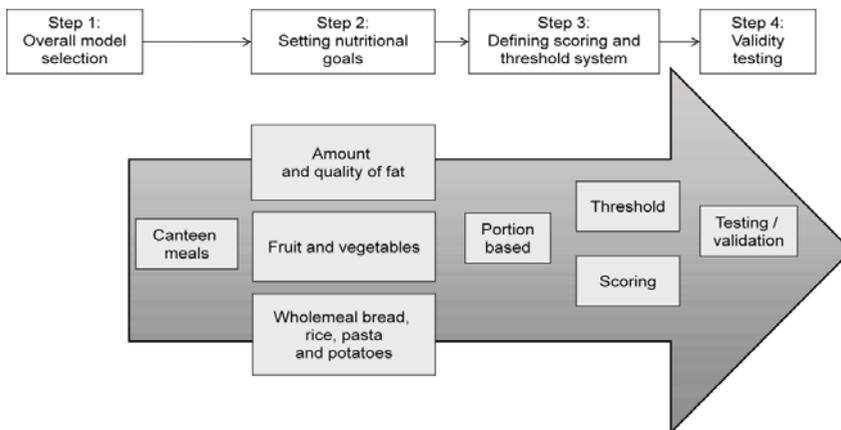
Agreement between actual and estimated weights was determined for each food category (all methods) and nutrients (method C only) by Bland-Altman plots, regression analysis and cross-classification into quartiles. With regard to method C weight values for the individual food categories and total energy content was log-transformed to approximate normality. Furthermore, comparisons were made on the energy-adjusted weight values (g/10 MJ) and on energy density (kJ/100 g). Finally, the intraclass correlation coefficient was estimated to the weighted data to assess the inter-rater variability (all methods). In all statistical analyses a significance level of 5% was applied.

The interviews (evaluating the feasibility of method C) were coded and analysed using the template analysis approach (King, 2004). For more details and description of the coding procedure see Paper II. Furthermore, a compliance rate was calculated by dividing the number of recorded meals with the total possible meal number during the recording period.

### 3.2. Development and validation of a simple Healthy Meal Index (Paper III)

#### *Development and validity study*

The development process is illustrated in Figure 3.2. Firstly, meetings were held with stakeholders to identify needs and requirements for developing the overall model of a simple HMI. Secondly, components to be included in the simple HMI were prioritized and nutritional goals established for each of the components. Thirdly, specific main and intermediate criteria and thresholds for each component goal were determined; and fourthly, a validity testing of the index was carried out.



**Figure 3.2.** Development and validation of the simple Healthy Meal Index following the nutrient profiling approach. Modified from Verhagen and van den Berg (Verhagen *et al.*, 2008).

Validity was examined qualitatively in terms of how well the nutritional goals corresponded with Danish nutrient recommendations and food based dietary guidelines (Astrup *et al.*, 2005; Mejborn *et al.*, 2008; Nordic Council of Ministers, 2004b), MyPyramid from US Department of Agriculture (Guenther *et al.*, 2008) and proportions illustrated by the Plate Model (Karlstrom *et al.*, 1989; The British Dietetic Association, 2003). Furthermore, to explore the effects of the simple HMI on nutrient and food content, the HMI was applied to a study sample consisting of 180 canteen meals. The sample was split into four almost equal sized categories according to total index score: The 'least healthy', the 'less healthy', the 'healthy' and finally the 'most healthy' categories. Finally, the validity of the fat content and quality component score was examined by comparison with analyzed fat contents in terms of percent of energy from both total fat and saturated fat. For more details and chemical analytical procedure see Paper III.

#### *Data analysis*

Continuous outcome data were compared using one-way ANOVA if distributed normally, i.e. age, portion size, protein (E%), total fat (E%) and saturated fat (E%), followed by Tukey's post hoc test to assess

differences among the categories. The Kruskal-Wallis test was used when data were skewed followed by Mann-Whitney post-hoc test. The chi-square-test was used to compare discrete data variables, i.e. sex distribution and prevalence of white collar employees. The Pearson correlation coefficient was used to assess the linear relationship between the log-transformed calculated number of fat versus starch units and total fat (E%) as well as the relationship between the fat content and quality score and both total and saturated fat (E%).  $P < 0.05$  was considered as statistically significant.

### **3.3. Effectiveness of a Canteen Take Away concept (Paper IV)**

#### ***Study design and dietary assessment***

A financial worksite that offered CTA twice a week to 750 employees was invited to participate in the present study. The worksite had offered take-away meals from an in-house canteen for almost five years, being one of the first companies to offer CTA in Denmark. The simple food-based Healthy Meal Index was provided to the canteen as a tool to evaluate the nutritional quality of the CTA-meals. All employees working at the worksite were given the opportunity to participate in the present study by an announcement in the worksite's internal newsletter describing the study. The number of participants included in analysis was 27. Participants received CTA meals free of charge throughout the study period to themselves as well as to their families. For more details and recruitment procedure see Paper IV.

Four non-consecutive in-person 24-h dietary recalls were applied to measure the food intake during the previous weekday in order to get total dietary intake on CTA and on days not receiving CTA (non-CTA days). Furthermore, a digital photographic method recording the evening meal intake at weekdays for three consecutive weeks was applied to obtain more precise nutrition information on CTA meals in relation to non-CTA meals. Participants were provided with digital cameras and given oral instruction as well as a detailed written information on how to capture images of their evening meals served on plates (both CTA and non-CTA meals) as described in Paper II and IV (Figure 3.3 shows three examples of images of CTA meals).

The software program General Intake Estimation Systems and the Danish Food Composition Databank (Saxholt *et al.*, 2008) were used to calculate food and nutrient intake for both dietary assessment methods. Besides, the simple Healthy Meal Index was applied to evaluate the nutritional composition of the dinner meals. For more details and background information assessment see Paper IV.



**Figure 3.3.** Three examples of images of CTA meals

### ***Data analysis***

First, all outcome variables were described univariately in terms of unadjusted mean differences between CTA and non-CTA meals. Then a multivariate analysis was performed by means of a mixed effects model. The meal type was included as a fixed effect as well as gender, age and education (2 levels). In order to adjust for dependency in repeated measures within subjects, random effects were added for employee. Homogeneity of variance and normality of the residuals were examined using graphical methods. Given the multitude of statistical tests, a P-value of  $<0.01$  was taken in order to reduce the probability of false-positive findings.

## 4. Results and discussion

### 4.1. Digital methods for dietary assessment (Paper I-II)

#### Validity

Table 4.1 and Table 4.2. summarizes the results from Paper I and II, respectively. Additional results have been added to the tables with regard to Bland-Altman limits of agreement and differences between estimated and actual weights expressed in percentage of the actual weights. High correlation coefficients between the digital methods and weighed records were found for all three variants of the digital method and for all food categories. Also high correlation coefficients were seen regarding energy and macronutrient estimation for method C. Moreover, the cross-classification analysis revealed that the majority of the estimated intakes were correctly ranked. The proportion of food categories classified in the same quartile ranged from 62% to 82% and from 69 to 92% using the digital methods A and B, respectively. With regard to method C the proportion of food categories (expressed as g/10 MJ), energy content and macronutrients classified into the same quartile ranged from 56% to 82%.

**Table 4.1.** Regression, cross-classification analysis and Bland-Altman limits of agreement between actual (weighed record) and estimated weights for different food categories in canteen meals using the digital methods A (no weight provided to the image analysts) or method B (total weight provided to the image analyst)

Canteen meals (Paper I)	Actual		Estimated		Difference <sup>2</sup> % P-value	Correlation coefficient <sup>3</sup>	Classified into same/same or adjacent quartile %	Regression slope 95% confidence intervals	Limits of agreement	
	content, g mean (SD)	content <sup>1</sup> mean (SD)	mean (SD)	mean (SD)					Lower	Upper
<b>Digital method A</b>										
<i>Food categories (g)</i>										
Meat/fatty products (n=50)	163 (101)	165 (98)	1	0.790	0.95	82/100	0.86 - 0.98	-52	56	
Fruit and vegetables (n=40)	91 (81)	82 (65)	-9	0.093	0.89	63/98	0.81 - 0.97	-56	58	
Starchy products (n=47)	126 (82)	120 (74)	-4	0.362	0.96	81/100	0.88 - 1.02	-47	55	
Total weight (n=50)	354 (126)	344 (117)	-3	0.065	0.90	62/98	0.79 - 0.97	-90	96	
<b>Digital method B</b>										
<i>Food categories (g)</i>										
Meat/fatty products (n=50)	173 (116)	168 (113)	-2	0.057	0.97	92/100	0.89 - 1.03	-39	30	
Fruit and vegetables (n=39)	89 (80)	90 (80)	2	0.390	0.97	69/100	0.94 - 1.09	-36	38	
Starchy products (n=45)	125 (85)	129 (88)	3	0.236	0.97	84/100	0.93 - 1.09	-34	42	
Total weight (n=50)	354 (142)	-	-	-	-	-	-	-	-	

<sup>1</sup> Average of the two image analysts' weight estimations

<sup>2</sup> (Estimated - actual content)\*100/actual content, signed rank test

<sup>3</sup> Spearman correlation coefficient

The correlation coefficients found in the present study using the digital methods were in accordance with correlation coefficients found using visual meal observation. In a study by Shatenstein *et al.* (Shatenstein *et al.*, 2002) among older adult residents in an institutional setting the correlation coefficients ranged from 0.72 to 0.95 for different food categories at lunch meals when compared to weighted records.

**Table 4.2.** Regression, cross-classification analysis and Bland-Altman limits of agreement between actual (weighed record) and estimated weights for different food categories in evening meals (free-living individuals) using the digital methods C (no weight provided to the image analysts)

Evening meals among free-living individuals (Paper II)	Actual content, g mean (SD)	Estimated content <sup>1</sup> mean (SD)	Difference <sup>2</sup> % P-value	Correlation coefficient <sup>3</sup>	Classified	Regression	Limits of	
					into same/same or adjacent quartile %	slope 95% confidence intervals	agreement <sup>5</sup>	
							Lower	Upper
<b>Digital method C</b>								
<i>Food categories (g)</i> <sup>4</sup>								
Meat products (n=85)	210 (145)	176 (104)	-16 <0.001	0.91	72/99	0.76 - 0.88	-85%	32%
Fruit and vegetables (n=58)	130 (95)	116 (80)	-10 0.002	0.94	74/100	0.78 - 0.93	-85%	36%
Starchy products (n=74)	173 (76)	157 (76)	-9 <0.001	0.86	68/95	0.85 - 1.03	-74%	29%
Fatty products and sauce (n=36)	58 (28)	50 (23)	-14 0.021	0.83	61/100	0.61 - 0.93	-108%	37%
Total weight (n=88)	462 (152)	404 (138)	-13 <0.001	0.83	63/93	0.85 - 1.08	-68%	21%
<i>Food categories (g/10 MJ)</i>								
Meat products (n=85)	1018 (781)	1005 (744)	-1 0.652	0.95	78/99	0.90 - 0.98	-386	360
Fruit and vegetables (n=58)	600 (437)	598 (435)	0 0.655	0.94	72/100	0.90 - 1.03	-241	236
Starchy products (n=74)	796 (342)	782 (303)	-2 0.644	0.87	65/95	0.74 - 0.90	-316	287
Fatty products and sauce (n=36)	271 (133)	251 (121)	-7 0.107	0.87	56/100	0.58 - 0.93	-178	138
Total weight (n=88)	2186 (628)	2148 (615)	-2 0.006	0.95	78/99	0.86 - 0.99	-555	478
<i>Nutrients</i>								
Energy (kJ) <sup>4</sup>	2220 (744)	1970 (691)	-11 <0.001	0.89	64/98	0.83 - 1.03	-60%	20%
Energy density (kJ/100g)	493 (131)	501 (132)	2 0.074	0.95	78/99	0.89 - 1.02	-75	91
Fat (E%)	32.8 (11.5)	33.2 (11.7)	1 0.564	0.97	82/100	0.94 - 1.04	-5.2	6.0
Carbohydrate (E%)	45.2 (13.3)	44.7 (13.3)	-1 0.358	0.96	77/100	0.89 - 1.02	-8.2	7.2
Protein (E%)	21.7 (6.8)	21.7 (6.5)	0 0.961	0.95	77/100	0.84 - 0.97	-4.3	4.3

<sup>1</sup> Average of the two image analysts' weight estimations

<sup>2</sup> (Estimated - actual content)\*100/actual content, signed rank test

<sup>3</sup> Spearman correlation coefficient

<sup>4</sup> Correlation and regression analysis on log-transformed data

<sup>5</sup> In case of log-transformed data, limits of agreement cannot be expressed in the absolute units of measurement. Instead, antilogs of the limits of agreement were calculated to express the intervals (range of percentages)

No significant differences between mean weighed values (g) were seen for method A and B for any of the measured food categories, whereas mean estimated weights for all food categories with regard to method

C were significantly lower than the weighed values when expressed as g per meal (log-transformed). Likewise, the energy content was significantly underestimated using the digital method C. However, none of the energy adjusted estimated mean weight values (g/10 MJ) differed significantly from the weighed values, nor did energy density or any of the macronutrients expressed as percentages of total energy.

Two studies evaluating the validity of the digital method among adults similarly found significant underestimation of energy intake compared to weighed measures (Kikunaga *et al.*, 2007; Martin *et al.*, 2009). This underestimation should be addressed in image analysts' training programs in order to improve the accuracy of estimates.

Examination of Bland-Altman plots indicated that using the digital method B providing the image analyst with the total weight of the meals slightly improved the estimation results for all food categories compared to method A by decreasing the number of extreme values (see plots in Paper I). This resulted in narrower ranges between the two limits of agreement. With regard to method C the Bland-Altman plots cannot be directly compared to those used in method A and B, as the weight values were either log-transformed or energy-adjusted (see selected plots in Paper II). However, compared to method A and B it seems that limit of agreements are a little wider. For more details and results on intraclass correlation coefficients between image analysts see Paper I and II.

Several aspects may influence the level of agreement including the number of hidden or unobservable foods or foods that are highly amorphous and thereby difficult to estimate. Method A and B provide reference dishes from the canteen facility with known weights of individual foods within the meals which may help estimating especially these types of foods that otherwise would be difficult to estimate. Method B furthermore provides the total weight which seemed to decrease the number of extreme values especially in the 'high ends'. With regard to method C used among free-living individuals the digital method procedure was developed to keep the eating situation as close as possible to normal in order to limit the interference of the dietary assessment method with the subject's usual dietary behaviour. It is possible that the estimation error could be reduced in free-living conditions if participants were asked to weigh their plates before and after they had finished eaten as was done in method B in canteen settings. More studies should investigate the best compromise between accuracy and subject compliance, including possible change in diet behaviour.

### **Feasibility**

Field tests of the use of digital method B (not published) showed that weighing the whole meal portion was feasible and could quickly be done after capturing the photo with practically no additional burden upon participants. While photographing and weighing the whole meal portion, the participants were asked to fill out a short questionnaire in order to get relevant background data on each respondent.

The digital method C among free-living adults required the participants to record the meals themselves. In the present feasibility study the compliance rate in terms of proportions of reported meals was 94%. The majority of the participants expressed that they would be willing to record their evening meals for one

month or more using the digital method. Concerns that other people would know about their meals was found to be a significant obstacle for the participants in the study by Wang *et al.* using the Wellnavi instrument as dietary assessment method (Wang *et al.*, 2006). This aspect was not perceived as a big concern for the present selected participant group.

### ***Strengths and limitations***

The sample sizes were too small to cover single food components but was assembled in food categories, thereby decreasing interpretation for single food components. However, no great differences were seen according to food categories, indicating the same size of estimation error in all cases.

Moreover, participants in the studies evaluating method C were more educated compared to the general adult population. Therefore, studies with other population groups are required. Also, the method's ability to record snack and in-between meals should be evaluated further. A major strength of the studies was that they were conducted in the context of participants' usual eating environment rather than on specific food served in laboratory environments. Beverages were not included in the evaluation studies as food and drinks have different effects on satiety and energy intake and to increase comparability with other studies (Johnson *et al.*, 2009; Rolls, 2009).

## **4.2. Development and validation of the simple Healthy Meal Index (Paper III)**

### ***Development***

Three key components were prioritized to be included in the simple HMI: 1) Fruits and vegetables (exclusive potatoes), 2) Total fat and fat quality, and 3) Wholegrain and potatoes. All components being associated with energy density and among the key measures to combat chronic diseases. Wholegrain and potatoes are combined in the same score as potatoes (cooked, baked or mashed) are common as accompaniment to hot meals for most Danes as an alternative to rice or pasta, and it is recommended to increase intake of potatoes (Mejborn *et al.*, 2008).

Scoring systems and thresholds for each index component were defined as summarised in Table 4.2. The following scoring system was chosen: Zero point corresponds to the lowest dietary quality, one point to medium and two points to maximum dietary quality. The scores for these individual components were summed to determine the overall score for the simple HMI. The specified cut-offs described in Table 4.2 were used to assign points.

Unit sizes were defined by household measures such as slices, cups and pieces. For validation purposes weights in grams were assigned to each of the units. With regard to the fat content and quality component, number of fat units was combined with number of starchy food units as a measure of the relative content of fat. Number of fat units was subtracted from number of starchy food units, and rounded to the nearest whole number. Positive values were assigned two points, whereas negative values were assigned zero

points. In the case of equal amount of fat and starchy units either one or two points were assigned dependent on the fat quality as described in Table 4.2. For more details and description of the unit size definition see Paper III.

**Table 4.2.** Scoring system for the simple Healthy Meal Index

Healthy Meal Index components	A:	B: Allocation of points for each component		
	Counting number of units	Criteria for minimum score, 0 points	Criteria for medium score, 1 point	Criteria for maximum score, 2 points
Fruits and vegetables	Count vegetable/fruit units <sup>1</sup>	Less than 1 unit vegetables/fruits	Minimum 1 unit vegetables/fruits	Minimum 2 units vegetables/fruits
Fat content and quality	Count fat units <sup>2</sup> and starchy units <sup>3</sup>	More number of fat units compared to number of starchy units	Same number of fat and starchy units Fat mainly animal based	1) Less number of fat units compared to number of starchy units or 2) Same number of fat and starchy units. Fat mainly vegetable based
Wholegrain and potatoes	Count wholegrain/potato units <sup>4</sup>	Less than ½ unit wholegrain products/potatoes	Minimum ½ unit wholegrain products/potatoes	Minimum 1 unit wholegrain products/potatoes
C: Summing number of points		Minimum 0 and maximum 6		

<sup>1</sup> One unit of fruit and vegetables corresponds to 1 cup of raw, leafy vegetables or ½ cup of other vegetables and fruits

<sup>2</sup> One fat unit equals 2 ounce (50-60 g) medium-fat products, 1½ tablespoon (20 g) high-fat products, 2 teaspoons (10 g) very high-fat products or 1 teaspoon (5 g) solid fats and oils. Low-fat products, fish and plain nuts are not counted

<sup>3</sup> One starch unit corresponds to ½ cup/1 dl of cooked pasta or rice, one slice of bread, 3 medium sized potatoes or 2 cups of vegetables

<sup>4</sup> One unit of wholegrain/potato corresponds to ½ cup/1 dl of cooked wholegrain pasta or rice, one slice of wholegrain bread or 3 medium sized potatoes

### Validity

Energy density as well as content of total fat, saturated fat, carbohydrate, and fruit and vegetables were all highly significant across categories ( $p < 0.001$ ) with higher scores being closer to dietary guidelines. Mean energy density of the canteen meals differed from around 880 kJ/100 g in the least healthy category to around 540 kJ/100 g in the most healthy category, thereby equalling the energy density recommended by World Cancer Research Fund and the American Institute for Cancer Research (2007). Also higher scores were significantly connected to bigger portion sizes ( $p = 0.049$ ). As regards wholegrain content only the 'least healthy' category differed significantly from the other categories ( $p = 0.03$ ). For more details and results on validity testing see Paper III.

The HMI was not able to distinguish between categories of meals with respect to salt content (not published). As the canteen meal provided on average more than half of the daily amount of the less than 5 gram per day recommended by WHO (World Health Organization Expert Committee, 1996), reliable indicators of salt content should be developed and tested for future extension of the HMI. With respect to

the nutritional recommendations concerning fish intake, food variety and sugar and discriminatory food intake these should preferably be evaluated over a time span for several meals.

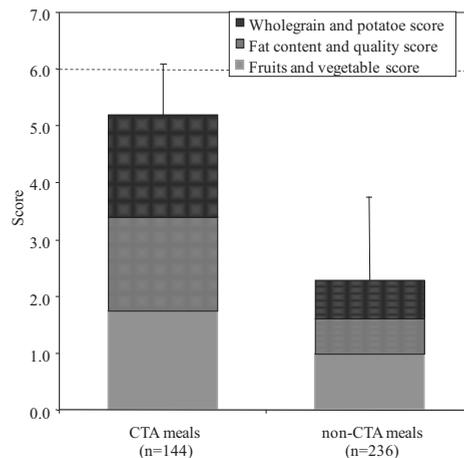
### Strengths and limitations

Limitations of the simple HMI should be noted. The index involves counting food ingredients from mixed dishes, which is a common challenge when assessing dietary intake (Newby *et al.*, 2003). It needs to be combined with recipe, product specification and menu preparation reviews. A major strength of the simple HMI is that it is designed to measure and communicate proportion of foods based on understanding through visual messages according to the Plate Model. It may thereby provide a bridge between scientific research and communication and meal components may be selected to match a range of different meal types and preferences.

### 4.3. Effectiveness of a Canteen Take Away concept (Paper IV)

#### Differences in evening meal intake

Having take away dinner meals from the worksite was associated with a high overall nutritional quality of the evening meals as measured both by the simple Healthy Meal Index (score 5.2, not published) (Figure 4.2) and using energy density as an overall dietary quality marker (462 kJ/100 g). This meets the recommendations from the World Cancer Research Fund and the American Institute for Cancer Research regarding lowering average energy density of diets towards 520 kJ (125 kcal) per 100 g excluding drinks (World Cancer Research Fund / American Institute for Cancer Research, 2007).



**Figure 4.2.** Healthy Meal Index: CTA and non-CTA meals, respectively (not published). The dotted line shows the maximum possible score

The Healthy Meal Index score was 2.9 higher (95% CI: 2.6 to 3.1,  $p < 0.001$ ) for CTA meals compared to non-CTA meals (Figure 4.2) and energy density on average was 187 kJ/100 g lower (95% CI: -225 to -150) ( $p < 0.001$ ) for CTA evening meals compared to non-CTA meals. For more results on employees' evening meal intake according to meal type see Paper IV.

In the present study we have no information on food intake of the participants' families. A supportive home environment with access to healthy foods has been found to be an important determinant of healthy eating habits among both children and adolescent (Pearson *et al.*, 2009; Woodruff *et al.*, 2010). Receiving take-away meals from the worksite could provide an alternative convenient and more nutritious food source (Rydell *et al.*, 2008) compared to other ready meals from the industry (Prim *et al.*, 2007). However, the success of the CTA as a health promoting activity relies both on the actual quality of the meals, including the nutritional quality, and on the employers' and the employees' willingness to pay for the meals. To match these expectations food service professionals need empowerment. Therefore, an important aim of the present public-private partnership was to develop and disseminate education and practical tools and conditions enabling the canteens to effectively implement and maintain a CTA service, including the simple Healthy Meal Index, and to provide network opportunities and newsletters.

### ***Differences in whole day's intake***

The difference in intake of daily fruit and vegetable intake on a daily basis was on average 129 g between CTA and non-CTA days (Table 4.3). Most of the difference in fruit and vegetable intake was accounted for by an increase of vegetable intake by 109 g equalling about 1 serving. This is promising, as it is considered more challenging to increase vegetable intake compared with fruits, which require little preparation, and have a sweet taste that appears to be preferred (Satia *et al.*, 2002). The effect size is comparable with some of some of the best practice worksite intervention studies focusing on changes in the physical food environment as summarized in Table 1.2. Moreover, energy density and protein content was significantly lower and higher, respectively, on days receiving CTA compared to non-CTA days.

The present study support findings by Lachat *et al.* that providing fruit and vegetables from a university canteen leads to a higher intake of fruit and vegetables among students both at lunch and on a daily basis (Lachat *et al.*, 2009). Other studies have shown that an increase in the consumption of fast foods and an increase in the consumption of convenience or ready-prepared foods were associated with less healthy diets (Jabs *et al.*, 2006). Bowen and colleagues compared adults' mean dietary intake on days having fast food compared to dietary intake on non-fast food days and found substantial differences in energy, energy density and macronutrient intakes in favour of the non-fast food days (Bowman *et al.*, 2004).

**Table 4.3.** Differences between employees' evening meal intake and whole day's intake on days receiving CTA compared to days not receiving CTA

	Evening meal intake				Whole day's intake			
	Adjusted difference <sup>4</sup>				Adjusted difference <sup>4</sup>			
	Mean	95% CI		p-value	Mean	95% CI		p-value
Energy (kJ)	-540	-791	-289	<0.001	250	-691	1190	0.60
Energy density (kJ/100 g) <sup>1</sup>	-187	-225	-150	<0.001	-77	-133	-22	0.01
Carbohydrate (E%)	2.4	0.1	4.8	0.04	-1.0	-3.8	1.7	0.46
Protein (E%)	6.7	5.3	8.2	<0.001	2.7	1.6	3.8	<0.001
Fat (E%)	-7.8	-10.2	-5.4	<0.001	-0.7	-3.1	1.7	0.57
Saturated fat (E%)	-6.5	-8	-5	<0.001	-1.4	-2.7	-0.1	0.03
Added sugar (E%)	-2.7	-4	-2	<0.001	-0.7	-2.4	1.1	0.46
Fibre (g/10 MJ)	18	15	20	<0.001	3	0	5	0.06
Fruit and vegetables (g) <sup>2,3</sup>	88	71	104	<0.001	129	49	210	0.002
- Vegetables (g) <sup>2</sup>	83	67	98	<0.001	109	63	156	<0.001
- Fruit (g) <sup>3</sup>	5	-1	11	0.10	17	-50	83	0.62
Fruit and vegetables (g/10MJ) <sup>2,3</sup>	390	323	457	<0.001	146	56	236	0.002
- Vegetables (g/10MJ) <sup>2</sup>	363	295	431	<0.001	126	61	191	<0.001
- Fruit (g/10MJ) <sup>3</sup>	27	7	46	0.01	17	-52	87	0.62

<sup>1</sup> Excluding beverages

<sup>2</sup> Excluding potatoes

<sup>3</sup> Including not more than 100 g fruit juice per person per day

<sup>4</sup> Adjusted difference between CTA and non-CTA days from a multivariate analyses performed by means of a mixed effects model

### **Strengths and limitations**

The methodology of the present study calls for caution when interpreting the results. Participants served as their own control by comparing nutritional intake on days receiving CTA meals with days not receiving CTA. But, the provision of CTA may have positive or negative nutritional effects on the meal quality and quantity on the days before or after consumption. The influence of these effects cannot be estimated. The present study is an explorative study testing the effectiveness of a health promotion strategy under real-life conditions. This may help the adaptation and expansion of research to practice (Bowen *et al.*, 2009). However, the naturalistic experimental approach is often more difficult to manage and often lacks the control that is present in the laboratory (Meiselman, 2006). Accordingly, participants in the present study could not be randomly selected and were not necessarily representative of the population as a whole. They were higher educated compared to the general population and probably more health conscious and had healthier lifestyles. This means that the ability to discriminate between nutritional intakes on different days receiving CTA or not receiving CTA could have been reduced to some degree. Moreover, extrapolation of the results to individuals with different occupational profiles cannot be done.

## Conclusions and perspectives

The present PhD thesis contributes to the evidence of effective healthy eating promotion initiatives at the worksites by providing novel insight into three research areas: Digital photographic methods for assessing food intake, the evaluation of the nutritional quality of individual meals and finally the effectiveness of a healthy Canteen Take Away concept in improving the diets of the employees.

The PhD thesis reinforces the importance of availability, accessibility and convenience as effective tools in promoting healthy eating habits. The results from the Canteen Take Away study showed that employees significantly improved the nutritional quality of their evening meal intake as well as their whole day intake on days receiving Canteen Take Away compared to days not receiving Canteen Take Away. Especially, an increase of vegetable intake by about one serving on days receiving Canteen Take Away seems to be promising, as it is considered more challenging to increase vegetable intake compared with fruits. The results thereby support further action in worksites in enabling and promoting healthy eating pattern among employees even across the contexts of worksite and family. Also, it may provide an inspiration for restaurants, the food industry and convenience stores to make more healthful products and meal choices available. The methodology of the study calls for caution when interpreting the results, however this kind of naturalistic experimental approach may also help the adaptation and expansion of research to practice.

The thesis also emphasizes the need for empowering the worksites and canteen staff in order to successfully implement the healthy eating initiatives. From a health promotion perspective the success of the Canteen Take Away is dependent on the actual nutritional quality of the meals. The thesis introduces a novel concept for evaluating the nutritional quality of individual meals aimed at both professionals, e.g. caterers and dieticians, and the general public who wishes to evaluate nutritional quality of meals in line with the recommendations for healthy eating without having to use nutrient-calculation software. The simple Healthy Meal Index consisting of three key component scores successfully ranked canteen meals according to their nutritional quality. The uses of the simple HMI may be multiple. Besides being used in the catering sector as a self-assessment tool for nutritional quality control, the index is also a valid measure of the nutritional quality of meals consumed elsewhere including ready-prepared meals and home-dinner-meals. The total score and each component score separately may be used as tools for nutritional quality control of the meals. For research purposes, the simple HMI could be used in combination with the digital photographic method in order to evaluate a representative sample of employee's food selection, and thereby provide an overall picture of the nutritional food environment. However, the HMI does not deal with all aspects of nutritional recommendations and reliable indicators of for example salt content should be developed and tested for future extension of the simple HMI. Also the HMI may be developed further as a Healthy Buffet Index reflecting the nutritional profile of the food offered at the canteen.

Finally, results from the present thesis demonstrated the usability of the digital photographic method for dietary assessment in two different context. Especially, the digital photographic technology was found to be useful in canteens, as food and nutrient intake data can be collected from a large group with minimum

participant burden. Results from the present thesis showed that measuring the total weights of the participants' meals at workplace canteens provides a new and feasible aspect of the digital method to improve the precision of the weight estimations of the individual foods within the meals. Results moreover suggest that the digital method is valid and feasible for evening meal estimation in real-time among a free-living adult population to measure macronutrient distribution, energy density and energy-adjusted foods. Digital photographic methods for food intake estimation may have a broad range of applications including studies evaluating the effectiveness of the various strategies for improvement of the food and eating environment at the worksites or other settings like nursing homes and residences for people with intellectual disabilities. Moreover, the method may be useful in studies assessing meal intake among a free-living population during a prolonged recording period. Especially, with future advances in technology the method is likely to be used in broader contexts. Future developments may include developing a wearable electronic system to measure both food intake via image capturing and physical activity.

Overall, the present PhD thesis supports a reorientation in health promotion from focusing primarily on individual level strategies towards a more extensive focus on feasible and effective environmental level strategies for health promotion within and across the settings of everyday life. In order to effectively promote healthy eating pattern and prevent obesity in the population as a whole we need to combine many strategies in neighbourhoods, schools, communities, worksites and in the family context. The results of the present thesis provide a stimulus for further development, evaluation and dissemination of environmental level strategies targeting the physical and social food environment. Over time, this type of dietary change programs has the potential for considerable access into communities and thereby to contribute significantly to a larger public health goal of reducing incidences of dietary related diseases.

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## Papers

### Paper I

#### **Evaluation of a new digital method for assessing food intake at workplace canteens**

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## Abstract

**Background/Objectives:** Digital images provide new options for diet assessment in food environments outside the home. The aim of this study was to evaluate two digital methods for assessing food intake at worksite canteens offering a variety of meals. Digital method A provided no reference information for the image analysts on weights whereas digital method B provided the total weight of the meals.

**Subjects/methods:** The two digital methods were evaluated using digital images of weighed duplicate plates of customers' self-selected canteen meals ( $n=100$ ). Two image analysts estimated the weights of individual foods within the meals, and recorded the individual foods into one of three food categories. Agreement between actual and estimated weights was determined for each food category by Bland-Altman plots, regression analysis and cross-classification into quartiles.

**Results:** High correlation coefficients between actual and estimated weights were found for both methods for all food categories (0.89 to 0.96). However, the Bland-Altman plots revealed wider limits of agreements for digital method A compared to digital method B. Moreover, no bias in regression slopes was found using digital method B. Cross-classification analysis showed that 69% to 92% of the estimated portion sizes were correctly ranked using digital method B compared to 62% to 82% using method A.

**Conclusions:** Measuring the total weights of the participants' meals at workplace canteens provides a new and feasible aspect of the digital method to improve the precision of the weight estimations of the individual foods within the meals.

## Introduction

Valid and feasible assessment methods are needed to evaluate the intake from food eaten away from home, e.g. at restaurants, fast-food places, work and school canteens. Weighed records are often regarded as a “gold standard” method for dietary assessment, but this method is time-consuming and demanding for the participants (Gibson, 2005). Also, meal observations are considered a reliable method for collecting dietary intake data, but there are limits regarding the number of observers who can be included and trained, and the number of persons who can be observed simultaneously (Burgess-Champoux *et al.*, 2008). Digital images provide new opportunities to capture dietary behaviour in real-time (Ngo *et al.*, 2009), and different digital methods have been explored in recent years to improve estimation precision and refine the method for use in various settings with various purposes.

Digital or photographic methods have been used both to assess food eaten at home (Boushey *et al.*, 2009; Higgins *et al.*, 2009; Kikunaga *et al.*, 2007; Martin *et al.*, 2009; Small *et al.*, 2009; Wang *et al.*, 2006; Wang *et al.*, 2002) and away from home (Mitchell *et al.*, 2009; Swanson, 2008; Williamson *et al.*, 2003; Williamson *et al.*, 2004; Swanson *et al.*, 2009; Martin *et al.*, 2007). Swanson and colleagues (2008) demonstrated the utility of a digital method at two elementary schools over two days serving 6-7 different meal options each day. Each food tray was reported to take less than 5 seconds to set up and photograph (Swanson, 2008), thereby causing minimum disruption to the participant’s normal behaviour and respondent burden. Mitchell and colleagues evaluated the School Food Checklist based on digital analysis, and found it to be a reliable method for measuring the food contained in children’s packed lunches in five school settings (Mitchell *et al.*, 2009). Also, Williamson and colleagues found a digital method to be valid when compared to weighed measures of six different test menus (Williamson *et al.*, 2003). They also demonstrated the validity of a digital method by comparing it to direct visual estimation of meals consumed in a university cafeteria setting during a single day (Williamson *et al.*, 2004). To our knowledge the digital method has not been evaluated in workplace canteens offering greater variety of menu options, including buffet meal options. Neither have any of the published studies evaluated the possibility of improving the estimation precision of the digital method by weighing the participants’ plates before and after consumption of the meals to get the total weights of the food consumed. The weighing can be done easily and quickly with probably no extra burden to the participants.

The aim of the present study was to evaluate two digital methods for assessing food intake at workplace canteens offering a variety of meals using digital images of weighed duplicate plates. One method provided no reference information for the image analysts on weights (digital method

A) and the other method provided the total weight of the meals (digital method B) to improve the precision of the weight estimations of the individual foods within the meals.

### **Material and methods**

Data used for this paper were derived from two studies that used the same methodology for data collection (Lassen *et al.*, 2007b; Lassen *et al.*, 2007a). The studies included 19 workplaces with in-house canteens. A modified duplicate plate method was used where a laboratory technician collected the duplicate plates, instead of participants collecting their own duplicate plates, in order to reduce respondent burden and to disrupt the food selection and eating pattern as little as possible. The laboratory technicians collected duplicate plates of customers' self-selected dishes on two different days at each workplace as well as 3-4 reference portions each day. One hundred meals (duplicate plates of customers' dishes) were included in the present study to comprise a considerable variety of meals. The meals were included successively with the following requirements: (a) no more than two dishes with the same food content and (b) the sample should include both hot meals, cold meals and buffet-style meals (e.g. including both hot and cold food items). This procedure was chosen to enhance the applicability of the study's results to different settings with various types of meal selections. Images were taken of the duplicate plates by the technicians using a Canon PowerShot A410 digital camera (3.2-Megapixel) based on the following standard procedure. Images were taken at a 45 degree angle looking down at the plates to get an idea of the depth of the foods. A specific set of cutlery was used in all images as an internal reference object. After the employees had finished eating their meals, they were asked to return their plates to the technicians and images were taken of possible food left unconsumed (4% of the customers). The individual foods on the duplicate plates excluding food left unconsumed, were identified and weighed by the technicians using a digital balance weight (Mettler PJ3600) after the participants had returned their plates. Beverages were not included in the analysis.

Two image analysts working within the area of food and nutrition were trained in portion size estimation of worksite canteen food shortly before the beginning of the study using images of reference meals. Three consecutive computer-based training modules were constructed for the purpose of use in the study. As part of the training the computer provided the image analyst with the correct answer after each weight estimation of individual foods. The aim of the first training module was to get the image analysts familiar with weights of individual foods frequently eaten at workplace canteens. They were provided with reference charts containing information about typical portion sizes of 700 different foods and were asked to estimate portion sizes in grams of individual

foods (spread, bread, filling, garnish, vegetables, pasta, rice, potatoes and meat dishes) with different shapes and/or weight densities. The second and third training modules covered portion size estimation of individual foods within cold and hot dishes/buffet meals, respectively. Here, the images of the reference meals were given in each case with provided weights of individual foods within the meals. The meals were displayed on the screen together with both the reference meals and a spreadsheet to type in the estimated weights. Finally, the image analyst underwent a test in which they estimated individual foods within different types of meals. The results were sent to an independent investigator that checked the image analyst' ability to estimate portion sizes before they finally were enrolled as image analyst in the present study.

The one hundred meals were stratified by meal type and randomly assigned to one of two groups in order to evaluate the estimation accuracy of the two different digital methods providing either no reference information for the image analysts on weights (digital method A, 50 meals) or providing the image analyst with the total weight of the meals (digital method B, 50 meals). The two image analyst independently identified the individual foods within each meal and estimated the weights of the foods for all the meals in random order using images of reference meals. The weights of the individual foods excluding leftovers were recorded into one of the following food categories in order to evaluate the estimation precision depending on the kind of foodstuff: Meat and fat rich products, fruit and vegetables and finally starchy products such as bread, cereals, rice, pasta and potatoes.

#### *Statistical analysis*

The modified Bland-Altman technique for repeated measurements (Bland *et al.*, 1986) was used to assess the degree of agreement between the estimated and actual weights. The modified Bland-Altman technique takes into account both the inter-rater variation and the variation of differences between mean estimated and actual weights. The limits of agreement are defined as twice the corrected standard deviations of the differences above and below the mean. The digital methods were evaluated separately in terms of limits of agreement, mean difference between actual and estimated weights, and possible heterogeneity between the mean weights and estimated differences. Furthermore, the ability to classify weights correctly was measured by cross-classification of quartiles. Measurement bias for each of the two methods was evaluated by comparing regression slopes where significant deviations from unity would indicate bias. Multiple linear regression was applied to test whether differences in agreement could be explained by different meal categories (hot, cold and mixed buffet style). In these multiple linear regression analyses the estimated

proportions of each food category were regressed on the actual proportion (percent of total weight) instead of the estimated weights to make the two methods comparable. Finally, the intraclass correlation coefficient was used to assess the inter-rater variability. In all statistical analyses a significance level of 5% was applied. The statistical software R (R Development Core Team, 2009) was used for all computations.

## Results

No significant differences were found between the two digital methods with regard to actual weights (not shown). Moreover, the meal type, i.e. hot meals ( $n=42$ ), cold meals ( $n=32$ ) and buffet-style meals ( $n=26$ ), did not affect the mean differences between actual and estimated weights, and data for all meal types were therefore analysed together.

High correlation coefficients were seen between all estimated and actual weights for both methods (from 0.89 to 0.97, Table 1). Results from the linear regression analysis, however, showed that the estimated slope was below 1 with regard to the two food categories (meat/fatty product and fruit and vegetables) using digital method A. The estimated slopes below unity indicate that increasing values of these food categories tend to be underestimated with method A. For method B we did not observe any difference in slopes from unity for any food category. Furthermore, average differences between estimated and weighed measures for all food categories were 4 g at the most (equalling 3% of actual weight) using the digital method B (Table 1).

Table 1 also presents the results of the capacity of the two digital methods to classify weights within the same quartile or adjacent quartile for each food category. The proportion of food categories classified in the same quartile ranged from 62% (fruit and vegetables) to 82% (meat/fatty products) using the digital method A. Using the digital method B cross-classification into quartiles showed that 69 to 92% of estimated portion sizes were correctly ranked. Misclassification into opposite quartiles was practically nonexistent irrespectively of the method used.

Figures 1 and 2 show Bland-Altman plots for the food categories for each method. A visual inspection of plots shows a tendency for greater estimation errors with increasing weights of the foods, particularly when using the digital method A. This results in the widest limits of agreement ranging from -56 to 58 g for the fruit and vegetable category using the digital method A (Figure 1). Using the digital method B, the widest limits of agreement were in the starchy category ranging from -34 to 42 g (Figure 2).

The intraclass correlation coefficient between the two nutritionists was high indicating a good inter-rater reliability (Table 2). Repeating the statistical analyses (i.e. linear regression and Bland-

Altman analysis) for each rater separately gave the same main results as averaging their estimation values.

## **Discussion**

The results showed that providing the image analyst with the total weight of the meals improved the weight estimation results for the individual foods within the meals. The results moreover showed that the digital estimation method could be a valid measure of food intakes in complex settings such as workplace canteens.

Both digital methods were characterized by high correlation coefficients for all food categories (0.89 to 0.96). The correlation coefficients found in the present study with the digital methods were in accordance with correlation coefficients found using visual meal observation. In a study by Shatenstein *et al* (Shatenstein *et al.*, 2002) among older adult residents in an institutional setting the correlation coefficients ranged from 0.72 to 0.95 for different food categories at lunch meals when compared to weighted records.

A high correlation, however, does not necessarily imply that there is good agreement between the methods, as the magnitude of coefficients depends partly on the range of observations. A better approach to agreement is to calculate the mean of the differences between the methods (Bland *et al.*, 1986). The agreements between mean estimated and actual weights were close for most assessed food categories. Moreover, no great differences were seen according to food categories, indicating the same level of estimation error. Examination of Bland-Altman plots indicates that using the digital method providing the image analyst with the total weight of the meals (digital method B) slightly improves the estimation results for all food categories by decreasing the number of extreme values resulting in narrower ranges between the two limits of agreement. Importantly, no bias in regression slopes was seen for any of the food categories when using this digital method.

The advantages of using the digital method are that it captures images in real-time and does not rely on participants' literacy, motivation or ability to recall portion size. Also, using the digital method in canteen settings requires only minor interaction with the participants, thereby decreasing response burden. This may be especially important when carrying out studies in workplaces, where the study population can be expected to have little time to devote to assessment due to job demands etc. (Glasgow *et al.*, 1996). Likewise, not published field tests showed that weighing the plates in connections with the images being taken before and after consumption of the meals was feasible and could be done with a minimum extra burden on participants as well as on the research team. The same procedure could probably be applied to a variety of settings where the weighing can be

accomplished by the research team. This may include day cares, school settings, nursing homes and residences for people with intellectual disabilities. The digital method could be useful for research on evaluating the impact of different intervention programs and experiments to improve understanding of various food environments and their impact on dietary behaviours (Mitchell *et al.*, 2009; Story *et al.*, 2009).

Challenges of using the digital method include costs in terms of human labour to identify food types and the quantity of the foods. In the present study the image analysts estimated portion sizes in grams as has been done previously in studies among free-living individuals (Small *et al.*, 2009). Other studies in food environments outside home with more limited numbers of food selections have estimated portion sizes as a percentage of the reference portion (Martin *et al.*, 2007; Williamson *et al.*, 2003; Williamson *et al.*, 2004). Furthermore, the data collected on weight estimates may need to be further converted to measures of nutritional quality. This can be done by simple counts of food servings as suggested by Swanson (Swanson, 2008) or by using a food based index or food checklists as done by Mitchell *et al.* (Mitchell *et al.*, 2009). Other studies have coupled the estimated food intake weights to nutrient databases (Higgins *et al.*, 2009; Small *et al.*, 2009). Greater automation is likely in the future as a result of developments in imaging and visualization technologies in terms of food identification and portion size calculation (Weiss *et al.*, 2010).

A limitation of the present study is that the duplicate plate method used was not validated. It has been suggested that food intake might change during a duplicate diet collection period resulting in a decrease in energy intake (Brady *et al.*, 2003; Gibson, 2005). Also, the duplicate plates were collected by visual measurement, which is prone to error. The purpose of the present study was however not to interpret the results of the intake data but merely to ensure that the digital method was evaluated under the best realistic conditions representing all the natural variety of meals found under real-life conditions in workplace canteens.

In conclusion, the present study adds to the limited literature on the use of image assisted dietary assessment and visual imaging technologies to collect information on peoples' food choice in food environments at worksite canteens. The present study shows that measuring the total weight of the participants' meals at workplace canteens provides a feasible and improved aspect of the digital method that enhances the precision of the weight estimations of the individual foods within the meals.

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**Table 1** Regression and cross-classification analysis between actual and estimated weights for different food categories using two digital methods

Method and food category	Classified into						
	Actual weight, g mean (SD)	Estimated weight <sup>a</sup> , g mean (SD)	Spearman's correlation coefficient	Differences <sup>b</sup> , g mean (SE)	same/adjacent quartile, %	Regression slope, 95% confidence intervals	
<i>Digital method A<sup>c</sup></i>							
Meat/fatty products (n=50)	163 (101)	165 (98)	0.95	1 (4)	82/100	0.92 0.86 - 0.98	
Fruit and vegetables (n=40)	91 (81)	82 (65)	0.89	-8 (4)	63/98	0.89 0.81 - 0.97	
Starchy products (n=47)	126 (82)	120 (74)	0.96	-5 (3)	81/100	0.95 0.88 - 1.02	
Total weight (n=50)	354 (126)	344 (117)	0.90	-10 (6)	62/98		
<i>Digital method B<sup>d</sup></i>							
Meat/fatty products (n=50)	173 (116)	168 (113)	0.97	-4 (2)	92/100	0.96 0.89 - 1.03	
Fruit and vegetables (n=39)	89 (80)	90 (80)	0.97	1 (3)	69/100	1.02 0.94 - 1.09	
Starchy products (n=45)	125 (85)	129 (88)	0.97	4 (3)	84/100	1.01 0.93 - 1.09	
Total weight (n=50)	354 (142)						

<sup>a</sup> Average of the two image analysts' weight estimations

<sup>b</sup> Estimated minus actual weight

<sup>c</sup> No weight provided to the image analysts

<sup>d</sup> Total weight provided to the image analysts

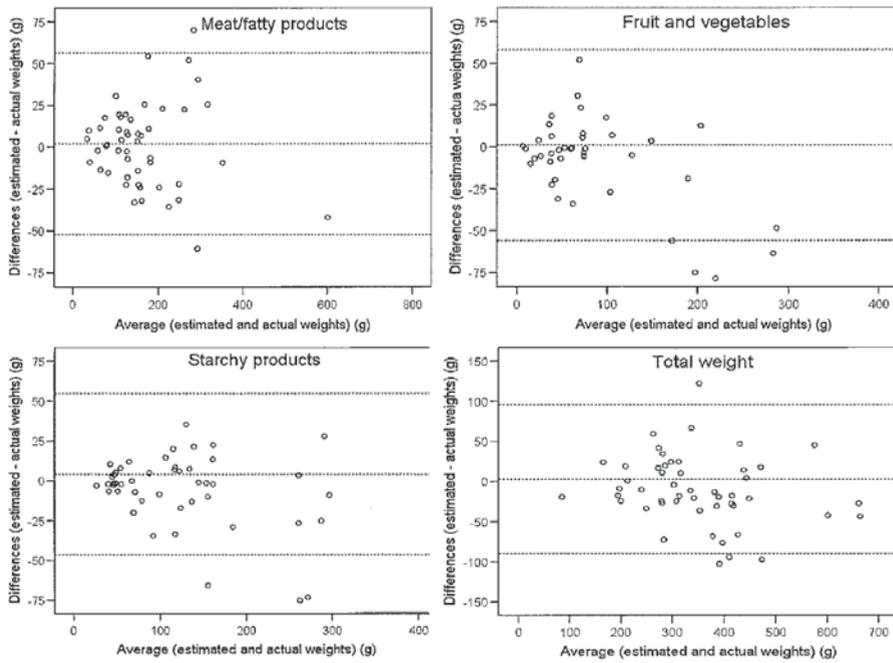
**Table 2** Intraclass correlation analysis for inter-rater reliability using two digital methods

Method and food category	Intraclass correlation coefficient, 95% confidence intervals
<i>Digital method A<sup>a</sup></i>	
Meat/fatty products (n=50)	0.952 - 0.985
Fruit and vegetables (n=40)	0.925 - 0.979
Starchy products (n=47)	0.929 - 0.978
<i>Digital method B<sup>b</sup></i>	
Meat/fatty products (n=50)	0.952 - 0.985
Fruit and vegetables (n=39)	0.953 - 0.987
Starchy products (n=45)	0.968 - 0.990

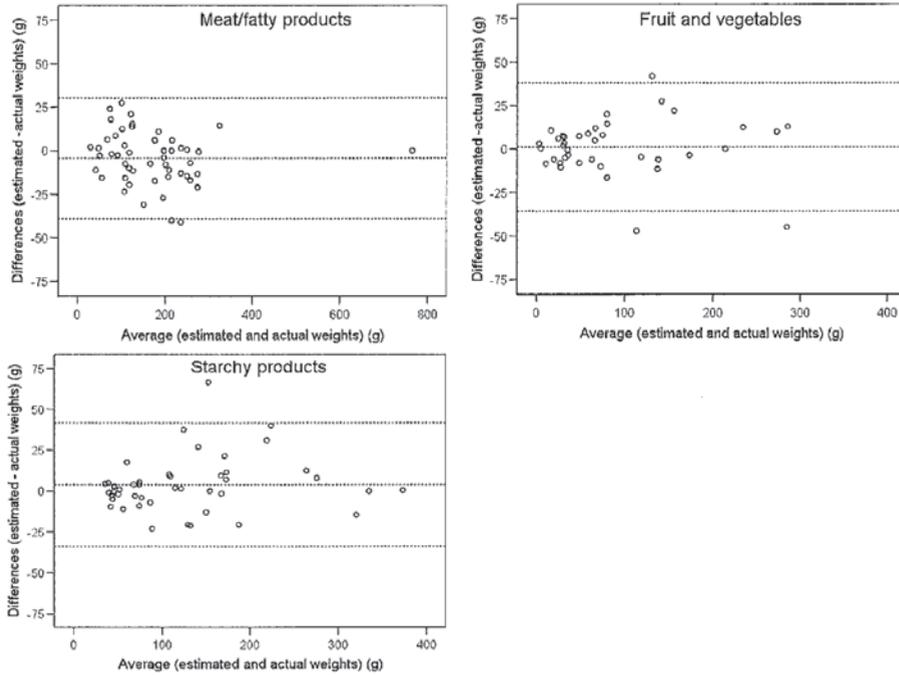
<sup>a</sup> No weight provided to the image analysts

<sup>b</sup> Total weight provided to the image analysts

**Figure 1** Bland-Altman plots showing the mean bias (middle line) and limits of agreement (top and bottom lines) between actual and estimated weights for the different food categories and total weight using the digital method providing no reference information to the image analysts (digital method A)



**Figure 2** Bland-Altman plots showing the mean bias (middle line) and limits of agreement (top and bottom lines) between actual and estimated weights for the different food categories using the digital method providing the total weight of the meals for the image analysts (digital method B)



## **Paper II**

### **Evaluation of a digital method to assess evening meal intake in a free-living adult population**

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# Evaluation of a digital method to assess evening meal intake in a free-living adult population

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## Abstract

**Background:** In recent years new applications of technologies, including digital images, to capture dietary behaviour in real time have been explored.

**Objectives:** To validate a digital method for estimating evening meal intake in a free-living adult population, and to examine the feasibility of the method for recording evening meal intake over a prolonged period of time.

**Design:** The digital method was compared against weighed records of 19 participants' usual evening meals for five consecutive days. Two trained image analysts independently estimated the weight of individual foods within the meals into major food categories, and the nutrient content was calculated. A second study included interviews with 28 participants recording their evening meals on weekdays for three consecutive weeks to get their perspective on the feasibility of the method.

**Results:** High correlation coefficients between the digital method and weighed records were found for all measured food categories and nutrients. Comparable means and acceptable limits of agreement (mean difference  $\pm 2$  SD) were found with regard to macronutrient distribution (e.g. fat content  $-5$  to  $6$  E%), energy density ( $-75$  to  $91$  kJ/100 g), and energy-adjusted foods (e.g. fruit and vegetable content  $-241$  to  $236$  g/10 MJ). The majority of the participants expressed satisfaction with the method and were willing to record their evening meals for 1 month or more using the digital method.

**Conclusion:** The digital method is valid and feasible for evening meal estimation in real-time where a prolonged recording period of participants' meals is needed.

**Keywords:** food intake; diet assessment; digital photography; dinner meals

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Valid and feasible dietary assessment tools are needed to capture actual food intake and allow for evaluation of intervention studies aiming at improving the diet of different population groups. However, achieving accuracy and precision in assessing dietary intakes is a challenge. There is no 'one-size-fits-all' dietary assessment tool appropriate for all research conditions, and there is always a trade-off with the choice of any diet assessment methodology. Several methods are available that possess both strengths and limitations. Traditional methods for assessing dietary intake such as 24-h dietary recalls, diet records, and food frequency questionnaires depend largely on the participants' memory and/or ability to estimate portion sizes (1). Moreover,

high intake variation within individuals in nutrient intake poses a challenge for dietary assessment in studies requiring estimates of usual intake under 'free-living' conditions (2). Weighed records for several days are often regarded as a 'gold standard' method for individual level dietary assessment, but this method is time-consuming and demanding for the participants (3) and may result in changed eating habits during the survey period.

In recent years new applications of technologies, including digital images, to capture dietary behaviour in real time have been explored (4). The use of digital methods seems to be especially useful in out-of-home facilities including laboratory facilities (5, 6) and dining facilities at worksites (7), universities (8), nursing homes

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(9), and elementary schools (10–12). Food and nutrient intake data can be collected from a large group with minimum participant burden and impact on the eating behaviour. The methodology generally involves taking images of participants' food selection and plate waste by a research team using a standardised procedure. Reference dishes from the dining facility with known weights of individual foods within the meals can be used to estimate the weights of participants' individual food intake. In an earlier study assessing food intake in worksite canteens, we showed that estimation error is reduced by weighing the dishes before and after eating and hereby obtain an estimate of total weight of food eaten (not published).

With regard to assessing the food intake of free-living individuals, several issues complicate the usability of the digital method. First, it is not possible to take images of reference dishes directly related to the food eaten. Instead a database with reference images of commonly eaten foods can be applied but this may increase estimation error. Second, it requires the participants to take images themselves thereby introducing greater participant burden and potentially lower image quality and compliance, which may also lead to increased estimation errors. Nevertheless, recent validation studies have shown promising results among both children (13, 14) and adults (5, 15) using different camera technologies including disposable cameras, mobile phones, or personal digital assistants with camera. Kikunaga and colleagues (15) compared a hand-held digital assistant with camera and mobile phone with weighed diet record as the reference method among college students, and found median nutrient intakes to be comparable. Martin and colleagues (5) tested the digital method using a camera-enabled cell phone for total energy estimation among a free-living adult population receiving pre-weighed evening meals to eat at home. Results indicated that the digital method produced reliable estimates of energy intake of the dinner meals. However, as the food was provided by the researchers, the variety of meals was limited and not necessarily representative of the habitual diet.

The objective of the present study was to evaluate the validity of the digital method to assess evening meal intake in an adult population compared with weighed diet records. The evening meal is an important regular event in the lives of the majority of the Danes. It is often considered as the most significant meal of the day and often has special meanings as family meals (16). A second objective was to examine, from the participants' point of view, the feasibility of the digital method for recording evening meal intake over a prolonged period of time.

## Methods

The study was performed in accordance with the ethical standards of the Helsinki Declaration of 1975, as revised

in 2008, and written informed consent was obtained from all participants.

### Validity study

A total of 23 volunteers (11 women and 12 men) were recruited from the local community and personal contacts. The participants' general characteristics were collected at enrolment. Inclusion criteria were healthy men and healthy non-pregnant women between the ages of 18 and 70 years. The mean age of the participants was 37 (SD 16, range 18–69) years and mean BMI was 24 (SD 3) kg/m<sup>2</sup>. There were 53% that had completed a medium- or long-term higher education.

Each participant was instructed to take images of evening meals for five consecutive week-days and asked to provide recipes according to the digital method procedure. In addition, each participant was instructed to weigh and record individual foods within the meals separately using a Soehnle 8026 digital balance (0–1,000 g = 1 g, 1,000–2,000 = 2 g). Beverages were not included in the analysis. The instruction took place at the participants' homes or another location convenient to them.

Data from two randomly selected persons (a total of 10 evening meals) were used to train image analysts in weight estimation. These meals were excluded from the validity study. Furthermore, data from two more participants as well as data from seven evening meals from five individuals were excluded due to incomplete weighing of the food items. In total 88 evening meals from 19 participants were included in the validity study.

A reference database was developed consisting of 16 different starchy foods, 21 fruit and vegetables, 7 fatty foods and sauces, and 17 meat and composite dishes. The foods were selected to represent the most frequently eaten foods at dinner taking into account foods with different shapes and/or weight densities. Each food was photographed at least three times from different angles and in up to eight different portion sizes from a half to four servings (example in Fig. 1). Two image analysts working within the area of food and nutrition were trained in portion size estimation. First, they were provided with reference charts containing information about typical portion sizes of different foods and were asked to estimate portion sizes in grams of individual foods (spread, bread, filling, garnish, vegetables, pasta, rice, potatoes, and meat dishes). As part of the training, the computer provided the image analyst with the correct answer after each weight estimation.

Second, the image analysts were asked to estimate the weights of individual foods within various dishes, including the 10 evening meals (data from two of the participants) on the basis of the reference database.

The weights of individual foods within the meals excluding possible leftovers were estimated independently

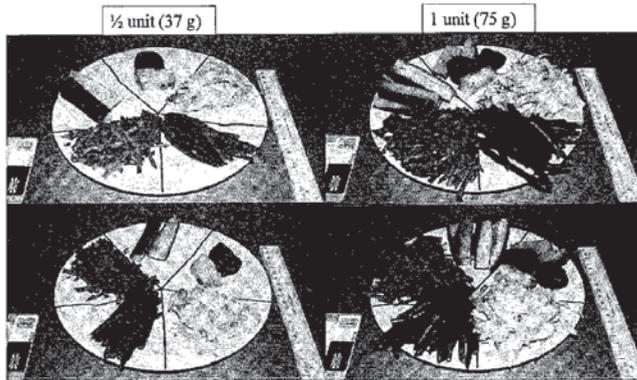


Fig. 1. Example of images from the reference material ( $\frac{1}{2}$  and 1 unit, respectively, of five different vegetable items from two different plate-angles).

by the two image analysts and recorded into one of the following main food categories covering the whole plate: (1) meat and composite dishes; (2) fruit and vegetables; (3) fatty products inclusive sauces; and (4) starchy products such as bread, cereals, rice, pasta, and potatoes. Nutrient calculations were conducted using the computer programme Dankost 3000 (Dansk Catering Center A/S, Denmark) on the basis of average weight estimations of individual foods provided by the two image analysts.

#### Feasibility study

A total of 28 volunteers (15 women and 13 men) were recruited from a financial company in the Copenhagen area order to evaluate the digital method from the participants' viewpoint. Inclusion criteria were healthy men and healthy non-pregnant women aged 18 years or older. The mean age of the participants was 40 (SD 6, range 27–52) years and mean BMI was 24 (SD 2) kg/m<sup>2</sup>. There were 63% that had completed a medium- or long-term higher education. On average, one out of 15 days was not recorded resulting in a compliance rate of 94%.

The participants were instructed to register their evening meals according to the digital method procedure on weekdays for three consecutive weeks. The instruction took place at the company. During the registration period, the participants were offered canteen take-away meals twice a week, which were provided by the company.

Semistructured interviews were conducted by two of the authors (SP and LE) individually at the end of the registration period. The main themes that were covered in relation to the digital method referred to details of how the method was used, pros and cons, as well as reasons for possible change in behaviour, and ethical concerns. All interviews were audio-recorded and transcribed in full. The interviews were coded and analysed by the main

author using the template analysis approach (19). Some initial codes were created based on the interview question. Further codes were added and modified after exploration of the data. Selected review of the coding was performed by an experienced colleague, and the coding levels as well as the analysis were discussed with the co-authors. The template method was chosen since it works well with 20–30 participants and the discipline of producing the template enables the researcher to take a well-structured approach to handling the data (20). Codes were organised in a hierarchical manner onto three levels of coding as shown in Table 1. Furthermore, a compliance rate was calculated by dividing the number of recorded meals with the total possible meal number during the recording period.

#### Digital method procedure

Participants were instructed verbally and given detailed written information on how to capture images of their evening meals served on plates before eating and again after they had finished eating, including possible leftovers. Images should be taken using the auto function with the provided camera whilst seated at the table pointing the camera at a 45° angle towards the plates. The camera was a Nikon Coolpix S210 with electronic VR image stabilisation and motion detection for sharp, steady results. The camera was precoded with date and participant number. A ruler was provided and placed beside the plate as an internal reference in all images. The participants were asked to keep different meal components separated on the plate, and it was emphasised that images should be taken of all foods, including extra food portions, if necessary on additional plates, as well as starters, desserts, and beverages. Additionally, participants were provided with a notebook to record the recipes used with

ingredients given in either grams or in common household measures like cups, spoons, slices, and so on.

#### Statistics

Comparisons between the digital and the weighed record methods were done on the log-transformed weight values for the individual food categories and on total energy content to approximate normality. Furthermore, comparisons were made on the energy-adjusted weight values (g/10 MJ) and on energy density (KJ/100 g). Macronutrient intakes were expressed as percentages of energy (E%). Estimation of variance components and subsequent analysis of variance were applied to the test whether a person-effect in taking the images was present.

The modified Bland-Altman analyse for repeated measurements (21) was used to assess agreement between methods. This analyse takes into account both the inter-rater variation and the variation of differences between methods. The limits of agreement are defined as two times the corrected standard deviations of the differences

above and below the mean. The methods were compared in terms of limits of agreement, mean difference between methods, and possible heterogeneity between the mean weights and estimated differences. In the case of log-transformed data, antilogs of the limits of agreement were calculated to express the intervals (range of percentages). Since nutrient calculation was made on the average estimation values from the two image analysts, no estimate on the inter-rater variation could be obtained in these cases. Therefore, the ordinary Bland-Altman procedure was used with regard to energy and macronutrient distribution.

For comparison of means between the digital and the weighed record methods the Wilcoxon's signed-rank test was used. Furthermore, measurement bias was evaluated by comparing regression slopes where significant deviations from unity would indicate bias. The ability to classify estimated weights and nutrients correctly was examined by cross-classification of quartiles. Finally, the intraclass-correlation coefficient was estimated to assess

Table 1. 'Coding tree' used to analyse interviews about use of the digital method

1st level code	2nd level code	3rd level code
(1) The methodology	(1.1) Overall	(1.1.1) Funny
		(1.1.2) Easy/becomes a habit
		(1.1.3) Can be hard to remember
		(1.1.4) Bothersome/require attention
	(1.2) Time spent	(1.2.1) Does not take much time
		(1.2.2) Takes time at the beginning
	(1.3) Taking images	(1.3.1) Easy/no problem
		(1.3.2) Awkward not mixing meal components on the plate
	(1.4) Writing down recipes	(1.4.1) Easy/no problem
		(1.4.2) Annoying/bothersome
		(1.4.3) Difficult sometimes
		(1.4.4) Difficult sometimes
(2) Influence on eating behaviour	(2.1) Influence due to practical considerations	(2.1.1) No (or minor) influence
		(2.1.2) Food quantity may be different
		(2.1.3) Food quality may be different
		(2.1.4) Eating pattern may be influenced
	(2.2) Influence due to other people watching what you eat	(2.2.1) No (or minor) influence
		(2.2.2) Embarrassing (in the beginning)
		(2.2.3) Tend to eat healthier
		(2.2.4) Awkward at restaurant visit
	(2.3) Influence due to increased consciousness on eating habits	(2.3.1) No (or minor) influence
		(2.3.2) Probably a small influence
(3) Registration period	(3.1) Lengths of registration period	(3.1.1) Three weeks ok, but not more
		(3.1.2) A few weeks more would be fine
		(3.1.3) Even longer period would be fine
	(3.2) Registration break in the weekend	(3.2.1) No influence
(3.2.2) Nice with a break		

the inter-rater variability (food categories). In all statistical analyses a significance level of 5% was applied. The SAS Enterprise Guide 4.0 was used for the computations.

## Results

### Validity study

Mean weights estimated by the digital method were significantly lower for all food categories than those obtained by the weighed record method when expressed as g per meal (log-transformed) (Table 2). Likewise, the energy content was significantly underestimated by an average of 11% using the digital method (Table 3). However, none of the energy adjusted mean weight values (g/10 MJ) estimated by the digital method differed significantly from the values attained by the weighed record method (Table 2), nor did energy density or any of the macronutrients expressed as percentages of total energy.

Lowest correlation coefficients between the digital and weighed record methods were seen in the food categories 'fatty products and sauces' and 'starchy products' (0.83 when expressed as g/10 MJ). Other measured food categories (g/10 MJ) and nutrients showed correlation coefficients between 0.89 and 0.98 (Tables 2 and 3). Results of the linear regression analysis showed that with regard to the macronutrient distribution, energy content, and density of the meals no bias in regression slopes was seen, except for the protein content (Table 3). With regard to the food categories, the fruit and vegetable group expressed as g per 10 MJ and the starchy group expressed as g were not biased below one.

Estimation bias was consistent over different levels of intake as shown by the Bland-Altman plots. Limits of agreement for estimation of fat content ranged from -5 to 6 E%, being respectively, narrower and wider compared to the limits seen for carbohydrate and protein (Fig. 2). With regard to energy content, in 95% of the cases the digital method gave from 60% lower to 20% higher values than the weighed record method (antilog of the log-transformed limits of agreement, not shown), whereas energy density limits of agreements ranged from -75 to 91 KJ/100 g (Fig. 2).

With regard to the fruit and vegetable category limits of agreement when expressed as g per 10 MJ was from -241 to 236, whereas the antilog transformed limits of agreement in g were from -85 to 36% (not shown). An almost similar range of agreement limits were found for the meat category (-32 to 85%), whereas ranges were a little wider for the fat and sauce category (-37 to 108%) and slightly narrower for the starchy category (-29 to 74%; not shown).

The capacity of the digital method to classify weights within the same quartile or adjacent quartile for each food category is shown in Tables 2 and 3. The proportion

of food categories classified into the same quartile ranged from 56 to 78% (expressed as g/10 MJ). With regard to energy content and macronutrient distribution, 64 to 82% of the intakes estimated by the digital method were correctly ranked. The intraclass-correlation coefficient (all food categories) between the two image analysts was 0.96 with a 95 confidence interval from 0.95 to 0.97 (not shown).

### Feasibility study

The participants expressed overall satisfaction with the digital method. Participants did not express great difficulties or problems with the digital method. However, one younger single woman said that she found it challenging to fit the digital method into her lifestyle because she often had a quick dinner meal without placing the food on a plate. Many found that it was easy and it quickly became routine. Some even expressed the view that it had been interesting and that the whole family had been involved in the assessment. The most difficult part was apparently to remember to record the intake, particularly when eating out. It was not so much the time it took but rather the attention it required, especially with regard to writing down recipes. In some cases it could also be difficult writing down recipes when the meal was not prepared by the participants themselves. All found it easy to operate the camera and take the images. Some said that they found it awkward not to mix different meal components on the plate and that it was forgotten from time to time.

None of the participants expressed that their eating habits were influenced to any great extent; however some mentioned that they had bigger first servings during the study to avoid second servings. Likewise, extra meal components, sauce, and so on were sometimes not selected in order to avoid taking extra images. Thus, both the type of food chosen and the quantities could be influenced to some degree due to practical concerns. Participants felt that their eating habits were not changed due to increased awareness of their dietary behaviour or as a result of concerns about having other people evaluate their food intake. Only a few mentioned that they felt embarrassed to show what they had for dinner especially at the beginning of the study, and others said that they were uncomfortable with taking images when eating at restaurants or friends' homes.

All participants completed the 3 weeks of recording. A few mentioned that this was the maximum length of time they would accept. The majority said that 1 or possibly 1.5 months would be acceptable, and about half of the study participants said that an even longer recording period would be acceptable.

Table 2. Regression and cross-classification analysis between weights estimated by the digital and by the weighed record methods, respectively, for different food categories (log-transformed and per 10 MJ)

Food categories	Actual content, g		Estimated content, g		P-value		Spearman's correlation coefficient		Classified into same/adjacent quartile %		Regression slope 95% confidence intervals	
	Mean	(SD)	Mean	(SD)	Log g	g/10 MJ	Log g	g/10 MJ	Log g	g/10 MJ	Log g	g/10 MJ
Meat products (n = 85)	210	(145)	176	(104)	<.0001	0.652	0.91	0.95	72/99	78/99	0.76-0.88	0.90-0.98
Fruit and vegetables (n = 58)	130	(95)	116	(80)	0.002	0.655	0.94	0.94	74/100	72/100	0.78-0.93	0.90-1.03
Starchy products (n = 74)	173	(76)	157	(76)	<.0001	0.644	0.86	0.87	68/95	65/95	0.85-1.03	0.74-0.90
Fatty products and sauce (n = 36)	58	(28)	50	(23)	0.021	0.107	0.83	0.87	61/100	56/100	0.61-0.93	0.58-0.93
Total weight (n = 88)	462	(152)	404	(138)	<.0001	0.006	0.83	0.95	63/93	78/99	0.85-1.08	0.86-0.99

\*Average of the two image analysts' weight estimations.

Table 3. Regression and cross-classification analysis between values estimated by the digital and by the weighed record methods, respectively, for total energy intake per meal, energy density, and macronutrient distribution (n = 88)

Nutrients	Weighed record			Digital method <sup>a</sup>			Spearman's correlation coefficient	Classified into same/adjacent quartile, %	Regression slope, 95% confidence intervals
	Mean	(SD)	Mean	(SD)	P-value				
Energy (kJ) <sup>b</sup>	2220	(744)	1970	(691)	<0.001	0.89	64/98	0.83-1.03	
Energy density (kJ/100g)	493	(131)	501	(132)	0.074	0.95	78/99	0.89-1.02	
Fat (E%)	32.8	(11.5)	33.2	(11.7)	0.564	0.97	82/100	0.94-1.04	
Carbohydrate (E%)	45.2	(13.3)	44.7	(13.3)	0.358	0.96	77/100	0.89-1.02	
Protein (E%)	21.7	(6.8)	21.7	(6.5)	0.961	0.95	77/100	0.84-0.97	

<sup>a</sup>Average of the two image analysts' weight estimations.

<sup>b</sup>Correlation and regression analysis on log-transformed data.

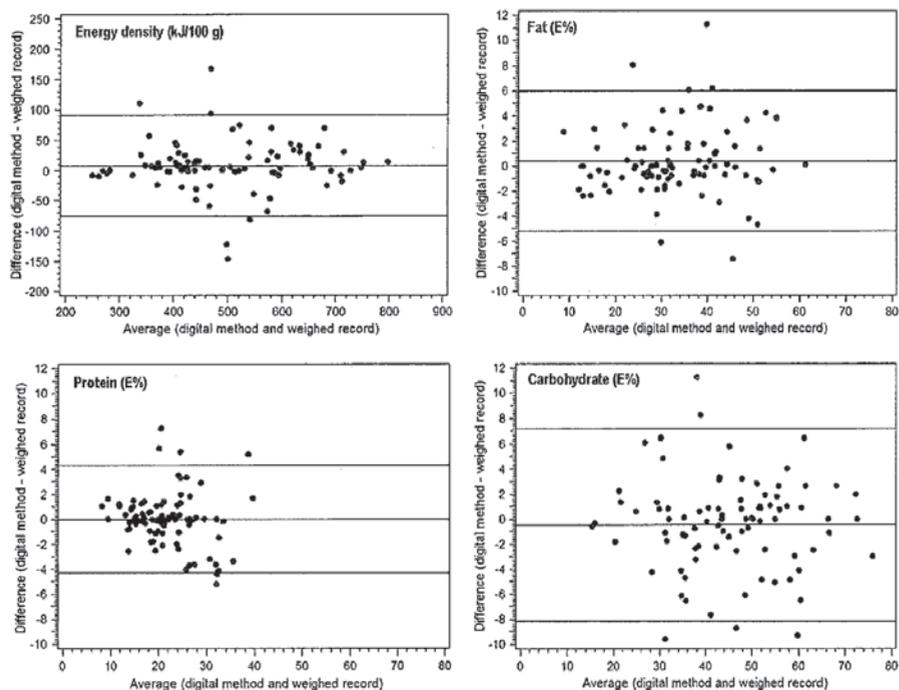


Fig. 2. Bland–Altman plots showing the mean bias (middle line) and limits of agreement (top and bottom lines) between the digital and weighed record methods, respectively, for energy density and macronutrients.

### Discussion

The present study suggests that the digital estimation method is a valid measure of evening meal intake with regard to macronutrient distribution, energy density, and energy-adjusted food categories compared against weighed records as the reference method. The digital method gave significantly lower values for total energy intake and for all measured food categories when expressed as absolute weights.

Two studies evaluating the validity of the digital method among adults under free-living conditions similarly found significant underestimation of energy intake compared to weighed measures of the same magnitude as seen in the present study (5, 15). This underestimation should be addressed in image analysts' training programmes in order to improve the accuracy of estimates. Intraclass correlation in the present study showed good agreement between image analysts (intraclass-correlation coefficient 0.96). Others have reported intraclass correlation for inter-rater reliability at about the same level or lower (5, 13, 14).

High correlation coefficients were found in the present study for all food categories (g/10 MJ), energy content, energy density, and macronutrient distribution (0.87–0.98) between the digital and weighed record methods. However, high correlation does not necessarily imply good agreement between methods. A more valid assessment of agreement is provided by a Bland–Altman plot of the differences between the methods against the mean values (21). Acceptable limits of agreement were found with regard to both energy density (–75 to 91 KJ/100 g), fruit and vegetable content (–241 to 236 g/10 MJ), and fat E% (–5 to 6 E%) – all being important nutritional factors to consider in evaluating diet quality. Several aspects may influence the level of agreement including the number of hidden or unobservable foods or foods that are highly amorphous and thereby difficult to estimate. Participants in the present study were asked to keep different meal components separated on the plate to improve the accuracy of the estimation process, but this may be difficult to accomplish. Also the weighted diet record may be prone to some degree of error and may

explain some discrepancies between estimated and weighed values in this study.

The feasibility study revealed that willingness to record home meal intake using the digital method was high. Compliance rate in terms of proportions of reported meals was 94% and participants expressed satisfaction with the method. Taking the images was not regarded as a problem but recording recipes could be perceived as a bothersome task. Yet, the majority of the participants expressed that they would be willing to record their evening meal intake for 1 or possibly 1.5 months. Wang et al. (22) likewise asked participants how long they could continue recording their diet using the so-called Wellnavi instrument – a hand held personal digital assistant with camera. About half of the participants were willing to do so for about 1 month. Higgins and colleagues (13) concluded that the digital method they tested was more convenient and less burdensome for children and their families compared to the traditional food diary method, and Boushey et al. (23) found that dietary assessment methods using technology (e.g. a personal digital assistant or a camera) were preferred among adolescents compared with the pen and paper record.

The concern that other people would know about their meals was found to be a significant obstacle for the participants in the study by Wang et al. (22) using the Wellnavi instrument as dietary assessment method. This may subsequently influence food selection. This aspect was not perceived as a big concern for the present selected participant group. This may be at least partly explained by the long registration period making the recording a routine over time. Another aspect that may influence the food intake is changes in the eating pattern due to the recording of foods (e.g. greater first servings to avoid taking images of a second serving). Participants, however, did not believe that their food intake was altered to any great extent. To limit the interference of the dietary assessment method with the subject's usual dietary behaviour, the digital method procedure was developed to keep the eating situation as close to normal as possible. More studies should investigate the best compromise between accuracy and subject compliance, including the possible change in diet behaviour. Possible ways of improving the accuracy of the method may involve asking participants to weigh the dishes before and after eating to obtain a more precise estimate of total weight of the food, providing specific plate mates, and/or using fixed photograph set-ups to improve image quality.

The digital method may have a broad range of applications including studies that require a long recording period. Multiple days of recording are required to capture individuals' usual intake under free-living conditions as day-to-day variability in diet is known to be high (2). Dietary surveys usually have a duration of 7 days at

the most, because participant fatigue otherwise may result in less accurate reporting by the end of the recording period (24). The method is potentially useful to evaluate the impact of different intervention programmes and natural experiments on dietary behaviours from diverse population groups across different age and ethnicities, including children and adolescents (23, 25). Compared to the 24-h dietary recall method the digital method does not rely on highly trained interviewers and repeated interviews to get dietary intake information over a number of days. In addition, the food images may be used qualitatively to gain more insight into the food habits of the target population (26).

The present study has certain limitations that need to be taken into account. The validation study was a small convenience sample, which is not representative of the adult population as a whole. Moreover, participants in both the validity and the feasibility study were more educated compared to the general adult population. Studies with other population groups are therefore required. Also, the method's ability to record in-between meals and complete dietary intake should be evaluated further. Beverages were not included in the present validation study as Johnson et al. (17) suggest that food and drinks should be treated separately, as they have differing effects on satiety and energy intake. Also, the exclusion of beverages in the calculation of energy density increase comparability with other studies (17, 18). This study also has several strong points. The study was conducted in the context of participants' usual eating environment rather than on specific foods or in laboratory environments. Also, it deals with the validity of the method and with participants' perspective on the method and its perceived impact on their food intake and behaviour. Challenges of using the digital method include costs in terms of human labour to identify food types and the quantity of the foods. Assessing food ingredients from mixed dishes is a common challenge when assessing dietary intake (6) and the images need to be combined with recipe and product reviews in order to measure all aspects of food intake reliably. In the future technological advancements can be expected both in terms of automatic volume calculation and in terms of more advanced cameras and devices to capture intake and get information from participants on product types, recipes, and so on (27–29) thereby reducing researcher workload significantly (4).

In conclusion, these findings suggest that the digital method is valid for assessing evening meal intake among free-living individuals with regard to macronutrient distribution, energy density, and energy-adjusted foods. Moreover, the method was found to be feasible for assessing evening meal intake over a prolonged period of time.

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### **Paper III**

#### **Development and validation of a new simple Healthy Meal Index for canteen meals**

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## Development and validation of a new simple Healthy Meal Index for canteen meals

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### Abstract

**Objective:** Nutrition evaluation tools should be developed both for scientific purposes and to encourage and facilitate healthy nutritional practices. The purpose of the present study was to develop and validate a simple food-based Healthy Meal Index (HMI) reflecting the nutritional profile of individual canteen meals.

**Design:** The development process included overall model selection, setting nutritional goals and defining scoring systems and thresholds. Three index components were included: (i) contents of fruit and vegetables, (ii) fat content and quality and (iii) contents of wholegrain products and potatoes. The development was built on the principles embodied by the Plate Model, but providing more specificity in some areas. The simple HMI was validated against weighed and chemically analysed food and nutrient content of a representative sample of canteen meals. The sample was split into four categories according to the total index score and compared across categories.

**Setting:** A total of 180 meals from fifteen worksite canteens.

**Results:** Average energy density decreased significantly across categories (from 876 kJ/100 g to 537 kJ/100 g,  $P < 0.001$ ). Also, the content of total and saturated fat, carbohydrate and fruit and vegetables varied across categories with higher score values being closer to dietary guidelines ( $P < 0.001$ ).

**Conclusions:** The simple HMI was successful in ranking canteen meals according to their nutritional quality. The index provides a valuable tool to both researchers and food and nutrition professionals, e.g. caterers and dietitians, who wish to evaluate nutritional quality of meals in line with the recommendations for healthier eating without the use of nutrition calculation programs.

**Keywords**  
Nutrition assessment  
Food services  
Energy density  
Plate Model

A growing body of evidence suggests that the worksite environment can have an important impact on employees' food choice and eating habits<sup>(1-3)</sup>. Besides supplying lunch and breakfast at the worksite, the take-away option from the worksite canteen is also growing in popularity among employees in Western countries<sup>(4)</sup>. It, therefore, becomes increasingly pertinent to take the worksite environment into account when designing new strategies for improving dietary behaviour among the working population.

Several policy papers, including the EU White Paper on Nutrition and the Nordic Plan of Action on Health, Food and Physical Activity, call for action to be taken at the worksites<sup>(5,6)</sup>. Different strategies are suggested, including worksites subsidising healthy meals, offering free fruit and/or creating opportunities for physical activity<sup>(6)</sup>. To evaluate the effectiveness of the various strategies, simple and valid monitoring tools are needed<sup>(7-10)</sup>.

A variety of indexes and scores have been developed to evaluate either overall diet quality<sup>(11-13)</sup> or overall nutrient

quality of foods using the nutrient profiling approach<sup>(14-18)</sup>. However, research on indicators of nutrient quality of whole meals, including canteen meals, remains limited. Recommendations and evaluations referring to the whole diet or individual foodstuffs may be difficult to translate by caterers and consumers into daily meal planning and practice. Development of a simple meal evaluation tool could encourage caterers to self-monitor and optimise the nutritional quality of the meals offered to their customers<sup>(19,20)</sup>. Self-monitoring has been shown to be a predictor of successful dietary change and maintenance<sup>(21)</sup>. Similarly, an intervention among five canteens based on self-monitoring and empowerment resulted in significant increases in fruit and vegetable consumption<sup>(2)</sup>.

One of the nutritional challenges to be addressed in the Western countries is to lower the energy density of meals<sup>(22)</sup>. The Second Expert Report from the World Cancer Research Fund and the American Institute for Cancer Research recommend the average energy density

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of diets to be lowered from the current around 770 kJ/100 g (185 kcal/100 g)<sup>(23)</sup> towards 520 kJ/100 g (125 kcal/100 g) excluding drinks to prevent and control overweight and obesity<sup>(24)</sup>. Generally, foods low in energy density are low-fat and/or water-rich foods, such as fruit, vegetables and wholegrain products<sup>(25)</sup>.

The purpose of the present study was to develop a simple Healthy Meal Index (HMI) reflecting the nutritional profile of single meals and to validate it against the measured nutrient content of a representative sample of canteen meals.

## Material and methods

### Development of the simple HMI

The development process is illustrated in Fig. 1. First, meetings were held with stakeholders (i.e. canteen managers, food service operators and food and nutrition professionals) to identify needs and requirements for developing the overall model of a simple HMI. Second, components to be included in the simple HMI were prioritised and nutritional goals were established for each of the components. Third, specific main and intermediate criteria and thresholds for each component goal were determined; and fourth, a validity testing of the index was carried out. Validity was examined qualitatively in terms of how well the nutritional goals corresponded with Danish Food and Nutrient recommendations<sup>(26–28)</sup>, MyPyramid from the US Department of Agriculture<sup>(13)</sup>, and by proportions illustrated by the Plate Model<sup>(29,30)</sup>. Furthermore, to explore the effects of the simple HMI on nutrient and food content, the HMI was applied to a study sample consisting of 180 canteen meals. The sample was split into four almost equal-sized categories according to the total index score: the 'least healthy', the 'less healthy', the 'healthy' and the 'most healthy' categories. Finally, the validity of the fat content and

quality component score were examined by comparison with the analysed fat contents in terms of the percentage of energy from both total and saturated fat.

### Study sample

The study sample consisted of 180 canteen meals, collected at fifteen randomly chosen Danish worksite canteens. Laboratory technicians observed twelve randomly chosen customers at each worksite canteen (on two different days) and collected identically double portions of the customers' self-selected meals. The collection procedure is described in more detail elsewhere<sup>(3)</sup>. The laboratory technicians asked the customers to provide basic demographic data about themselves in terms of gender, age, weight, height and employment. Food items of all double-portion meals were weighed separately, and the portions were individually mixed and homogenised. Contents of protein, fat and ash were analysed for the 180 meals according to the procedures given by the Nordic Committee on Food Analysis<sup>(31–33)</sup>. Dry matter content was determined by drying in a vacuum oven at 70°C to constant weight. Carbohydrate and energy contents were calculated from the contents of dry matter, protein, fat and ash<sup>(34)</sup>. Recipes, product specification and methods for meal preparation were provided by the staff of the worksite canteens.

### Statistical analysis

All statistical analysis was performed with Statistical Package for the Social Sciences statistical software package version 13 (SPSS Inc., Chicago, IL, USA). Continuous outcome data were compared using one-way ANOVA, if distributed normally, i.e. age, portion size, protein (E%), total fat (E%) and saturated fat (E%), followed by Tukey's *post hoc* test to assess the differences among the categories. The Kruskal–Wallis test was used when data were skewed followed by the Mann–Whitney *post hoc* test. The  $\chi^2$  test was used to compare discrete data variables,

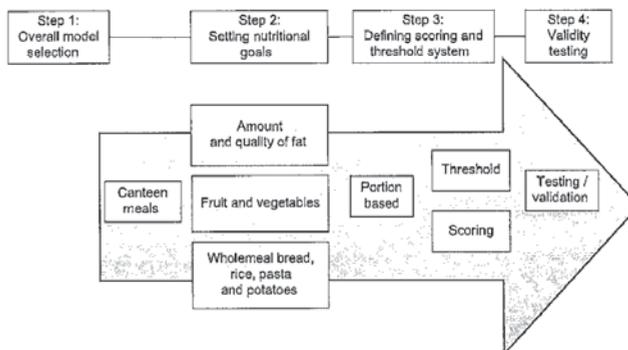


Fig. 1 Development and validation of the simple Healthy Meal Index following the nutrient profiling approach. Modified from Verhagen and van den Berg<sup>(46)</sup>

i.e. sex distribution and prevalence of white-collar employees. The Pearson correlation coefficient was used to assess the linear relationship between the log-transformed calculated number of fat *v.* starch units and total fat (E%), as well as the relationship between the fat content and quality score and both total and saturated fat (E%).  $P < 0.05$  was considered statistically significant.

## Results

### Step 1: Overall model selection

The following main requirements for developing an HMI were identified: The index should follow food and nutrient recommendations, be simple and easy to implement without the use of nutrient-calculation software, yet sensitive enough to measure relevant differences. In addition, the index should offer a visual meal-planning approach communicating proportion and balance of the meals, and also be flexible with regard to different types of meals and serving sizes. Finally, the index should be innovative, i.e. encourage caterers to make stepwise progress towards the nutritional goals. It was suggested to build the index on the principles embodied by the Plate Model, originally promoted by the Swedish Diabetic Association<sup>(29,30)</sup>, but providing more specificity in some areas, i.e. indicators of fat content and quality, as well as wholegrain content.

### Step 2: Setting nutritional goals

Three key components were prioritised to be included in the simple HMI: (i) fruits and vegetables (exclusive potatoes), (ii) total fat and fat quality and (iii) wholegrain

and potatoes, all components being associated with energy density and among the key measures to combat chronic diseases. Wholegrain and potatoes are combined in the same score as potatoes (cooked, baked or mashed) are common as accompaniment to hot meals with most Danes as an alternative to rice or pasta, and it is recommended to eat many potatoes (at least 150 g/d)<sup>(27)</sup>. The nutritional goals were defined as summarised in Table 1. For comparison, Table 1 also shows the general Danish food and nutrient recommendations, as well as the MyPyramid scaled proportionally to the content of one meal (2–2.5 MJ), and the proportions illustrated by the Plate Mode. Although communicated very differently, good agreement was seen when converting the different recommendations to common serving quantities and goals for individual meals.

### Step 3: Defining scoring systems and thresholds

Scoring systems and thresholds for each index component were defined as summarised in Table 2. The following scoring system was chosen: zero point corresponds to the lowest dietary quality, one point to medium and two points to maximum dietary quality. The scores for these individual components were summed to determine the overall score for the simple HMI. The specified cut-offs described in Table 2 were used to assign points.

Unit sizes were defined by household measures, such as slices, cups and pieces. For validation purposes, weights in grams were assigned to each of the units. One unit of fruit and vegetables corresponds to minimum 75 g fruits and vegetables. One unit of wholegrain/potato

**Table 1** Nutritional goals as defined for the simple Healthy Meal Index and comparison with recommended intake and proportions illustrated by the Plate Model

Healthy Meal Index components	Danish food and nutrient recommendations	MyPyramid scaled proportionally to 2–2.5 MJ*	Plate Model†	Healthy Meal Index: nutritional goals
Fruits and vegetables	– 600 g fruits and vegetables per d (excluding potatoes)‡ – 150 g per canteen meal§	About one cup of raw or cooked fruits and vegetables, or two cups of leafy salad green	40% of the plate (~150 g)	Minimum 150 g vegetables and/or fruits per meal (excluding potatoes)
Fat content and quality	– Population goal is 30% of energy from fat   – Saturated plus <i>trans</i> fatty acids should be limited to 10% or lower of the total energy	6 g oil plus discretionary energy allowance	Protein sources and fats: 20% of the plate (~75 g)	Maximum 30% of energy from fat in meals and preferably fat of vegetable origin
Wholegrain and potatoes	– 75 g wholegrain per 10 MJ¶ – Potatoes at least four times a week (~150 g/d)‡	About half cup of cooked wholegrain rice/pasta or one slice of wholegrain bread and half cup of cooked refined grain rice/pasta or one slice of bread	Bread, rice, pasta, potatoes: 40% of the plate (~150 g; wholegrain amount not specified)	Minimum 50–75 g wholegrain bread, cooked rice or pasta per meal (corresponds to approximately 15–25 g wholegrain) or 150 g potatoes

\*USDA food guidance system<sup>(12)</sup>.

†Adapted from the British Diabetic Association<sup>(30)</sup>; the plate is divided into three sections (like a 'Y'). Although the Plate Model is a visual model, an estimated average portion size of each component was estimated from total average lunch canteen weight (i.e. 360 g; adapted from Lassen *et al.*<sup>(3)</sup>).

‡Danish Food-Based Dietary Guidelines<sup>(26,27)</sup>.

§Danish Canteen Nutrition Guidelines (in Danish: <http://www.almkost.dk>).

||Nordic Nutrition Recommendations<sup>(28)</sup>.

¶Danish dietary recommendation for the intake of wholegrain<sup>(27)</sup>.

Table 2 Scoring system for the simple Healthy Meal Index

Healthy Meal Index components	B: Allocation of points for each component		
	A: Counting number of units	Criteria for minimum score, zero points	Criteria for medium score, one point
Fruits and vegetables	Count vegetable/fruit units*	Less than 1 U vegetables/fruits	Minimum 1 U vegetables/fruits
Fat content and quality	Count fat unit§ and starchy unit	More number of fat units compared with number of starchy units	Same number of fat and starchy units Fat mainly animal based
Wholegrain and potatoes	Count wholegrain/potato units§	Less than 0.5 U wholegrain products/potatoes	Minimum 0.5 U wholegrain products/potatoes
C: Summing number of points	Minimum 0 U and maximum 6 U		

U, unit.

\*One unit of fruit and vegetables corresponds to one cup of raw, leafy vegetables or half cup of other vegetables and fruits.

†One fat unit equals two ounce (50–60 g) medium-fat products, 1.5 tablespoon (20 g) high-fat products, two teaspoons (10 g) very high-fat products or one teaspoon (5 g) solid fats and oils. Low-fat products, fish and plain nuts are not counted.

‡One starch unit corresponds to half cup<sup>1</sup> of cooked rice or pasta, one slice of bread, three medium-sized potatoes or two cups of vegetables.§One unit of wholegrain/potato corresponds to half cup<sup>1</sup> of wholegrain pasta or rice, one slice of wholegrain bread or three medium-sized potatoes.

||In order to get maximum score, at least half of the total fat amount should be of vegetable origin.

corresponds to minimum 75 g wholegrain pasta or rice, 50 g wholegrain bread or 150 g potatoes. With regard to the fat content and quality component, number of fat units was combined with number of starchy food units as a measure of the relative content of fat. Number of fat units was subtracted from the number of starchy food units, and rounded to the nearest whole number. Positive values were assigned two points, whereas negative values were assigned zero points. In the case of equal amount of fat and starchy units, either one or two points were assigned depending on the fat quality as described in Table 2.

Fat units were defined as equivalent to 5 g of fat, and all fat-containing products were categorised into the following main groupings to simplify the measure: low-fat products (e.g. ham lean, cottage cheese; 5% fat or less), medium-fat products (e.g. chicken with skin, whole egg; approximately 10% fat), high-fat products (e.g. liver pate, sausage, feta cheese; approximately 25% fat), very high-fat products (e.g. bacon, pepperoni, regular vinegar/oil salad dressing; approximately 50% fat) and solid fats and oils (e.g. butter, oil, mayonnaise; approximately 80% or more fat). Fish and plain nuts were not counted as fat units regardless of fat content, as these foods are considered a part of a healthy diet. The starch food units included low-fat starchy products, whereas sweets, such as cakes, were excluded. One starch unit corresponds to an energy content of about 400–500 kJ (not shown).

#### Step 4: Validity testing

No significant differences were found with respect to the tested background variables (i.e. age, sex distribution, prevalence of white-collar employees and BMI) over the four HMI categories. The study population ( $n$  180) included 39% women and 62% white-collar workers. Average age was 40 (sd 9) years and average BMI was 24.6 (sd 3.7) kg/m<sup>2</sup>.

Food and nutrient content by HMI categories is shown in Table 3. Energy density as well as the content of total fat, saturated fat, carbohydrate and fruit and vegetables were all highly significant across categories ( $P < 0.001$ ) with higher scores being closer to dietary guidelines. In addition, higher scores were significantly connected to bigger portion sizes ( $P = 0.049$ ). As regards wholegrain content only the 'least healthy' category differed significantly from the other categories ( $P = 0.03$ ).

Figure 2 examines the fat content and quality component. As shown in Fig. 2a, the calculated amount of fat units compared to starchy food units (log-transformed) correlated well with the measured percentage of energy from fat ( $r = 0.85$ ). Figure 2b shows that the allocation of points for the fat content and quality component also seemed to correlate well with both the measured total and saturated fat contents expressed as a percentage of energy ( $r = 0.82$  and  $0.65$ , respectively). Mean values were 43%, 29% and 20% of energy from fat for meals allocated zero, one or two points, respectively. Corresponding mean

**Table 3** Nutrient and food content of fifteen canteens' meals categorised into quartiles according to the simple Healthy Meal Index total scores

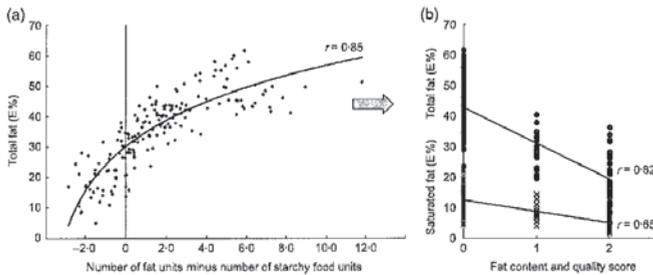
	'Least healthy' category Score: 0-1 (n 38)		'Less healthy' category Score: 2 (n 52)		'Healthy' category Score: 3 (n 45)		'Most healthy' category Score: 4-6 (n 45)		P-value
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Energy density (kJ/100g)	876 <sup>a</sup>	42	722 <sup>b</sup>	32	640 <sup>b</sup>	20	537 <sup>c</sup>	21	<0.001
Energy (MJ/meal)	2.6	1.9	2.5	1.4	2.4	0.1	2.1	0.1	0.052
Portion size (g/meal)	317 <sup>a</sup>	25	353 <sup>ab</sup>	15	375 <sup>ab</sup>	18	389 <sup>b</sup>	17	0.049
Carbohydrate (E%)	40 <sup>a</sup>	1	40 <sup>a</sup>	2	46 <sup>b</sup>	2	55 <sup>c</sup>	2	<0.001
Protein (E%)	18	1	19	1	21	1	20	1	0.27
Fat (E%)	42 <sup>a</sup>	1	41 <sup>ab</sup>	2	33 <sup>b</sup>	2	25 <sup>c</sup>	1	<0.001
Saturated fat (E%)	13 <sup>a</sup>	1	11 <sup>ab</sup>	1	9 <sup>bc</sup>	1	7 <sup>c</sup>	1	<0.001
Fat (g/meal)	29 <sup>a</sup>	2	27 <sup>ab</sup>	2	22 <sup>b</sup>	2	15 <sup>c</sup>	2	<0.001
Saturated fatty acids (g/meal)	9 <sup>a</sup>	1	8 <sup>ab</sup>	1	6 <sup>b</sup>	1	4 <sup>c</sup>	1	<0.001
Vegetables and fruit (g/meal)*	49 <sup>a</sup>	7	97 <sup>b</sup>	11	127 <sup>c</sup>	9	200 <sup>d</sup>	16	<0.001
Wholegrain (g/meal)†	3 <sup>a</sup>	1	8 <sup>b</sup>	2	9 <sup>b</sup>	1	8 <sup>b</sup>	2	0.03

E%, percentage of food energy.

a,b,c,d Values within a row with different superscript letters are significantly different ( $P < 0.05$ ).

\*Excluding potatoes.

†Calculated from the amount of wholegrain bread, rice and pasta.

**Fig. 2** Examination of the fat content and quality component score. (a) Calculated number of fat minus starchy food units compared with the percentage energy (E%) from the total fat. (b) Allocation of point (based on the calculated number and whether the fat is mainly of animal or vegetable origin) compared with the percentage energy (E%) from the total fat (●) and saturated fat (X), respectively (n 180)

values for the percentage of energy from saturated fat were 13, 9 and 5 (not shown).

## Discussion

The HMI was developed as a simple food-based method for evaluating the nutritional quality of canteen meals based on three components and three levels of component scores. The first component measures compliance with recommendation for fruit and vegetables; the second component measures compliance with respect to fat content and quality; and the final component measures compliance with respect to the contents of wholegrain cereals and potatoes. Our findings indicate that the simple HMI is a valid estimate of overall diet quality of canteen meals. Increasing index scores were significantly associated with decreasing energy density, contents of energy, total fat, saturated fat and carbohydrate, and with increasing portion size and content of fruit and vegetables in the 180 canteen meals tested.

Mean energy density of the canteen meals differed from around 880 kJ/100 g in the least healthy category to around 540 kJ/100 g in the most healthy category, thereby equalling the energy density recommended by the World Cancer Research Fund and the American Institute for Cancer Research<sup>(24)</sup>. The recommendation is mainly intended to prevent excess energy intake. In addition, lower energy density seems to be connected to increased nutrient density and overall diet quality<sup>(35)</sup>. In the present sample of canteen meals, the energy content of the meals in the healthiest category, as defined by the simple HMI, was about 20% lower than those in the least healthy category. This is in line with differences in the total daily energy intake found by Biloft-Jensen *et al.*<sup>(11)</sup> between compliers and non-compliers identified by the simple dietary quality index and by Schröder *et al.*<sup>(35)</sup> between subjects eating diets differing in overall energy density.

The present HMI was developed to assist caterers in making healthy meal offers without having to use nutrient-calculation software. The catering industry has an

important responsibility to provide nutritious food to the consumers, but also to influence perceived norms regarding eating behaviour<sup>(4,36)</sup>. However, caterers must also deal with the practical realities of limited resources<sup>(37)</sup>, and therefore have neither the time nor the skills to make complicated calculations<sup>(38)</sup>. In addition, there seems to be a widespread confusion among caterers over what constitutes healthy meals<sup>(39,40)</sup>.

The limitations of the simple HMI should be noted. The index involves counting food ingredients from mixed dishes, which is a common challenge when assessing dietary intake<sup>(41)</sup>. It needs to be combined with recipe, product specification and menu preparation reviews. The contents of the nutrients, on the other hand, were chemically analysed, which is considered to give the most reliable results<sup>(38)</sup>. Beverages were not included in the study, as the focus was on meals provided by the caterers, and the relationship between energy density and macronutrient content and beverages is more complex than that of individual foods or meals<sup>(42)</sup>. Beverages, however, may contribute significantly to the total energy intake. In addition, the index does not deal with all aspects of nutritional recommendations, and reliable indicators of, for example, salt content should be developed and tested for future extension of the simple HMI.

A major strength of the simple HMI is that it is designed to measure and communicate the proportion of foods based on an understanding through visual messages according to the Plate Model. It may therefore provide a bridge between scientific research and communication. The Plate Model has been found to be the preferred educational nutrition model by both professionals and the public<sup>(43)</sup>, and meal components may be selected to match a range of different meal types and preferences. However, paradoxically, the simplicity has been seen as a disadvantage by some, who expect a more complex approach to meal planning<sup>(44)</sup>. The present HMI provides more specificity to the Plate Model, introducing the concept of fat units to evaluate fat content and quality. The basic idea of the fat content and quality score being that there is room for one fat unit, preferably of vegetable origin (equalling 5 g fat) per starchy food unit. For example, one piece of bread with a thin layer of butter is assigned one point (due to animal origin), an open sandwich with some mayonnaise is assigned two points (due to vegetable origin), whereas an open sandwich with both butter and mayonnaise results in zero points. Fat and fatty products are categorised into main groups to simplify the counting of fat units. The fat content and quality component score was found to correlate well with the measured percentage of energy from total ( $r=0.82$ ) and saturated fat ( $r=0.65$ ).

The uses of the simple HMI may be multiple. In addition to being used in the catering sector as a self-assessment tool for nutritional quality control, the index could be used as a valid measure of the nutritional quality

of meals consumed elsewhere, including take-away dinners and home dinner meals. The canteen meals in the present study represented a great variety of meal types, including hot and cold meals (open as well as closed sandwiches), salads and buffet-style combinations. The total and each component scores separately may be used as tools for nutritional quality control of the meals. In addition, food and nutrition professionals may use the index in counselling clients how to modify meals to meet dietary goals. For research purposes, the simple HMI could be used in combination with the digital photography method<sup>(45)</sup> to evaluate a representative sample of an employee's food selection, and thereby provide an overall picture of the nutritional eating environment. The nutritional profile of what was eaten is largely determined by what is offered as found by Lachat *et al.*<sup>(46)</sup> in a Belgian university canteen.

## Conclusion

In conclusion, the present paper introduces a novel concept for evaluating the nutritional quality of individual meals. The simple HMI successfully ranked canteen meals according to their nutritional quality. It has implications for both research and practice, and provides a valuable tool to both professionals, e.g. caterers and dietitians, and the general public who wish to evaluate nutritional quality of meals in line with the recommendations for healthy eating without the use of nutrition calculation programs.

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## **Paper IV**

### **Effectiveness of a Canteen Take Away concept in promoting healthy eating pattern among employees**

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## **Abstract**

*Objective:* To investigate the effectiveness of a relatively novel concept of providing employees with healthy ready-to-heat meals to bring home to their families, here referred to as Canteen Take Away (CTA)

*Design:* Employees' dietary intake on two weekdays receiving free CTA was compared with weekdays not receiving CTA. Four non-consecutive 24-h dietary recalls were applied to assess dietary intake on a daily basis. Moreover, a digital photographic method was used to assess evening meal intake for three consecutive weeks. Data were analysed using a mixed effects model.

*Setting:* A financial worksite offering CTA

*Subjects:* Twenty-seven employees

*Results:* Overall dietary quality as expressed by the energy density of the food (excluding beverages) was found to be significantly lower on days consuming CTA meals compared to days not consuming CTA with regard to evening meal intake (average difference -187 kJ/100g, 95% CI: -225 to -150) and on a daily basis (average difference -77 kJ/100g, 95% CI: -133 to -22). Other favourable differences included increased fruit and vegetable intake (an average difference of 88 g per evening meal, 95% CI: 71 to 104, and an average difference of 129 g on a daily basis, 95% CI: 49 to 210).

*Conclusions:* The present study shows that providing healthy take away dinners constitute a potential for promoting healthy dietary habits among employees. This reinforces the importance of availability and convenience as effective tools to promote healthy eating habits.

## **Introduction**

The prevention of obesity has become a major public health target. Focus has shifted from considering obesity, nutrition and health as mainly private issues to recognizing the responsibility of the society in creating environments and conditions that may support and promote healthy eating habits and an active lifestyle<sup>(1-3)</sup>. Consequently, settings like worksites and schools have received increasing attention as important health promoting platforms<sup>(3,4)</sup>, and many private and public companies are showing interest to invest in health promoting initiatives to protect and develop their human resources<sup>(5)</sup>.

Health promoting initiatives aimed at increasing the availability and accessibility of healthy food at the worksite have been shown in some environments to provide an efficient and sustainable approach to improving employees' dietary habits (e.g. free available fruit and serving more fruit and vegetables at worksite canteens)<sup>(6-8)</sup>. Moreover, these kinds of environmental level initiatives may not be restricted to a self-selected subset of motivated individuals who choose to participate in worksite health promotion programs but rather has the potential to impact the entire worksite population<sup>(9)</sup>.

Health promoting initiatives across the settings of the worksite and home environments provide new opportunities for enabling and promoting a healthy eating pattern. A previous study found that involving the family to create a supportive home environment in addition to a supportive worksite environment resulted in an increase in total fruit and vegetable intake among workers in the worksite-plus-family group compared with the control group<sup>(10)</sup>.

A direct way of reaching the families is by providing employees with healthy ready-to-heat meals offered by the worksite to bring home to their family or elsewhere at subsidized or market prices. This relatively novel concept, here referred to as healthy Canteen Take Away (CTA), seems to be growing in popularity among employees in Western countries<sup>(11)</sup>. However, to our knowledge the effectiveness of this health promoting concept in improving employees' dietary habits has not been described in the scientific literature. Possible nutritional health benefits may include improvement of the nutritional quality of the diet of employees and their families directly by provision of healthy meals that may substitute less healthy meals, including other types of ready meals and fast-food<sup>(12)</sup> and in the long term influence the norms for healthy eating<sup>(13)</sup>. Lack of time to prepare healthy meals as well as habits are frequently reported barriers for not following nutritional recommendations, especially for those who intend to eat healthily but do not do so<sup>(14)</sup>. From the perspective of the employee another important argument for supplying CTA meals is a

way of tackling the work-family conflict<sup>(15)</sup>. CTA meals may reduce the time needed for shopping, cooking and cleaning at home thereby helping the employees in their daily life to balance work demands with personal and family commitments<sup>(16)</sup>.

The aim of the present study was to investigate the effectiveness of a CTA concept in promoting healthy eating habits among employees by evaluating the nutritional quality of employees' evening meal intake and their total daily intake on weekdays receiving CTA compared to weekdays not receiving CTA.

## **Methods**

### *Recruitment and study design*

A financial worksite that offered CTA twice a week to 750 employees was invited to participate in the present study. The worksite offered take-away meals from an in-house canteen for almost five years, being one of the first companies to offer CTA in Denmark. The employees may buy the CTA meals for a price equivalent to the cost of the raw materials and labour. The worksite also offers lunch meals in the canteen as well as free fruit. To participate in the present study the CTA meals supplied during the study period should follow generally recognized nutritional recommendations. The simple food-based Healthy Meal Index was provided to the canteen as a tool to evaluate the nutritional quality of the CTA-meals. The Healthy Meal Index, as described in a previous paper, focuses on the contents of fruit and vegetables, fat content and quality and contents of wholegrain products and potatoes<sup>(17)</sup>. Furthermore, the worksite supported the participation of the employees in the study by paying time off work in order to receive instruction and to complete the dietary interviews. No health promotion activities were directly connected with the CTA project.

All employees working in the worksite were given the opportunity to participate in the present study by an announcement in the worksite's internal newsletter describing the study. Participants received CTA meals free of charge throughout the study period for themselves as well as for their families. Eligible for inclusion were healthy men and healthy non-pregnant women aged 18 years and older expecting to be present at the worksite throughout the 7 week study period (middle of October to the beginning of December). The study was performed in accordance with the ethical standards of the Helsinki Declaration of 1975, as revised in 2008. Written, informed consent was obtained from all participants.

A total of 34 employees responded to the announcement. Out of these 28 enrolled in the study. Reasons for not enrolling were either time pressure (4 employees) or illness (2 employees).

Moreover, data from one participant were excluded from the analysis due to deliberate weight loss during the study. Thus, the number of participants included in analysis was 27.

#### *Dietary assessment and background information*

Two different dietary assessment instruments were applied for both CTA days and days not receiving CTA (non-CTA days). Four non-consecutive in-person 24-h dietary recalls were applied to measure the food intake during the previous weekday in order to get total dietary intake on CTA and on non-CTA days. Due to employees having weekends off it was not possible to perform interviews on Saturdays to measure food intakes on Fridays. The 24-h dietary recall questionnaire was a modified form of the dietary record questionnaire from the Danish National Dietary Survey 2000-2002<sup>(18)</sup>. For canteen lunch and take-away meals, recipes were gathered in order to obtain more precise estimates of intake.

Furthermore, a digital photographic method recording evening meal intake at weekdays for three consecutive weeks was applied to obtain more precise nutrition information on CTA meals in relation to non-CTA meals. Participants were provided with digital cameras and were instructed orally and given a detailed written information on how to capture images of their evening meals served on plates (both CTA and non-CTA meals) for all weekdays in three consecutive weeks. The cameras were Nikon Coolpix S210 with electronic VR image stabilization and Motion Detection for sharp, steady results. Briefly, images should be taken before eating and again after finishing eating, including possible leftovers, using the auto function whilst seated at the table pointing the camera at a 45 degree angle towards the plates. A ruler was provided to be placed beside the plate as an internal reference in all images. The participants were asked to keep different meal components separate on the plate, and it was emphasized that images should be taken of all foods, including extra food portions, if necessary, on additional plates. Additionally, participants were provided with a notebook to record the recipes and ingredients given in either grams or in common household measures like cups, spoons, slices, etc. Two trained image analysts estimated the weights of individual foods within the meals. Beverages were not included as food and drinks have differing effects on satiety and energy intake and in order to enhance comparability with other studies<sup>(19,20)</sup>. The validity of the digital photographic method was tested prior to the survey in another study against the weighed record method of 19 participants' usual evening meals for five consecutive days. Correlation coefficients between the two methods for intake of major food groups and nutrients, including energy content and macronutrient distribution, were between 0.83 and 0.97.

Comparable means and acceptable limits of agreement (mean difference  $\pm$  2 SD) were found with regard to macronutrient distribution, energy density and energy-adjusted foods<sup>(21)</sup>.

The software program General Intake Estimation Systems (version 0.995f, 2008-08.04; Danish Food Institute, Technical University of Denmark, Soeborg, Denmark) and the Danish Food Composition Databank<sup>(22)</sup> were used to calculate food and nutrient intake for both dietary assessment methods. At the beginning of the study period height and body weight without shoes wearing light indoor clothing were measured at the beginning of the study period using a Soehnle Verona Quattrotronic digital scale (model: 63686) to the nearest 0.1 kg, and a Soehnle 5001 Ultrasonic Height Measure to the nearest cm, respectively. Basal metabolic rate (BMR) was estimated according to Schofield's equations<sup>(23)</sup> and the ratio of estimated energy intake (EI) to the estimated basal metabolic rate (EI:BMR) was calculated. Background information such as gender, age, education, and occupation was assessed using a questionnaire based on the questionnaire from the Danish National Dietary Survey 2000-2002<sup>(24)</sup>.

#### *Statistical analysis*

Outcome variables included fruit and vegetable intake (g per day and per 10 MJ, excluding potatoes and a maximum of 100 g of fruit juice a day in accordance with the Danish dietary guidelines<sup>(25)</sup>), dietary fibre intake (g per 10 MJ), total energy intake (kJ) and energy density excluding beverages (kJ per 100 g) and finally macronutrient intake including total fat, saturated fat, protein, carbohydrate and added sugar (percent of total energy intake). First, all outcome variables were described univariately in terms of unadjusted mean differences between CTA and non-CTA meals. A multivariate analysis was then performed by means of a mixed effects model, using SAS Enterprise Guide 4.0. Meal type was included as a fixed effect as well as gender, age and education (2 levels). To adjust for dependency in repeated measures within subjects, random effects were added for employee. Homogeneity of variance and normality of the residuals were examined using graphical methods. Given the multitude of statistical tests, a P-value of  $<0.01$  was taken in order to reduce the probability of false-positive findings.

## **Results**

### *Subject characteristics*

Half of the participants (52%) were women. The mean age was 40 (SD 6, range 27-52) years and mean BMI was 24 (SD 2) kg/m<sup>2</sup>. Sixty-three % of the participants had completed a medium-term

or long-term higher education. The majority of the participants lived with a partner and children (70%). The rest either lived alone (11%), with a partner or another adult (11%) or with children only (7%).

#### *Evening meal intake*

Employees' nutritional intakes from CTA and non-CTA meals assessed by the digital photographic method are shown in Table 1. The CTA meals contained on average 2.6 MJ (SD 0.8), of which 30.3% (SD 11.0) came from fat, and on average 217 g (SD 78) fruit and vegetables. Average energy density was 462 kJ/100 g (SD 60).

The results from the mixed effects model analysis showed that the CTA meals contained on average 88 g (95% CI: 71 to 104) more fruit and vegetables and 18 g more dietary fibre per 10 MJ (95% CI: 15 to 20) compared to the non-CTA meals ( $p < 0.001$ ). Fat content was on average 7.8 E% lower (95% CI: -10.2 to -5.4) for the CTA meals compared to the non-CTA meals, whereas energy density on average was 187 kJ/100 g lower (95% CI: -225 to -150) compared to the non-CTA meals ( $p < 0.001$ ). A gender-related effect of energy intake was seen (0.9 MJ lower for women compared to men) as well as an age-related effect of dietary fibre intake with decreasing intake with increasing age. Otherwise, there were no significant effects of gender, education or age.

#### *Daily dietary intake*

Average EI:BMR was 1.44 (SD 0.3) with 11% of the participants below the Goldberg cut-off value of 1.06<sup>(26)</sup> (not shown). The data presented on total daily intake in Table 2 include the possible under-reporters, as removal of under-reporters did not change the overall results. The results from the mixed effects model analysis revealed that participants' intake of fruit and vegetables was significantly higher on days receiving CTA compared to days not receiving CTA when expressed both as g per day and as g per 10 MJ, as shown in Table 2. The intake of fruit and vegetables was on average 129 g higher on CTA-days compared to non-CTA days (95% CI: 49 to 210,  $p = 0.002$ ). Difference in intake of vegetables alone was 109 g between meal types (95% CI: 63 to 156,  $p < 0.001$ ). Moreover, energy density and protein content was significantly lower and higher, respectively, on days receiving CTA compared to non-CTA days (95% CI: -133 to -22 kJ/100 g,  $p = 0.007$ , and 1.6 to 3.8 E%,  $p < 0.001$ , respectively). No significant effects were seen of gender, education or age on differences.

## Discussion

The results showed that receiving CTA from the worksite was associated with a higher overall nutritional quality of the evening meals compared to non-CTA meals when using energy density as a dietary quality marker<sup>(27)</sup>. Average energy density of the consumed CTA meals excluding beverages was 462 kJ/100 g (SD 60), which meets the recommendations from the World Cancer Research Fund and the American Institute for Cancer Research regarding lowering average energy density of diets towards 520 kJ (125 kcal) per 100 g excluding drinks<sup>(28)</sup>. Compared to the non-CTA meals, the CTA meals showed several other positive nutritional benefits, including a higher content of both dietary fibre and fruit and vegetables as well as a lower content of fat and saturated fat.

The differences observed in the food and nutrient content between the CTA and the non-CTA meals were generally reflected in dietary intakes across the whole day. The difference in intake of daily fruit and vegetable intake was on average 129 g between CTA and non-CTA days, suggesting that the fruit and vegetables supplied by the CTA did not replace fruit or vegetables that might have been eaten anyway. Most of the difference in fruit and vegetable intake was accounted for by an increase of vegetable intake by 109 g equalling about 1 serving. This is promising, as it is considered more challenging to increase vegetable intake compared with fruits, which require little preparation, and have a sweet taste that appears to be preferred<sup>(29)</sup>.

The present study support findings by Lachat et al that providing fruit and vegetables from a university canteen lead to a higher intake of fruit and vegetables among students both at lunch and on a daily basis<sup>(30)</sup>. Other studies have shown that an increase in the consumption of fast foods and an increase in the consumption of convenience or ready-prepared foods were associated with less healthy diets<sup>(31)</sup>. Bowen and colleagues compared adults mean dietary intake on days having fast food compared to dietary intake on non-fast food days and found substantial differences in energy, energy density and macronutrient intakes in favour of the non-fast food days<sup>(32)</sup>. This seems to be in accordance with consumers' perception that ready meals and fast food are not seen as appropriate for dinner meals<sup>(33)</sup>.

In the present study we have no information on food intake of the participants' families. The evening meals often have special meanings in a family and is often considered as the most significant meal of the day<sup>(34)</sup>. It is likely that the evening meal intake of all the participants' family members were influenced on days receiving CTA. A supportive home environment with access to healthy foods has been found to be an important determinant of healthy eating habits among children and adolescent<sup>(35,36)</sup>, and Jabs and colleagues argue that there is a need to develop

healthful, affordable, child-acceptable, quickly prepared food that could help parents feel good about the way they feed their families<sup>(37)</sup>.

Providing take-away meals from the worksite could provide an alternative convenient and more nutritious food source<sup>(38)</sup> that the consumers also might place more trust in compared to other ready meals from the industry<sup>(33)</sup>. However, the success of the CTA as a health promoting activity relies both on the actual quality of the meals, including the nutritional quality, and on the employers' and the employees' willingness to pay for the meals, that is their perceived costs versus benefits. It is expected that the promotion of healthy CTA provides benefits for the employers in terms of work satisfaction and higher productivity and benefits for the employees and their families in terms of providing tasty, healthy and convenient meals. To match these expectations food service professionals need empowerment. Therefore, an important aim of the present public-private partnership was to develop and disseminate education and practical tools and conditions enabling the canteens to effectively implement and maintain a CTA service, including providing network opportunities and newsletters. Moreover, the simple Healthy Meal Index<sup>(17)</sup> was developed in order to help the canteen personnel to monitor and improve the nutritional quality of the meals offered without the use of nutrition calculation programs. Often, the canteen staff has neither the time nor the skills to perform complicated calculations<sup>(39)</sup>.

The methodology of the present study calls for caution when interpreting the results. Participants served as their own control by comparing nutritional intake on days receiving CTA meals with days not receiving CTA. However, the provision of CTA may have positive or negative nutritional effects on the meal quality and quantity on the days before or after consumption. The size of such systematic errors cannot be estimated. The present study is an explorative study testing the effectiveness of a health promotion strategy under real-life conditions. This may help the adaptation and expansion of research to practice<sup>(40)</sup>. However, the naturalistic experimental approach is often more difficult to manage and often lacks the control that is present in the laboratory<sup>(41)</sup>. Accordingly, participants in the present study could not be randomly selected and were not necessarily representative of the population as a whole. They were higher educated compared to the general population and probably more health conscious and had healthier lifestyles. This means that the ability to discriminate between nutritional intakes on different days receiving CTA or not receiving CTA could have been reduced to some degree. Moreover, extrapolation of the results to individuals with different occupational profiles cannot be done.

The present study is the first study to our knowledge to evaluate the effectiveness of the CTA concept in promoting healthy eating. The results are supported by two different dietary assessment methods assessing total daily intake using 24-h recalls as well as dinner meal intake separately using a digital photographic method for recording in real time over a prolonged period of time. The limitations of 24-h recalls in capturing habitual intake at the individual level include a large day-to-day variation as well as possible under-reporting due to dependence on memory<sup>(42)</sup>. Another limitation of the 24-h recall is that social desirable answers could be higher due to the presence of an interviewer. The mean EI:BMR of 1.4 in the present study likewise indicates that some under-reporting did occur. To avoid bias caused by either underestimation or different energy requirements the amount of fruit and vegetables and nutrients were adjusted for energy intake and expressed either per 10 MJ or as percentage of total energy intake. More studies are needed to confirm the initial findings of the present study and to further develop feasible and effective environmental level strategies for health promotion within and across the settings of everyday life.

In conclusion, the results from the present study suggest that providing healthy take-away dinners from the worksite constitute a potential for promoting healthy dietary habits among employees. The nutritional quality of the employees' evening meals as well as the overall quality of their diet was significantly enhanced on days receiving CTA compared to days not receiving CTA. This reinforces the importance of availability and convenience as effective tools in promoting healthy eating habits and provides the worksites with an important role in enabling and promoting healthy eating pattern even across the contexts of worksite and family.

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**Table 1** Employees' evening meal intake on days receiving CTA and on days not receiving CTA (beverages not included)

	CTA meals (n=144)		non-CTA meals (n=236)		Un- adjusted difference	Adjusted difference <sup>3</sup>			P- value
	Mean	SD	Mean	SD	Mean	Mean	95% CI		
Energy (kJ)	2557	802	3102	1598	-545	-540	-791	-289	<0.001
Energy density (kJ/100 g)	462	60	648	227	-186	-187	-225	-150	<0.001
Carbohydrate (E%)	41.8	9.0	40.8	13.0	1.0	0.8	-1.4	3.2	0.47
Protein (E%)	27.7	5.6	20.9	8.0	6.8	6.7	5.3	8.2	<0.001
Fat (E%)	30.3	11.0	38.2	12.3	-7.9	-7.8	-10.2	-5.4	<0.001
Saturated fat (E%)	9.3	4.4	15.8	6.9	-6.5	-6.5	-8	-5	<0.001
Added sugar (E%)	0.3	1.2	2.9	6.4	-2.7	-2.7	-4	-2	<0.001
Fibre (g/10 MJ)	42	13	24	14	18	18	15	20	<0.001
Fruit and vegetables (g) <sup>12</sup>	217	78	129	89	88	88	71	104	<0.001
- Vegetables (g) <sup>1</sup>	200	71	117	87	83	83	67	98	<0.001
- Fruit (g) <sup>2</sup>	16	30	12	28	5	5	-1	11	0.10
Fruit and vegetables (g/10MJ) <sup>23</sup>	868	252	478	372	390	390	323	457	<0.001
- Vegetables (g/10MJ) <sup>1</sup>	807	250	444	380	363	363	295	431	<0.001
- Fruit (g/10MJ) <sup>2</sup>	61	111	34	82	27	27	7	46	0.01

<sup>1</sup> Excluding potatoes

<sup>2</sup> Including not more than 100 g fruit juice per person per day

<sup>3</sup> Adjusted difference from a multivariate analyses performed by means of a mixed effects model

**Table 2** Employees' total daily intake on days receiving CTA and on days not receiving CTA

	CTA days		non-CTA		Un-	adjusted			
	(n=41)		days (n=67)		difference	Adjusted difference <sup>4</sup>			
	Mean	SD	Mean	SD	Mean	Mean	95% CI		p-value
Energy (kJ)	9881	3357	9581	3204	301	250	-691	1190	0.60
Energy density (kJ/100 g) <sup>1</sup>	603	140	685	182	-82	-77	-133	-22	0.01
Carbohydrate (E%)	47.4	6.8	49.0	7.9	-1.6	-1.3	-4.0	1.4	0.33
Protein (E%)	18.8	3.3	15.8	3.0	3.0	2.7	1.6	3.8	<0.001
Fat (E%)	32.1	6.5	32.8	6.9	-0.7	-0.7	-3.1	1.7	0.57
Saturated fat (E%)	12.1	3.6	13.6	3.7	-1.4	-1.4	-2.7	-0.1	0.03
Added sugar (E%)	5.6	5.0	6.7	5.1	-1.0	-0.7	-2.4	1.1	0.46
Fibre (g/10 MJ)	32	10	29	10	3	3	0	5	0.06
Fruit and vegetables (g) <sup>23</sup>	703	241	555	266	148	129	49	210	0.002
- Vegetables (g) <sup>2</sup>	383	190	254	162	129	109	63	156	<0.001
- Fruit (g) <sup>3</sup>	320	203	301	204	20	17	-50	83	0.62
Fruit and vegetables (g/10MJ) <sup>23</sup>	784	379	615	321	169	146	56	236	0.002
- Vegetables (g/10MJ) <sup>2</sup>	440	330	285	242	155	126	61	191	<0.001
- Fruit (g/10MJ) <sup>3</sup>	344	210	330	218	14	17	-52	87	0.62

<sup>1</sup> Excluding beverages<sup>2</sup> Excluding potatoes<sup>3</sup> Including not more than 100 g fruit juice per person per day<sup>4</sup> Adjusted difference from a multivariate analyses performed by means of a mixed effects model

The present PhD thesis contributes to the evidence of effective healthy eating promotion initiatives at the worksites. It provides novel insight into three research areas: Digital photographic methods for assessing food intake, development of a tool to evaluate the nutritional quality of individual meals and finally the effectiveness of a healthy Canteen Take Away concept in improving the diets of the employees.

The results from the thesis reinforce the importance of availability and convenience as effective strategies to promote healthy eating habits, and it provides a stimulus for further action in worksites to enable and promote healthy eating pattern among employees even across the contexts of worksite and family.

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