

## Web-based Dietary Assessment for 8-11 Year Old School-children

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# Web-based Dietary Assessment for 8-11 Year Old School- children



Anja Biloft-Jensen  
PhD Thesis  
2012



# **Web-based Dietary Assessment for 8-11 Year Old School- children**

**PhD thesis 2012**  
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DTU Fødevareinstituttet  
Afdeling for Ernæring

# Web-based Dietary Assessment for 8-11 Year Old Schoolchildren

PhD Thesis by Anja Biloft-Jensen

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# Preface

This thesis describes the development and validation of a Web-based Dietary Assessment Software for 8-11-year-old Children (WebDASC) that is suitable to be used in the OPUS (Optimal well-being, development and health for Danish children through a healthy New Nordic Diet) School Meal Study, and supported by a grant from the Nordea Foundation. This PhD project is based on work carried out at the Division of Nutrition, National Food Institute, Technical University of Denmark through May 2009 to April 2012.

The OPUS School Meal Study is part of the OPUS Centre that runs from 2009 till 2013. It includes six research institutions and is based at LIFE - The Faculty of LIFE Sciences at Copenhagen University. The OPUS centre aim to develop a healthy and palatable new eating concept "The New Nordic Diet" and to examine how such a diet can affect mental and physical health. The OPUS School Meal Study compares the New Nordic Diet with the current situation in schools (packed lunch from home and/or school canteens/small shops etc.). The purpose is to study how school meals based on the New Nordic Diet affects children's academic performance and behaviour, body weight and body composition as well as their risk of developing lifestyle diseases such as type 2 diabetes, osteoporosis and cardiovascular diseases. Children aged 8-11 (grades 3 and 4 in the Danish school system) will participate in the OPUS School meal study. The current PhD thesis is conducted within the frame of the first part of the OPUS School Meal Study the so-called OPUS School Meal *pilot study*, which ran from January 2011 to May 2011.

The intention with the present project was to contribute with a suitable dietary assessment method for children that were developed for the purpose of a large intervention study, and to devote effort to ensure that it was carried out the best way possible in order to obtain the best possible data.

In the end, as Socrates pointed out, the big question is: "How should one live one's life? To decide, one needs good data!"

Anja Biloft-Jensen, May 2012



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I would also like to thank Senior Advisor Tue Christensen for conduction of data processing, ensuring web-hosting, assisting with web-based background interview, for sharing his insight into web-design, and assistance with many technological challenges and for ideas to the administration modules and solutions for coping with open answers, Project Assistants Mia H. Frandsen and Trine H. Nielsen for helping with the food list and the portion size images and for assisting with study materials, coordination and conduction of interviews, instructions and observations, PhD Anne Vibeke Thorsen for assisting with the observations, Data Manager Karsten Kørup for helping designing the output tables, conduction of data processing and for developing the In-House administration module, and to Research Dietician Karin Hess Ygil for skilled design of the recipe database and help with the final data processing of the digital images. All from DTU National Food Institute, Division of Nutrition. Their help and assistance was indispensable for the success of the project.

A special thank to David Wiktorsson for coding the software and for many invaluable input during the process and to Simon Egenfeldt-Nielsen and Mikkel L Overby for design input and managing the software development. All from Serious Games Interactive.

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Finally, I am so grateful to my family, to my husband Peter and my children Cecilie, Kasper and Nikoline for their love, understanding and support they have given me during this project.

# Abbreviations

DANSDA	Danish National Survey of Diet and Physical Activity
BMI	Body Mass Index
BMR	Basal Metabolic Rate
DIT	Diet Induced Thermogenesis
EDTA	Etylen-Diamin-Tetra-Eddikesyre
EI	Energy Intake
FFQ	Food Frequency Questionnaire
FD	Food Diary
FJV	Fruit, Juice and Vegetables
HPLC	High Performance Liquid Chromatography
NND	New Nordic Diet
OPUS	Optimal well-being, development and health for Danish children through a healthy New Nordic Diet
PAEE	Physical Activity Energy Expenditure
PAL	Physical Activity Level
SD	Standard Deviation
TEE	Total Energy Expenditure
24 hour recall	24hR
WebDASC	Web-based Dietary Assessment Software for Children

# List of papers

This PhD thesis is based on the following three papers (Paper 1-3), referred to in the text by their numbers and are reproduced in full as appendices.

## Paper 1:

Biltoft-Jensen A, Trolle E, Christensen T, Islam N, Andersen LF, Egenfeldt-Nielsen S, Tetens I. A Web-based Dietary Assessment Software for 8-11 Year Old Danish Children. *Journal of Human Nutrition and Dietetics*, 2012 (Accepted).

## Paper 2:

Biltoft-Jensen A, Hjorth MF, Trolle E, Christensen T, Brockhoff PB, Andersen LF, Tetens I, Matthiessen J. Comparison of estimated energy intake in children using Web-based Dietary Assessment Software with accelerometer-estimated energy expenditure. February 2012 (Submitted).

## Paper 3:

Biltoft-Jensen A, Bysted A, Trolle E, Christensen T, Knuthsen P, Damsgaard CT, Andersen LF, Brockhoff P, Tetens T. Evaluation of a Web-based Dietary Assessment Software for children: comparing reported fruit, juice and vegetable intake to plasma carotenoid concentration and lunch intake observation. April 2012 (Submitted)

# Summary

## *Background and aim*

The potential health effects of a New Nordic Diet (NND) are to be tested in the Danish OPUS (Optimal well-being, development and health for Danish children through a healthy New Nordic Diet) School Meal study among 8-11-year-old school-children. Valid and reliable dietary assessment methods are essential for identifying how eating habits may change in response to the intervention and for identifying the impact of the children's dietary habits on their health and weight status. Several challenges are connected to collecting dietary data from children including their cognitive ability and social desirability which in addition is influenced by the OPUS study. Furthermore, they are untrained in the task and they may not be involved in food shopping or preparation and therefore have little insight into the foods they eat.

The overall aim of the present project was to deliver a validated and suitable dietary assessment tool that could be used by 8-11-year-old Danish school children to assess dietary intake in the OPUS School Meal Study. The specific objectives were to develop a dietary assessment tool suitable for 8-11-year-old children feasible to be used in the OPUS School Meal Study (Paper 1), to validate the developed dietary assessment tool by a combination of validation methods in order to obtain information about the reporting accuracy including the acceptability, under-reporting and over-reporting, and repeatability of WebDASC (Paper 2), and the overall- and lunch specific reporting accuracy of fruit, juice and vegetables (Paper 3).

## *Materials and methods*

The development of a Web-based Dietary Assessment Software for 8-11-year-old Children (WebDASC) followed a prototyping approach: Considerations about factors connected to the OPUS study aim of relevance to the dietary assessment, data level, available resources, and input from professionals, focus groups, literature review, and usability tests preceded its release. Special consideration was given to age-appropriate design issues.

In the validation study, which were conducted as a part of the OPUS School Meal *pilot study*, 81 school children 8-11-year-old, assisted by parents, recorded their diet in the WebDASC and wore an accelerometer on the same 7 consecutive days twice: at baseline with the habitual diet, and at intervention with the NND. On the same 5 school days as they reported their diet in WebDASC the children's school lunch was photographed and weighed before and after lunch. During the week after the baseline food- and activity recording fasting blood samples were taken. The acceptability of WebDASC was assessed with a questionnaire. Energy intake (EI) estimated with WebDASC was evaluated against accelerometer-estimated energy expenditure using Bland-Altman plot, correlation and Kappa statistics. The repeatability of EI was assessed using Intraclass correlation coefficient. Furthermore, the accuracy of self-reported fruit, juice and vegetable (FJV) intake was evaluated by comparing intake to plasma carotenoids concentration using correlations and Kappa statistics. Intervention effect, weekday and meal effect in FJV intake, and effects of background factors were assessed using Linear Mixed Models. Finally, the accuracy of reporting FJV intake at school lunch were measured by scoring the reported intake in WebDASC against FJV actually eaten observed by the digital photos as either matches, intrusion, omission and faults.

## *Main findings*

WebDASC was developed as an intuitive, cost-effective, and engaging method to collect detailed dietary data from 8-11-year-old children. Results from the acceptability questionnaire demonstrated that it was well accepted among children and adults. Results from the validation study showed that on group level reported EI was in agreement with total energy expenditure (TEE). However, 20% was classified as under-reporters and 20% as over-reporters. Mis-reporting was associated to weight status and a higher body mass index (BMI) characterized under-reporters, and a lower BMI characterized over-reporters compared to acceptable-reporters. The repeatability of EI was fair. Reporting that illness affected eating influenced reported EI and FJV intake. The WebDASC estimated intake of FJV was significantly correlated with carotenoid plasma concentration, and Spearman and Partial correlation coefficients adjusted for gender, BMI, and TEE showed correlations of 0.58 and 0.49 respectively ( $p < 0.01$ ). Fruits and juice showed higher correlations than vegetables with plasma carotenoid concentration. The results from the photographic observations of school lunch demonstrated that WebDASC

attained 82% reporting matches overall and higher percent match for reporting fruits compared to beverages. Intrusions (reporting of FJV not eaten or reporting too large portion size) were the most common reporting mistake (90%). Among intrusion it was more common to report fruit and vegetables not eaten (65%) than reporting a portion size image illustrating a larger portion than the eaten portion size (35%).

#### *Conclusions and implications*

The thesis demonstrated that it is possible to develop a child appealing web-based dietary assessment tool that can be used at home on the family's home computer. The developed WebDASC was acceptable to use for both 8-11-year-old children and their parents, and feasible to use in the OPUS School Meal *pilot study*.

The WebDASC provides good estimates of average energy intake compared to the estimated total energy expenditure. Moreover a moderate repeatability of EI was observed. The ability of the WebDASC to rank participants according to energy intake was fair. The validation study demonstrated that under-reporting and over-reporting was associated to the weight status and BMI of the children. Possible causes may be the weight and health focus of the study, social desirability and the diet reporting itself.

When using plasma carotenoid concentrations as a reference, the WebDASC's ability to rank participants according to FJV intake was good and the WebDASC obtained a high percent matches for FJV intake and overall intake at school lunch.

In conclusion the WebDASC is both acceptable and feasible to use to collect dietary data from 8-11-year-old children in intervention studies. This project demonstrated that, in the study population, data could be used to estimate energy intake on group level and to rank individuals according to EI, and to rank FJV intake both overall and on school meal level, and thereby contribute to the understanding about associations of fruit and vegetable intake, which is an important nutritional indicator for healthy eating habits, and the development of lifestyle diseases.

# Sammendrag (Danish summary)

## *Baggrund og formål*

De potentielle sundhedsmæssige virkninger af Ny Nordisk Hverdagskost (NNH) skal testes i en dansk skolemadsundersøgelse blandt 8-11 årige skolebørn kaldet OPUS (Optimal trivsel, udvikling og sundhed for danske børn gennem en sund ny nordisk kost) skolemadsundersøgelsen (OPUS School Meal Study). I den forbindelse er en valid og pålidelig kostregistreringsmetode afgørende for at kunne identificere, hvordan børnenes kost ændrer sig som følge af interventionen med NNH og for at måle effekten på deres sundhed og vægtstatus. Der er forbundet adskillige problemer med at indsamle kostdata fra børn. Dels pga. deres kognitive formåen og dels pga. den påvirkning, de får fra selve deltagelsen i OPUS skolemadsundersøgelsen. Herudover kan børnene have ønske om at afgive socialt accepterede svar. Desuden er børn i 8-11 års alderen utrænede i at kostregistrere, og hvis de ikke er involveret i madlavning eller indkøb, har de måske også lille indsigt i den mad, de spiser.

Det overordnede formål med nærværende projekt var at blive i stand til at måle effekten af kostinterventioner blandt børn generelt og i OPUS skolemadsinterventionen ved at udvikle et alderssvarende og nøjagtigt kostregistreringsværktøj der kan anvendes af 8-11 årige danske skolebørn.

De specifikke formål var:

1. At udvikle et målrettet kostregistrerings værktøj velegnet til 8-11 årige børn til brug i OPUS skolemadsundersøgelsen (artikel 1),
2. At validere det udviklede værktøj ved hjælp af en kombination af valideringsmetoder med henblik på at få indsigt i brugernes accept, forekomst af under-og over-rapportering, samt reproducerbarhed (artikel 2)
3. At validere det rapporterede frugt, juice og grønt indtag generelt og på skolemåltids niveau (artikel 3).

## *Materialer og metoder*

Der blev udviklet et web-baseret kostregistreringssoftware velegnet til 8-11 årige børn (WebDASC).

Udviklingsstrategien, som fulgte en prototype strategi, inkluderede: overvejelser vedrørende OPUS skolemadsundersøgelsens formål med relevans for kostregistreringen, det nødvendige data-niveau, de tilgængelige ressourcer, samt input fra fagfolk, fokus grupper, litteratur gennemgang og brugertests. I udviklingen blev givet særlig fokus til alderssvarende design.

Valideringen af WebDASC blev foretaget som en del af OPUS pilot skolemadsundersøgelsen. 81 skolebørn i 8-11 års alderen registrerede, med hjælp fra deres forældre, deres kost i WebDASC og bar et accelerometer i 7 på hinanden følgende dage. Dette gjorde de i 2 perioder: ved baseline, hvor de spiste deres sædvanlige skolefrokost, og ved interventionen, hvor de fik NNH til skolefrokost og mellemmåltider. På de samme 5 skoledage, hvor de registrerede deres kost i WebDASC, blev børnenes skolefrokost fotograferet og vejet før og efter frokost. I ugen efter kostregistreringen ved baseline fik børnene taget blodprøver. Brugeraccepten af WebDASC blev vurderet ved hjælp af et spørgeskema udviklet til formålet. Energiindtaget (EI) estimeret med WebDASC blev evalueret i forhold til accelerometer-beregnet energiforbrug og testet statistisk ved t-test, Bland-Altman plot, korrelation og Kappa analyser. Reproducerbarheden af EI blev vurderet ved hjælp af Intraclass korrelation. Endvidere blev validiteten af selvrapporteret frugt, juice og grønt (FJG) undersøgt ved at sammenligne det rapporterede indtag med koncentrationen af karotenoider i plasma. Linære mixede modeller blev anvendt til at undersøge for interventionseffekt, ugedag- og måltidseffekt på FJG indtaget og effekten af baggrundsvariable på henholdsvis EI, energiforbrug og FJG. Endelig blev nøjagtigheden af det rapporterede FJG indtag til skolefrokosten undersøgt ved at vurdere det rapporterede indtag i WebDASC mod det faktisk spiste FJG (vurderet ved digitale fotos). Denne vurdering blev opgjort som enten overensstemmelse (matches), lagt til (intrusions), udeladelser (omissions) og fejl (faults).

## *Resultater*

Resultater fra brugerundersøgelsen viste, at både børn og voksne fandt WebDASC velegnet til at registrere kosten i OPUS pilot skolemadsundersøgelsen. Resultater fra valideringen af EI viste, at det gennemsnitlige rapporterede EI var i overensstemmelse med det gennemsnitlige samlede energiforbrug. Imidlertid blev 20 % af børnene klassificeret som under-rapportører og 20 % som over-rapportører. Fejl-rapporteringen var associeret til

vægtstatus, og det blev fundet, at et højere body mass index (BMI) karakteriserede under-rapportører, og et lavere BMI karakteriserede over-rapportører i forhold til acceptable-rapportører. Reproducerbarheden af EI var acceptabel. Sygdom i registreringsperioden havde både indflydelse på EI og FGJ indtag.

Det rapporterede indtag af FJG var signifikant korreleret med plasma koncentrationen af karotenoider. Spearman og Partial korrelationskoefficienter justeret for køn, BMI, og energiforbrug viste korrelationer på henholdsvis 0,58 og 0,49 ( $p < 0,01$ ). Frugt og juice viste højere korrelationer end grøntsager med koncentrationen af karotenoider i plasma. Resultater fra de digitale observationer af skolefrokosten viste, at 82 % af det rapporterede indtag ved skolefrokost var i overensstemmelse med det faktisk spiste, og at frugt i flere tilfælde var korrekt registreret i forhold til drikkevarer. Den mest almindelige fejlrapportering, når børnene rapporterede FGJ, var FGJ som de havde lagt til (90 %). Blandt FJG som var lagt til, var den mest almindelig fejl at rapportere FJG, som de ikke havde spist ifølge det digitale billede (65 %) i resten af tilfældene (35 %) rapporterede de en eller flere portionsstørrelser større end den faktisk spiste.

#### *Opsummering og konklusion*

WebDASC blev udviklet som en intuitiv og engagerende metode til at indsamle detaljerede kostdata fra 8-11 årige børn. Afhandlingen viser, at det er muligt at udvikle et web-baseret kostregistreringsværktøj, der er målrettet børn, og som kan bruges hjemme på familiens hjemmecomputer. Det udviklede WebDASC var acceptabelt at bruge for både 8-11-årige børn og deres forældre og muligt at anvende i OPUS skolemads pilotundersøgelsen.

OPUS undersøgelsens fokus på vægt og sundhed, ønske om at fremstå med socialt accepterede kostvaner og selve kostregistreringen, har muligvis påvirket forældre til at ændre familiens kostvaner og rapportere en gunstigere kost i forhold til barnets vægtstatus.

På gruppeniveau blev der registreret et EI i WebDASC i overensstemmelse med energiforbrug, og EI var reproducerbar mellem baseline og intervention. På individniveau kunne vises en acceptabel rangering af EI i forhold til energiforbrug. Herudover udviste det rapporterede indtag af FJG en god rangering i forhold til koncentrationen af karotenoider i plasma. Det registrerede indtag af FJG i WebDASC til skolefrokost havde en god overensstemmelse med det, der ifølge observationer foretaget med billeder, blev spist.

Som konklusion viste projektet at det både er acceptabelt og muligt, at anvende WebDASC til at indsamle kostdata fra 8-11-årige børn i interventionsstudier. I undersøgelsespopulationen kunne data bruges til at estimere energiindtag på gruppeniveau. På individniveau kunne data anvendes til at rangere individer efter EI og FJG indtag både generelt og på skolemåltidsniveau og dermed bidrage til forståelsen af sammenhænge mellem frugt og grønt indtag, som er en vigtig ernæringsmæssig indikator for sunde kostvaner og udvikling af livsstilssygdomme.



# 1. Background

This thesis presents the development and validation of a suitable dietary assessment method for 8-11-year-old Danish School Children to be used in the OPUS (Optimal well-being, development and health for Danish children through a healthy New Nordic Diet) School Meal Study. This chapter first presents, in short the OPUS School Meal Study. Thereafter descriptions of factors influencing children's ability to self-report diet intake, and finally feasible and relevant methods that can be used to validate a newly developed dietary assessment tool are described.

## 1.1 Rationale for the OPUS School Meal Study

Children's lifestyle have increasingly become a focus of research, since obesity and other life-style related diseases seem to be initiated already in childhood (Koplan *et al*, 2005). The children's diet influences to a large extent their health, growth and development (World Health Organisation, 2003). Recent data from the Danish National Survey of Diet and Physical Activity (DANSDA) 2003-08 show that the diets of Danish children contain too many energy-dense, nutrient-poor foods and too much sugar, salt and fat and saturated fat and to little wholegrain, fruits and vegetables and fish (Pedersen *et al*, 2010). Furthermore, data from DANSDA show that between 1995 and 2005-08, the proportion of overweight children (4-18 years) in Denmark has increased from 11% to 17% (Personal communication with Jeppe Matthiessen).

Continued efforts that focus on healthy eating in childhood may have greater prevention potential than later changes (Morrison *et al*, 2008; Freedman *et al*, 2004; Magarey *et al*, 2003). Therefore, initiatives to establish healthy dietary habits should start in childhood. Several intervention studies have been conducted within the framework of the school with the purpose of changing unhealthy eating habits among children (Lien *et al*, 2010; Foster *et al*, 2010). One of the advantages of using a school-based approach is that children attending public schools constitute a population across all ethnic and socioeconomic groups. This makes it possible to reach also socially disadvantaged whom are likely to benefit most from an intervention with a healthy diet.

## 1.2 The OPUS School Meal Study design

The large multidisciplinary OPUS Centre was established in 2009 to advance public health and obesity prevention among children. OPUS promotes the concept of the New Nordic Diet (NND). NND is based on sustainable food items native to the Nordic region, and three fundamental guidelines have been formulated:

- More energy from plant foods and lesser from meat.
- More foods from the sea and lakes.
- More foods from the wild countryside (Mithril *et al*, 2012).

Whole-grains, fruits and berries, root vegetables, cabbages, legumes, game, seaweed, fish, nuts, rapeseed oil and meat from free range livestock are characteristic foods of the NND.

In a Danish 3 month intervention study, The OPUS School Meal Study, the school lunch menus of 8-11-year-old school children will be based on these NND guidelines.

The overall research aim of the OPUS School Meal Study is to examine the impact of serving school meals based on the NND on dietary intake, nutrient status, growth, body composition, and risk markers of lifestyle diseases (assessed by a metabolic syndrome score and a omega-3 Index in whole-blood), common illnesses (e.g. cold, headache, flu etc.) and medicine use, absence from school, cognitive function, social and cultural features, food acceptance, food waste and cost.

The OPUS School Meal Study is a cluster-randomized controlled unblinded cross-over study. In two 3-month periods children receive either school meals, including snacks, based on the NND (3 months intervention) or their usual packed lunch (3 months control) in random order. Dietary assessment and other measurements will be performed three times: before the start of the intervention/control period (1), at the end of the intervention/control period (2) and at the end of the control/intervention period (3) Figure 1.

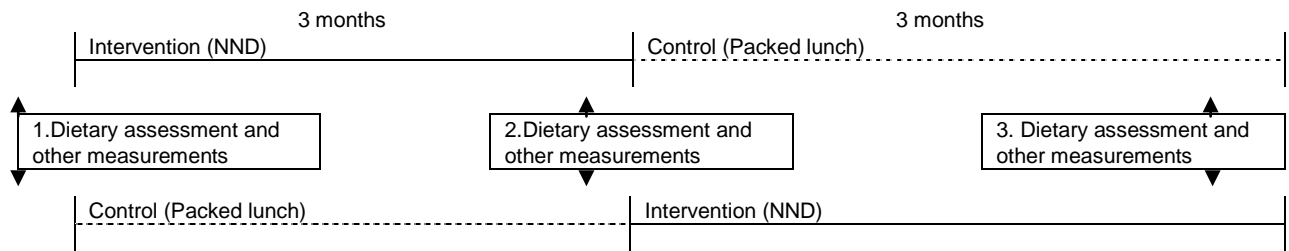


Figure 1. The design of the OPUS School Meal Study

An overview of the intended content of the dietary components in the NND compared to the content in diets of 8-11-year-old children from the DANSDA 2000-08 is presented in Table 1. The NND will be served during school days only, and after an “ad libitum” concept: the children choose themselves the combination and amount of foods.

Table 1. Content of the average dietary components in New Nordic Diet (NND), compared to content in the diet of 8-11 year old children (from the Danish National Survey of Diet and Physical Activity 2000-2008).

NND* Foods/Nutrient	Content in the NND	Intake of children 8-11 years 2000-08	Difference aimed at by NND
	g/10 MJ	g/10 MJ (std)	g/10 MJ
Whole grain	>75	35 (24)	40
Potatoes	140	85 (64)	55
Vegetables	>400	150 (81)	250
Root vegetables	>150	43 (46)	107
Legumes	>30	0,4 (4)	30
Cabbage	>29	3 (9)	27
Fresh herbs	Unlimited	>1	-
Seaweed	5	>1	5
Fruit	>300	213 (145)	87
Berries	50 -100	4 (18)	46 - 96
Nuts	>30	0,5 (2)	29
Fish and shellfish	>43	14 (16)	29
Free range livestock	85 -100	131(39)	-46 - -31
Game	>4	>1	4

The assessment of what the children in the OPUS School Meal Study eat and drink, and how this changes in response to the intervention with the NND is crucial to document intake, and to measure a potential effect of the NND diet and if it influences growth, health, overweight and obesity etc. A special challenge is to assess the intake of the NND. A feasible dietary assessment tool to accomplish this, within available resources, did not exist in Denmark. Therefore, there was a need to develop and validate a dietary assessment tool suitable for 8-11-year-old children that in the context of the OPUS School Meal Study could provide for a comprehensive assessment of the children’s diet including intake of NND.

### 1.3 Assessment of dietary intake in school children (8-11-year-old)

To assess dietary intake is an ongoing challenge, with specific challenges for children.

Assessing diet intake often require the respondent to remember and give a lot of information about diet intake itself and also other issues related to diet intake. This can include information about weekday of intake, time used for eating, naming of eating occasion, place of eating occasion, and reporting diet intake at a detailed level, portion size of the intakes, and hence, being able to relate the portion size eaten to e.g. images, household measures or models. At many of these tasks the children’s attention can get lost due to burden/complexity. The abilities required to self-report food intake has been identified as an adequately developed concept of time, a good memory and attention span, and knowledge of the names of food. However, these skills are not always sufficiently developed in school aged children (National Cancer Institute, 2007).

Both 24 hour Recalls (24hR), Food Diaries (FD) and Food Frequency Questionnaires (FFQ) have been used in school age children (McPherson *et al*, 2008;National Cancer Institute, 2007).

Validation studies among children show that correlations between the reference method and dietary assessment tool are almost always higher for 24hR and FD than for FFQ and that diet history seldom has been used in studies with children (McPherson *et al*, 2008).

Dietary assessment rely in general on respondents self-reported intakes either by children them self or by parents or a combination. The accuracy of these self-reports may be compromised because of: 1. Cognitive factors as children's memory of food intake, ability to estimate portion size and knowledge of food names etc. (Livingstone *et al*, 2004); 2. Social desirability such as reporting in line with perceived norms (Macdiarmid & Blundell, 1998); and study factors as taking part of an intervention study focusing on healthy dietary habits and the diet reporting itself may also cause a change in eating habits.

Ways to reduce mis-reporting in dietary assessment may include obtaining cooperation from the respondent, use of engaging methods, and employing a level of detail that children are able to respond to.

### **1.3.1 Cognitive factors**

Errors associated with children's recall of food intake include both under-reporting (missing foods), over-reporting (phantom foods/intrusions), and incorrect identification of foods because of a limited knowledge about foods (Baxter, 2009). It has been suggested that children are able to provide reliable reports on their food intake by the age of 10 years, but only for the previous 24 hours, and provided that the time period under investigation is not subject to irregular events and/or eating pattern (Livingstone & Robson, 2000). This has, however, been questioned by Domel Baxter who found that 10 years old children only reported 67% of the items observed eaten, at school breakfast and lunch the previous day, and 17% of the items reported were not observed eaten (Baxter *et al*, 2003a). Diet records, if filled in while eating or immediately after eating, is not necessarily prone to the same memory biases.

The accuracy of children's estimates of portion size using age-appropriate photographs has shown not to be different from that of adults in a study by Foster *et al*. (Foster *et al*, 2009), however the validation was conducted in an artificial situation where the foods were provided and all children were served the same foods and the same portion size. To document their usability, the portion size images should be validated against habitual intake in a free living situation.

#### *Level of detail*

The scientific literature has delivered more specific information on what age children can self-report their diet (National Cancer Institute, 2007), however, the literature is limited regarding the level of details children can report about their food intake.

From the literature dealing with children as respondents in surveys in general, a rule of thumb is that children are able to answer many questions that are directly relevant to them. On the contrary they usually do not have any insight or knowledge into other people's doings (Haraldsen & Dale, 2002). This means that most children to some extent can report what they are eating (taking from the plate or glass and put into their mouth). If the children are not involved in cooking or food shopping, which 97 % of Danish children are not, they will have little knowledge of food preparation and brand names of the foods and will be unable to answer questions concerning this (DANSDA 2005-08, unpublished results). Therefore, details about cooking and brand names should not be included in a diet assessment method targeted this age group.

#### *Parent assistance*

Most validity and reliability studies among children younger than 9 years have included adult assistance providing information on the child's intake (National Cancer Institute, 2007). Results from studies comparing the results of direct observations of children's food intake with 24hR by parents, suggest that parents can be reliable reporters of their children's food intake in the home setting, but less reliable reporters of their children's food intake out of home (Baranowski *et al*, 1991). Given that most Danish parents work out-of-home, the suitability of parents to be the only informants of their child's intake is limited. Proxy persons, as child minders, are often used as surrogate

reporters in studies of younger children's intake, when the child is away from home (National Cancer Institute, 2007).

For a part of children 10 years and older, assistance from parents or teachers would be seen as an intrusion, and the children would want to complete the dietary assessment by themselves (Livingstone *et al*, 2004).

Some questions have also been raised about the bias that parents may provide to their child's report of intake (Livingstone *et al*, 2004). A Finnish study showed that parents were more likely to report health behaviours in line with recommended and desired behaviours than children do (Ross *et al*, 2009). However, a recall where the mother and/or father assists and cooperate with the child may yield better estimates than the child or parent alone as suggested by Eck *et al* (Eck *et al*, 1989). The parents can assist by prompting children, adding food details and assist with practical issues connected to reporting.

### **1.3.2 Social desirability**

Children may purposely under-report or over-report some dietary habits because they are either socially undesirable or desirable, respectively. Children and/or their parents may alter their reports of intake to avoid feelings of guilt, embarrassment or criticism which may arise from deviating from the social norm.

Social desirability has been found to bias reports of diet and confound associations between body mass index (BMI) and energy intake (EI). A study found that socially desirable responses are more frequently given by younger than by older children (Baxter *et al*, 2004a) and another study found that the number of reported items for breakfast was negatively associated to social desirability (Guinn *et al*, 2008).

The effect of social desirability will be exaggerated when the individual is aware of being observed (Macdiarmid & Blundell, 1998). Interviewer administered 24hR, where children and/or parents are sitting in front of an interviewer, have shown to provide social desirability biases (Guinn *et al*, 2008; Sherwood, 2008). This may not occur to the same extent when reporting in private.

Groups wanting to appear with a socially desirable image have a higher probability of being overweight (Macdiarmid & Blundell, 1998). Dieting and weight consciousness have been identified as having the most frequent and consistent associations with mis-reporting. Reporting accuracy may also be compromised by parental obesity status and/or by the extent to which parents perceive that such information is a reflection of their child's weight (Livingstone *et al*, 2004). In a study by Baranowski and colleagues children (9-11 years) were asked to provide a hair sample and were told, "We can tell some of what you eat from a chemical analysis of your hair". Obtaining a hair sample reduced the omission rate and increased the match rate for 24hR versus observation (Baranowski *et al*, 2002). This finding suggests that a small part of the inaccuracy of children's self-reports is deliberate and might be due to social desirability (National Cancer Institute, 2007).

### **1.3.3 Study factors**

Study factors is the sum of study introduced factors beyond wilful control. They can include factors as: the entering of an intervention study that focuses on body weight and healthy eating habits, having clinical measurements or blood samples taken as indicators of diet, health or lifestyle diseases. These factors may unconsciously change what and how much a respondent consume, because the focus of respondents change. Reporting food intake may in itself cause reactivity and a change in habits because focus changes towards the diet. This is especially a risk with the FD method, because reporting foods as they are being eaten can affect both the types of foods chosen and the quantities consumed and lead to under eating in the reporting period (Thompson & Subar, 2008). Furthermore, completing food records is time consuming, and for some perceived as boring. Boredom and fatigue affect dietary information retrieval especially when using self-administered tools with children (Domel *et al*, 1994). This may lead to mis-reporting or alternative eating habits substituting foods which is easier to report or not taking second helpings, because it is too much hassle to report it (Macdiarmid & Blundell, 1998). Mis-reporting can also be a result of the participant's limited ability to use- and report in the dietary assessment tool.

24hR and FFQ are known to place less burden on respondent compared to records, because the administration time is relatively low, and in the case of a 24 hour interviewer administered recall, the interviewer administers the tool and records the responses. It is often emphasized that the 24hR and FFQ do not alter eating habits because diet intake has already occurred at the time reporting takes place.

### **1.3.4 Co-corporation of respondent**

A factor connected with self-reported dietary intake, which might help overcome some of the mentioned difficulties, and which is seldom mentioned in the literature, is the importance of obtaining full cooperation from respondent. A special challenge is to engage children and obtain the needed cooperativeness in diet reporting because they are unfamiliar with the respondent tasks needed in dietary assessment. Assessment tools should back up the cooperativeness of children and parents by being e.g. intuitive, easy and fast to complete, flexible in choices, non-intrusive, engaging, age appropriate and fun. The possibility for feedback, and/or recognition in form of a payment/gift that indicates that respondent is doing an important job may also be important. Furthermore, it may also be important how (face to face or not) the assessment tool is introduced and demonstrated for the respondent.

### **1.3.5 Use of technology to collect dietary data in children**

Using web-based technology for dietary assessment offers superior questionnaire interface, standardization of the questioning sequence, can include audiovisual stimuli, immediate results, increased flexibility, and easy and fast updating facilities. Web-based, computer, PDA or mobile phone assisted questionnaires, recalls or diaries are becoming increasingly common (Moore *et al*, 2008; Boushey *et al*, 2009; Vereecken *et al*, 2008; Vereecken *et al*, 2005; Beasley *et al*, 2005; Wang *et al*, 2006; Weiss *et al*, 2010). The use of technology to collect dietary intake data is especially engaging to children, adolescents and younger adults who are familiar with the technology in their daily lives. Perceptions of “enjoyable” and “easy to use” are rated highly in many computerized diet programmes (Probst, 2007). However, new technologies requires experience in how to use them correctly before they can be employed, otherwise their use end up as a frustration instead of a motivation. Most modern children are pc-users and in 2004, 79-92% of 7-12- year-old children used computers in their free time, mostly for playing games but also for other activities (Bille & Wulff, 2006).

## **1.4 Validation**

Despite the many difficulties and limitations, assessing dietary intake remains important in dietary intervention studies, and it is acknowledged that there is a degree of uncertainty around the merits of different dietary assessment methods, and in the selection of the best method for any particular circumstance.

The next sections include the description of feasible and relevant validation methods that can be used to evaluate newly developed dietary assessment tool. This includes reference methods like energy expenditure measurements, biomarkers of dietary intake, and direct observation.

When assessing diet intake, it is important to identify and quantify sources of potential errors. The knowledge gained from validation studies can be used to minimize errors through careful design of the study and analyses of the data. All newly developed tools should be tested for reliability and validity. For a measurement tool to be considered reliable its results must be reproducible and stable under the different conditions in which it is likely to be used. Most often reliability refers to test-retest reliability which is the degree to which a dietary assessment tool gives similar results when used repeatedly in the same situation (Gibson, 2005). Test-retest methods may be problematic in the assessment of diet because some methods are likely to have particularly high day-to-day variation e.g. 24hR, and it is more than likely that the results from repeated 24hR will differ. In general repeatability is difficult to measure because the food intake may change from test to retest, and therefore only an estimate of reproducibility can be made (Gibson, 2005). A high reproducibility does not necessarily produce accurate answers e.g. if subjects consistently under- or overestimate portion sizes.

There is also inter-rater reliability which is the degree to which the measuring instrument yields similar results at the same time with more than one assessor (Muller & Buttner, 1994; Baglio *et al*, 2004). This is particularly important in methods where several persons are needed to describe behaviour such as in direct observation.

Validity is the extent to which a measurement tool assesses the true dietary intake. Validity refers to the accuracy of a measurement. Validating dietary assessment methods are difficult because the “true intake” is never known with absolute certainty (Gibson, 2005) e.g. EI estimated from a dietary assessment method may be equal to total energy expenditure (TEE) measured with doubly labelled water even if the respondents report are biased towards reporting more healthy foods, and less unhealthy foods.

Often relative validation are used in validation of dietary assessment methods e.g. diet records are used to validate 24hR or FFQ (McPherson *et al*, 2008). This may add to the understanding of how a method works in a particular research setting. Information from relative validation studies can be used to calibrate/adjust the method, and in the interpretation of the results from the overall study. However, it may be problematic to 'validate' one dietary assessment method against another due to the risk of correlated errors between the methods.

Within available validation options the optimal way of validating a dietary assessment tool is to include an objective measure of intake, which reflects diet, and at the same time does not have the same correlated errors as the diet assessment method. Examples of objective measures are TEE measured by doubly labelled water or by the use of motion monitors, biomarkers measured in blood or urine or direct observation. These will be described below.

#### **1.4.1 Energy expenditure**

Often EI is used as a proxy for dietary intake. If EI is underestimated, it is probable that the intakes of foods and other nutrients are also underestimated (Livingstone & Black, 2003). Validation of dietary reports therefore often concentrates on comparing estimated EI with measures or estimates of TEE. This is based on the assumption that energy intake must equal TEE in weight stable individuals (i.e. in a state of energy balance) (Livingstone & Black, 2003).

The gold standard to validate energy intakes is to compare them to measures of TEE made by doubly labelled water, but the method is expensive and impractical in larger studies since several spot urine has to be sampled and handled immediately (Bingham, 2002). Furthermore, it may be hard to recruit children via parents because they may be uncomfortable with letting their children drink the labelled water (Personal communication with Ulla Gondolf).

Alternatively, standard equations, which estimate basal metabolic rate (BMR) can be applied e.g. Schofield (Schofield, 1985; Henry, 2005), and a physical activity level (PAL) factor added to the calculated BMR to provide an estimate of TEE. A direct measure of BMR can be made by indirect calorimetry. Where no measured BMR is available it may be estimated from gender, age, weight and height (Black, 2000a) or from data on body composition of fat mass and fat-free mass plus gender, height and sometimes race (McDuffie *et al*, 2004).

Estimates of TEE will be improved if physical activity is measured e.g. by accelerometers.

Accelerometers is the most common objective method used to measure physical activity, and body acceleration, and the outcome is often expressed as a count value (Medical Research Council, 2012b).

Accelerometer counts can be translated into physical activity energy expenditure (PAEE) by prediction models. It is suggested that triaxial accelerometer-based prediction models may provide accurate estimate of PAEE in children at group level (de Graauw *et al*, 2010), and a combination of BMR (measured or estimated), Diet Induced Thermogenesis (DIT) and physical activity translated to PAEE can provide an acceptable method for validating reported energy intake in adults (Goris *et al*, 2001a). TEE estimated from motion monitors has previously been used to evaluate EI in children and adults (De Keyzer *et al*, 2011; Gigante *et al*, 2010; Biloft-Jensen *et al*, 2009; Andersen *et al*, 2005; Lillegaard & Andersen, 2005).

#### **1.4.2 Biomarkers of dietary intake**

Biomarkers are components of body fluids or tissue that have "strong" direct relationship with dietary intakes of one or more dietary components, and therefore these components can be used to compare to the dietary component estimated by dietary assessment (Gibson, 2005). The underlying assumption of a biomarker applied to validate a measure of nutrient or food intake is that it responds to intake in a dose-dependent way (Gibson, 2005). Biomarkers of dietary exposure can be used for indicating prior consumption, to identify high and low consumers (ranking), and as direct quantification of prior intake (Arab, 2003).

There are different types of biomarkers:

Recovery biomarkers reflects total absolute intake over a defined time, and are considered the gold standard. These include doubly labelled water to measure TEE, urinary nitrogen to measure protein intake, and urinary potassium to measure potassium intake.

Doubly labelled water measures TEE by observing the differential rates of elimination of a dose of the stable isotope tracers  $^2\text{H}$  (deuterium) and  $^{18}\text{O}$ . In practice the subject is asked to drink a known dose of water enriched in  $^2\text{H}$  and  $^{18}\text{O}$ . Samples of urine, from which the isotopic composition of the body water can be determined, are collected over the next 5-14 days. As  $^2\text{H}$  is eliminated exclusively as water, whereas  $^{18}\text{O}$  is eliminated from the body as carbon dioxide and water, the  $\text{CO}_2$  production rate can be estimated from the difference between the two elimination rates. The  $\text{CO}_2$  production can then be translated into TEE. However, doubly labelled water are very expensive and does not give information about food intake (Bates *et al*, 1997; Medical Research Council, 2012b). Urinary nitrogen used to validate protein intake is one of the most common biomarkers used. The measure is based on the following equation: reported protein intake (g) = (24h urinary N + 2) X 6.25 (g). Like a single 24hR, a single 24-hour urine collection does not reflect usual intake but nitrogen intake has been shown to be less variable than protein intake, such that only 8 days of collection are required compared to 16 days of dietary intake data to assess habitual protein intake (Bates *et al*, 1997; Medical Research Council, 2012a). The accuracy of the method depends on the completion of the urine collections and this can be confirmed by using P-aminobenzoic tablets for which average urinary recovery is 93% of the administered dose in single 24-hour collections (Bingham *et al*, 1995). However, complete collections are very difficult to obtain in adults (Nelson, 1997), and would be almost impossible to collect in children 8-11-year-old children.

Concentration biomarkers may be influenced by behaviours independent of dietary intake such as individual variability in absorption, availability and metabolism or use of supplements, and therefore they are correlated to but do not reflect total dietary intake. They can therefore only be used for ranking respondents, and to compare with the ranking estimated in the dietary assessment.

Examples include plasma vitamin C, plasma carotenoids, plasma lipids etc. These are often less expensive, rapid to collect, require minimum amount of active participation by the respondent, and can be useful for prediction of some dietary intakes (Medical Research Council, 2012a).

A relevant biomarker for dietary intake of fruit, juice and vegetables (FJV) is plasma carotenoids concentration. A dose-response relationship between carotenoids intake and appearance in plasma has been shown (Broekmans *et al*, 2000), making carotenoids a reasonable biomarker of intake. Plasma concentrations of carotenoids reflects short to medium-term intake (Bates *et al*, 1997).

The provitamin A compounds:  $\alpha$ -carotene,  $\beta$ -carotene and  $\beta$ -cryptoxanthin, plus lutein, lycopene, and zeaxanthin represent more than 95% of total blood carotenoids (Maiani *et al*, 2009), and these have been used before to validate reported fruit and vegetable intake measured by various dietary assessment methods among adolescents and predominantly among adults (Carlsen *et al*, 2011; Crispim *et al*, 2011; Slater *et al*, 2010; Andersen *et al*, 2005; Brantsaeter *et al*, 2007). Only very few studies have been carried out with children (Vioque *et al*, 2011; Parrish *et al*, 2003), and none in Danish children.

Biomarkers can also serve as a proxy for intake when it is not possible to capture intake due to limited nutrient databases to assess intake they are then called replacement biomarkers. Examples include sodium, and polyphenols (Medical Research Council, 2012a; Fraser, 2003).

### **1.4.3 Direct observations**

Direct observation of meals is often considered the “gold standard” to validate a dietary assessment tool because eating is an observable behaviour (Sherwood, 2008). Direct observation is practical, independent of the subject's memory, and can provide unbiased information about the subject's actual intake. Examples of studies in which direct observation has been used include studies to validate 24hR, FFQ, and FD as well as studies to assess dietary intake of individuals and to evaluate nutrition education interventions (Baglio *et al*, 2004).

Direct observation of dietary intake is typically limited to specific times that individuals can be observed since it is almost impossible to perform during a whole day and for longer periods. The method requires many field workers trained in the collection of dietary data and is therefore expensive. The number of field workers required depends on the number of people being observed in one session. For direct observation of meals, observers typically watch subjects throughout a defined period (e.g., school lunch) and take notes on the subjects' eating behaviours regarding items and amounts consumed, traded and/or spilled (leftovers) (Baglio *et al*, 2004).

Digital photographic methods provide new possibilities for conducting observations and validating dietary assessment, and have been used before to document school lunch intake in children (Martin *et al*, 2007).

There is no ideal or comprehensive method to validate a specific dietary assessment method, and it depends on the research aim, the study design, the feasibility of the validation method, and the resources allocated. Use of a mix of methods e.g. comparison of an objective measure of intake together with observation or a relative validation standard may provide wider aspects of the validity and performance of a dietary assessment tool.

#### **1.4.4 Challenges for the dietary assessment method and the validation**

Dietary intake is complex and not readily amenable to simple measurements. There are many challenges in choosing, designing and validating a dietary assessment method suitable for 8-11-year-old school children for the OPUS School Meal Study. The choice of method, design and the following validation will most likely represent a compromise between accuracy and feasibility. Several challenges should be taken into account in choosing and designing a method that:

- Provides diet intake data at a suitable level of detail
- Fits with the study circumstances
- Addresses systematic biases as cognitive, social desirability and study biases when possible
- Obtains (Back up) cooperativeness from- and engage children and parents
- Is low burden/ non-intrusive.

The challenge in the validation of a developed tool is to apply objective validation methods that give information about usual intake at a level that can be used to rank individuals. Furthermore, it is desirable to validate the dietary assessment tool at school meal level, since the tool is to be developed for use in the OPUS School Meal Study. School meals represent a further challenge in the dietary assessment of children, because they are eaten away from home, and away from parents who normally observe/control what is eaten and who can assist the child with the dietary assessment.



## 2. Aim and objectives

### 2.1 Aim

The aim of the present project was to be able to assess the effects of dietary interventions in Danish school children in general and in the OPUS School Meal Study by delivering an age appropriate and accurate dietary assessment tool that can be used by 8-11-year-old Danish school children.

### 2.2 Objectives

- To develop a dietary assessment tool suitable for 8-11-year-old children which was, guided by the aim of the OPUS School Meal Study, formative research and user testing in order to be adapted to the children's cognitive abilities as much as possible without compromising the research question. Furthermore, to use a child appealing design and technology, which motivate children to self-report dietary intake to increase likelihood of corporation (Paper 1).
- To validate the developed dietary assessment method by a combination of methods, to obtain information about the performance of the tool with respect to acceptability, repeatability, validity including under-reporting and over-reporting. Furthermore, to obtain information about the accuracy of reporting usual fruit, juice and vegetable intake in general and at school meals, as fruits and vegetables are key focus points in the NND (Paper 2 and 3).

## 3. Materials and methods

The choice and development of a suitable and feasible dietary assessment strategy and tool is first addressed in this chapter (Objective 1). Secondly the research methods used in the validation of the developed tool is described, and as a part of this the final dietary assessment tool is explained (Objective 2). The chapter begins with the considerations and choice about a suitable dietary assessment approach and the formative research conducted, through to the interface design completion in December 2010. Thereafter it presents the methods used in the validation study conducted from early January 2011 until June 2011.

### 3.1 Development of the dietary assessment tool

The development of the dietary assessment strategy and tool followed a prototyping approach as illustrated in Figure 2. The steps included were not entirely separate steps, but overlapped or were repeated as test was performed.

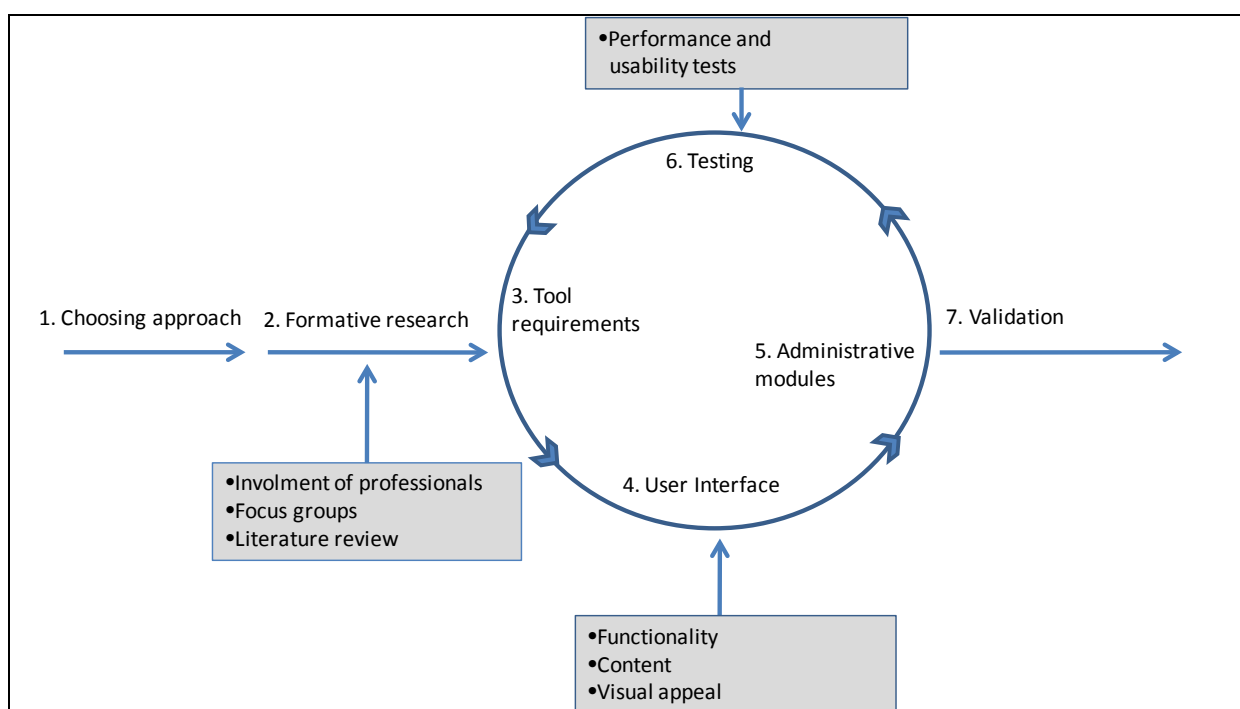


Figure 2. Diagram illustrating the prototyping approach used to develop a dietary assessment strategy and tool for 8-11-year-old Danish Children.

#### 3.1.1 Choosing dietary assessment approach. Step 1.

Before choosing an appropriate dietary assessment method for the specific research aim in the OPUS School Meal Study, considerations, reflections and professional judgement were applied to a number of project aspects. These aspects included the primary research aim and outcome measures, relevant aspects of dietary intake, dietary assessment level, the number of collection days needed to obtain the dietary assessment level, and research constraints in terms of money, time, and staff. Professional judgement is in this thesis defined as the application of knowledge, skills, values and expertise (that cannot be put to reference) of qualified professionals. Professional judgement was used several times in this project to complement the process in combination with scientific principles and research.

#### *Primary research aim and relevant aspects of diet*

The primary outcomes of the OPUS project are markers for metabolic syndrome and an omega-3 index in blood. These markers are not related to the dietary intake on a specific day or meal, but to the usual diet. The dietary assessment method, therefore, has to cover the whole diet and represent weekdays and weekend days.

Furthermore, it has to assess the current baseline and the intervention diet, and to be food and meal specific in order to measure the intake of the NND served at school lunch and as snacks. The method also has to be flexible with regard to updating of food items and recipes, because the supply with NND specific food items for the intervention will most likely be unstable depending on weather, season, prices etc., and there will be a need for continuous update with alternative food items and recipes. Furthermore, it should be possible to include contextual questions on social and physical environment in which eating occurs as school day, meal format, intake of dietary supplements and if dietary reporting was affected by unusual circumstances as illness. Given the aim, FFQ and diet history can be excluded because details of the diet are not measured, it is not quantitatively precise, not meal specific and cannot estimate the combination of foods in a meal, and they are cognitively complex.

#### *Data level and number of reporting days needed to obtain desired level*

Data at the individual level are needed since comparison with risk markers for lifestyle diseases is the primary outcome of the OPUS School Meal Study. In interpreting the results there will be a need to rank individuals according to risk markers and food intake e.g. n-3 PUFA will be associated with fish and fish oil supplement intake. The number of days needed to obtain individual level was calculated as suggested by Gibson, 2005 (Gibson, 2005) and Black et al. 1983 (Black *et al*, 1983) using the within- and between variances from the DANSDA 2000-06 for 8-10 years old (n=500). The results showed that 100 days were needed to determine absolute intake of single individuals. This is not feasible. However, with 7 days of dietary collection it is possible to rank individuals so over 60% should be correctly classified in the extreme fourths of intakes of most nutrients and commonly eaten food groups and food items (Biltoft-Jensen, 2010). In addition, measuring dietary intake for a full week includes both school days and weekend days and thereby the variability in the NND served for the children. The NND includes in a weekly repertoire a soup day, a fish day, a meat day, a vegetarian day and a mixed buffet day. The above considerations exclude 1 and 2 x 24hR alone or combined with FFQ. The 1 and 2 x 24hR alone is not suitable for analysing dietary data at the individual level, and it does not cover the variability in the NND meal repertoire, and combined with the FFQ the method it is not feasible with the target group or the cross-over design of the OPUS School Meal Study (Risk of FFQ periods overlap in memory).

#### *Research constraints*

The method should also fit the resources available for the heavy workload of the intervention study, with performing approximately 21000 dietary assessments (1000 children x 7 days x 3 periods) and including data collection, reviewing, entering, processing and analyzing the data. A web-based data collection would be able to handle the need in the OPUS School Meal Study for 3 data collection periods, would save data scanning/entering, and could provide easy and fast update facilities of e.g. food lists. This could be a feasible and cost-effective solution since almost all Danish families and especially families with children have a computer in their homes and internet access (Tassy, 2009). An interactive Web-based method may also be engaging for the children.

On the background of the above reflections, considerations and judgments it was decided that for the OPUS School Meal Study a Web-based Dietary Assessment Software for Children (WebDASC) 8-11 year old should be developed that could facilitate a self-administered record/recall diet assessment method, preferable covering a full week (7-days).

### **3.1.2 Formative research. Step 2.**

Involvement of professionals, focus groups and a literature review were used to gain input to different aspect of dietary assessment with children including self-reporting abilities, needed support, computer literacy, preferred interface components, food list, portion size aid and children as participants in surveys. The formative research included:

#### *Involvement of professionals*

In order to generate relevant issues and concrete themes that was not preconceived by the author and that should be focused on during the development four experts was interviewed, in person, before the development start. The four experts had diverse perspectives on children, dietary assessment, and the internet and included an ethnologist, a sociologist, a child psychologist and an information technologist. The interviews were semi structured with questions developed from interview to interview depending on the expert perspective. During the interviews it was suggested to start out with conducting focus groups with the target group to get children's own perspective on the concrete themes involved in dietary assessment. These inputs were used to guide the development of the first mock-ups (paper based model of the web-design) of the software.

In addition, during development, input was sought on the mock-ups or functional prototype, in person, from research groups involved in Technology Based Dietary Assessment (TBDA) with children. The professionals included researchers from Newcastle University (UK), Durham University (UK), Baylor College of Medicine (USA) and Ghent University (Belgium). The involvement of professionals gave input to several aspects of dietary assessments with children that would not appear in the scientific literature e.g. that it would be waste of time to develop a tutorial, since children in that age group should not be expected to be passive viewers, and that maximum time required for completing the WebDASC should be less than 20 minutes.

#### *Focus groups*

Four focus groups were conducted to get insight into children's understanding and use of the elements included in the dietary assessment. Children were recruited from 3 schools in 2 different suburbs of Copenhagen. The class teacher helped to recruit the children so that different gender, ethnicity and background would be presented in each group. Written consent was obtained from parents. Each focus group consisted of five 8-11-year-old children and took place in the school, and hence in a "safe" and neutral environment. The groups focused on four aspects of dietary assessment. To involve the children and make them talk naturally, the themes were conducted as four exercises that the children could hold up against their everyday life:

- Memory in relation to foods and meals consumed. The day before the focus groups the researcher met with the children at school lunch and asked them to take photos, using a digital camera, of their lunch before and after eating. These photos were used in the focus groups the day after to talk about what they could remember from the lunch the day before. The photo shooting it selves was also talked about, since this presented a supplementary strategy to assessment of intake.
- Understanding of eating occasions (meals and snacks). The children were asked to place pictures of different foods on a "time line" over a day. Afterwards, they were asked to name the different eating occasions. This was to establish eating occasions and what type of foods they ate at the different eating occasions.
- Understanding of food groupings. The children were asked to gather photos of different foods (52), which they thought should be in the same group. Afterwards, they were asked to name the different food groups. This was to establish food groupings.
- Preferred way to estimate portion size: Images or models. They were asked to estimate the portion sizes of two meals, using pictures or food models depicted in a model book (borrowed from the NHANES) (Bliss, 2004), and it was talked about what was easy, and what was difficult, and if one method was better than the other to establish preference of method.

All interviews were transcribed and analysed by extraction of themes supplemented by new aspects that appeared under the interviews, and the children's understanding and ideas in relation to the extracted themes (Biltoft-Jensen, 2009).

### Literature review

The literature review conducted in connection with the development of WebDASC is reported elsewhere (Biltoft-Jensen, 2010), and included several recently published, comprehensive reviews (Ngo *et al*, 2009;McPherson *et al*, 2008;Sherwood, 2008;National Cancer Institute, 2007;Livingstone *et al*, 2004) and individual method studies (Thompson *et al*, 2010;Baranowski *et al*, 2010;Subar *et al*, 2010;Vereecken *et al*, 2010). The literature review gave insight into children's competences in diet assessment (e.g. the need for a meal based structure, appropriate prompts to help memory retrieval, and use of portion size estimation aids).

For more details about results from the formative research see Paper 1

### 3.1.3 Requirements. Step 3.

The formative research resulted in an overview of the elements needed to perform dietary assessment, the problems likely to occur, and appropriate methods to handle them, which represented a "tool box" of relevant principles that guided the development of WebDASC. For more details about the toolbox, see Paper 1. The resulting set of software requirements is listed in Table 2.

Table 2. Overall software requirements for the development of the Web-based Dietary Assessment Software (WebDASC) for 8-11-year-old Danish children.

<p>The WebDASC should:</p> <ul style="list-style-type: none"><li>• Be developed as a data entry application</li><li>• Facilitate food intake report among school children</li><li>• Motivate children to complete daily recalls</li><li>• Appear with a child appealing design</li><li>• Use visuals to engage young respondents</li><li>• Have a guided meal-based approach</li><li>• Provide context-driven help</li><li>• Be easy to navigate (simple, fast-paced, and intuitive)</li><li>• Have internal checks for frequently forgotten eating occasions (e.g. snacks), foods, and beverages</li><li>• Use food photography to illustrate portion size</li><li>• Use a combination of search methods: browse, type-in aided by an adapted spell check and open-ended</li><li>• Allow multiple-day reporting in several periods for each respondent</li><li>• Be able to locate and display reports per respondent, per day, per session and per meal</li><li>• Have an administrative module to facilitate project registration, manage respondent's data as well as food list terms, probes, and portion size photography</li><li>• Be able to run on almost every home computer</li><li>• Handle up to a maximum of one thousand respondents at a time</li></ul>
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Besides the technical and design considerations social aspects were also included in the requirements. It was considered essential to get the WebDASC delivered and explained to the children in a personal and professional way to increase the cooperation between the child/ parent and the researcher despite separation in time and place. It was also anticipated that a good initial contact would help increase response rate (Kiezebrink *et al*, 2009;Yu & Cooper, 1983). WebDASC was developed for this scenario.

### 3.1.4 User interface. Step 4.

The user interface between human and the computer otherwise known as the UI can be defined as "the point of contact between the application and the end user". Dietary assessment is complex, and embraces to remember what was eaten when, and where, and to describe what was eaten, and to estimate the amount. There are many steps where the respondent's attention can get lost due to burden/complexity. When developing the software it is

therefore important to focus on the different user issues that child and parents will interact with using the software.

These include:

- Functionality
- Content
- Visual appeal, interface elements and motivators

### *Functionality*

Functionality is the capability of the software to provide functions which will facilitate the registration of children's complete dietary intake in a suitable way. It is what appeals to "Homo Faber". This includes the:

Accessibility: Compatibility to different browsers.

Speed: Speed of the interactions.

Navigation: Logic and flexible navigation.

Response: Effective search functions that make food selection simple and understandable for the end user, and appropriate prompting.

### *Content*

Content is the information and experiences that provide value for the participant's ability to report their specific diet. It is what appeals to "Homo Sapiens". This includes the:

Obviousness of the software: Is it intuitive, and is it clear what the user should do in the software?

Information: Does the food list, food grouping, naming of food groups, portion size estimation allow children to adequately assess their diet, and are questions relevant and understandable?

Language: Is the language short, clear and understandable?

In developing the food lists and the food groups, analyses of DANSDA intake data for 8-11-year-old children 2003-08 were used together with professional judgement. This included analyses of the different foods most often eaten together at different meals. Different meal types were identified at each meal e.g. for breakfast a bread meal, a cereal meal or a yoghurt based meal were identified. For those children eating e.g. a bread meal for breakfast, all the days where a bread meal was consumed were analysed for frequency in intake of other foods. This information contributed to refining the creation of the food grouping, including the placement of foods in several food groups and also of which foods should be included in internal checks, and which foods should be used as prompts. Analyses of DANSDA intake data were also used to determine the maximum number of portions that can be added of each food item (median value between 95 percentile number of portions reported by children and adults in DANSDA 2003-08).

Food and food groups were renamed with input from professionals, to simplify the description. The food list included types of foods on a general level (no brand names). The use of a PC for obtaining dietary data, offer the possibilities of retrieving a third layer of information besides food type and portion size. However, introducing many detailed questions about related qualities to the foods increase the risk of non-relevance followed by fatigue and boredom among children. The detail level aimed at in the WebDASC was therefore type of food consumed, however, more specified compared to DANSDA, where diet is reported on a generic group level (e.g. all casseroles containing beef is reported as one type). In the WebDASC a food list catering for a broad range of food intake patterns were aimed at.

To make the NND easy to register during the intervention period, the NND foods were marked with "OPUS" to make them easy to recognize from other foods in the food list.

The images for portion size estimation included those developed for the DANSDA 2011 (n=75 photo series) and those produced at the Children's Nutrition Research Center, Baylor College of Medicine, Houston, Texas (n=245) for use in two web-based, self-administered 24-hour dietary recall systems: the Food Intake Recording Software System (FIRSS) (Baranowski *et al*, 2002), and the Automated Self-Administered 24-hour dietary recall (ASA 24) (Subar *et al*, 2010). Since our formative research indicated that children preferred clear and fewer answer choices, each portion size series consists of four digital images. In those instances where multiple digital photos were available, the best four images depicting children-sized portions (for ages 4-14) were selected.

#### *Visual appeal, interface elements and motivators*

This is what appeals to the senses, and "Homo ludens". It includes the:

Visual appeal: Visual elements, icons, use of colour, originality typography etc. and WebDASC was designed and programmed by a computer-gaming company experienced in creating user-friendly interfaces for children.

Layout: Clarity, and help functions that make food selection simple and understanding for the respondent.

Motivators: Features that can engage and inspire/involve children to sustain diet reporting for 7 consecutive days in 3 periods.

For more details about the UI development and results see Paper 1.

A total of 5 small scale mock-ups (paper based model of the web-design) were developed following an iterative modification process to create an overview of the WebDASC before coding the prototype. This enabled "cheap" alterations to the software architecture, before the more "expensive to change" coding started.

#### **3.1.5 Administrative modules. Step 5.**

Two administrative modules: a "web-site" application and a "survey" application were developed in order to manage dietary reporting and to allow updates of food list terms, portion size images etc. An initial requirement specification was made for the "web site" application based on the OPUS School Meal Study process and the need for a flexible system.

The development of the survey application was done "in-house" and followed more an "agile development approach" where functionalities were negotiated with the data manager as the need for them occurred.

The survey application provides overview over participant progress, diet reports, and facilitated coding of open ended answers. For more details about the content of the backend administration see Paper 1.

#### **3.1.6 Testing. Step 6**

The tests conducted during the development of WebDASC and in the validation studies are illustrated in Table 3.

Table 3. Overview of testing and evaluating the Web-based Dietary Assessment Software (WebDASC) for 8-11-year-old Danish children.

Test types	Initial performance test	Think aloud test	Usability test	Validation
<b>Issues tested</b>	Suitability of a food list. Identifying spell check opportunities	Ability of functionalities, and flow to meet the requirements of the users	Evaluation of design elements and search functions	Ability of the target group to provide plausible reports of dietary intake using WebDASC
<b>Test population</b>	<ul style="list-style-type: none"> <li>•22 weighed records from 8-11 year old children.</li> <li>•500 spelling mistakes from children's own reporting of school lunch.</li> </ul>	5 selected children 8-11-years with their parents.	70 children 8-11 years	81 children 8-11 years
<b>Methods</b>	<ul style="list-style-type: none"> <li>•Weighed food records from children were entered into the prototype by BSc in Nutrition.</li> <li>•Entering children's spelling mistakes in free spell check applications.</li> </ul>	Child and parent were saying out loud what they thought while completing a day's diet using the WebDASC	<ul style="list-style-type: none"> <li>•Children entered their own diet in the presence of a researcher and the researcher noted problems.</li> <li>•Afterwards children were asked questions about design elements and the animated guide.</li> </ul>	<ul style="list-style-type: none"> <li>•7 day dietary assessment and accelerometer carrying at baseline and during intervention.</li> <li>•Blood samples for carotenoids analyses</li> <li>•Observation at lunch 5 days at baseline and during intervention.</li> </ul>

A functional prototype was tested to identify and address acceptance, performance and usability issues. The following tests were performed:

#### *Initial performance tests*

Five hundred food spelling errors were identified from children's own report of a school lunch, and subsequently tested with the Methaphone algorithm, the GoogleSpell, and the Google's search engine to find out which method was better suited to match the misspelled term with the correct food item.

Four nutrition graduates entered weighed food records from 22 8-10-year-old children to evaluate the suitability of the food list, the search function, and to uncover programming bugs.

#### *Think-aloud test*

Five eight year old children together with one of their parents were tested in participants home. Minimal instructions were provided and a think-aloud protocol was encouraged.

Participants were asked to verbalize what they were thinking while interacting with the functional prototype to record their intake (Rasmussen & Fischer, 2008). This allows the researcher to gain insights into the mind of the users as thoughts are expressed at the time of occurrence. This test was meant to evaluate flow and functionality.



### *Usability test*

Usability testing refers to the process of employing people who are representative of the end users of the system and evaluating the ability of the system to satisfy its usability criteria (Gardener & Madsen, 2002). The final prototype was tested among seventy 8-11-year-old children from 3<sup>rd</sup> and 4<sup>th</sup> grade. They were recruited from one school in the west suburb of Copenhagen. The test was conducted in the school during school time as a mixture of observations and questions. The child was sitting with the researcher and asked to enter some meals from the present day or the day before into the software. After the diet reporting the child was asked general questions about using the design elements to report in the WebDASC

Usability was assessed in terms of:

- Children's perception of the animated guide. This was assessed by a number of questions about the animated guide (Sex, name, age, grade in school, mood, what does he like to do, does he remind you of someone, could he be your friend, does he look like a good guide to help children in a dietary assessment programme, what could be fun to do together with him, what music does he like to hear, what kind of computer game could he be in?)
- Design elements that could cause disruptions in the flow (e.g. icons and buttons): This was assessed during the child's diet reporting where the researcher noted if, where, and why the child got stuck. The questions asked afterwards regarded any difficulties experienced when answering questions about the meal format which included questions about where the food was eaten, where it was prepared and how long time the meal lasted.
- Cognitive appropriateness of the search strategy. This was assessed by the researcher during the child's diet reporting. Afterwards the child was asked about this task, and how difficult the child experienced it was to find what he/her had been eating using the search facilities.

The performance and usability testing showed that the WebDASC needed to be further adapted to the target group. Major improvements in the WebDASC between- and after tests included re-design of the avatar, the introduction of a "copy meal" function to expedite data entry, development of a spell check function that prioritizes food list terms, simplification of the food list, less text and increased use of food images as prompts.

Further results from the performance and usability testing see Paper 1.

## **3.2 Validation of WebDASC**

### **3.2.1 Validation study. Step 7.**

The final WebDASC emerging from the development phase is the tool to be validated in the validation study, and therefore the function of the final WebDASC is described in this chapter. The validation of the WebDASC includes:

1. Comparisons or estimated EI with accelerometer determined energy expenditure.
2. Comparison of estimated fruit, juice and vegetable intake with plasma carotenoid concentration.
3. Comparison of reported fruit, juice and vegetable intake at school lunch, with the observed intake of fruit, juice and vegetables by a digital photographic method.

Furthermore the usability was assessed by a questionnaire containing both quantitative and qualitative questions.

The validation of WebDASC was performed in connection to the first part of the OPUS School meal Study the so-called OPUS School Meal Study *pilot study*. The *pilot study* placed a heavy work load on participants with a lot of measurements and samples to be taken. Therefore it was important to choose as less invasive reference methods for the validation part as possible, which could give as much information about several important factors.

Accelerometers can provide measures for both physical activity and sleep, and at the same time they can be used with little disruption to everyday life. They were therefore chosen for estimating energy expenditure. The observation part of the validation could provide data for both validation of WebDASC on meal level, and at the same time give data about plate waste. Blood samples were also taken to be used for other analyses.

### 3.2.2 Overall study design (Paper 2 and 3)

The validation study was a part of the OPUS School Meal *pilot study*, and the data collection was performed in January (baseline) and March (Intervention) 2011. The full study design is illustrated in Figure 3.

3<sup>rd</sup> and 4<sup>th</sup> grade children (8-11 years) in one school situated in the North-eastern part of Denmark were recruited for the *pilot study*. 105 pupils and their families were invited and 81 gave written consent to participate.

Detailed instructions on how to report food intake and how to use the accelerometer were provided individually to all participants by the research team. Written instructions were given as well.

Participants reported their diet in the WebDASC each day for 7 consecutive days during two periods: at baseline and during the intervention. During the baseline period the participating school children had their normal packed lunches, and during the intervention period, the children were served NND for lunch and snacks in school. On the same 7 consecutive days as the WebDASC was completed, the participants wore an accelerometer for movement registration in order to estimate energy expenditure. Before the intervention period participants were reminded by telephone to repeat diet and activity reporting. On the same 5 schooldays as they reported their diet in WebDASC the children's school lunch was photographed and weighed before and after lunch.

After the baseline measurements participants completed an acceptability questionnaire about the diet recording in the WebDASC. All the participants' parents were interviewed, in person, about social background, attitudes and knowledge about food and health. A random sample of 250 children from the DANSDA 2003-08 were included for comparison of background characteristics to evaluate generalization of the results from the validation study.

Fasting blood samples were taken, and fasting body weight and height was measured once by trained personnel during the week after the baseline food reporting and activity recording.

The participants received feedback on their diet intake and other measurements approximately two months after the *pilot study* had finished.

The procedures followed were approved by the Committee on Biomedical Research Ethics in the Capital Region of Denmark (no. H-1-2010-023).

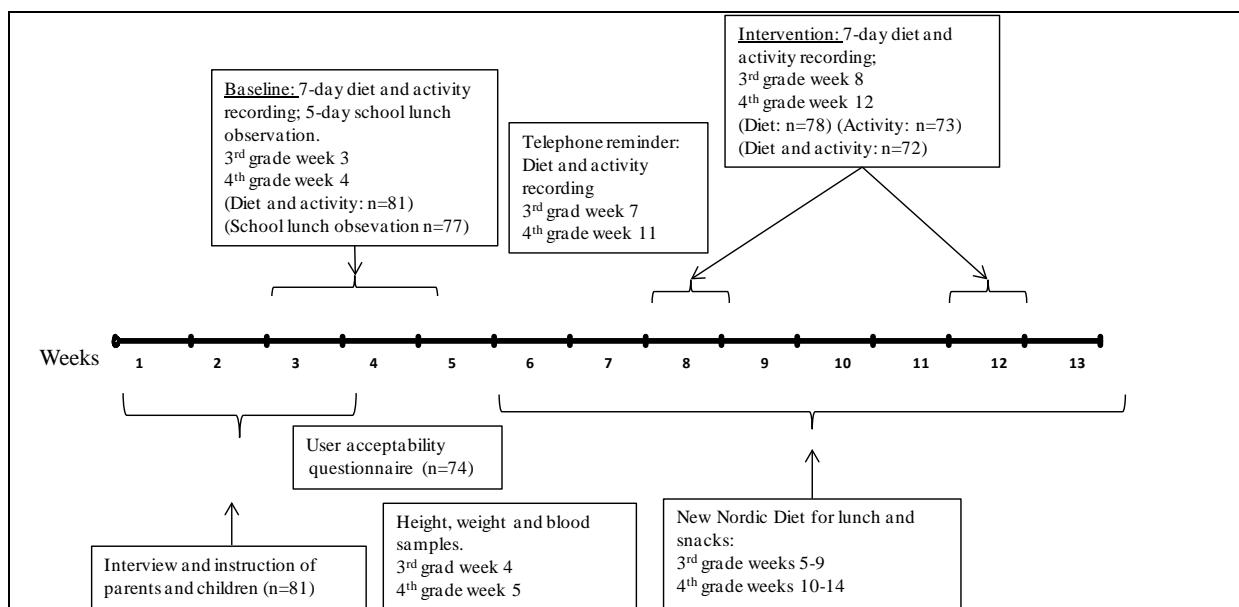


Figure 3. Study design of the Web-based Dietary Assessment Software for 8-11 Year Old Danish children validation study.

### 3.2.3 Dietary assessment using WebDASC (Paper 2 and 3)

After login an animated guide (armadillo) guided the respondents through six daily eating occasions (breakfast, morning snack, lunch, afternoon snack, dinner, and evening snack) and helped them to report foods and beverages consumed during the day. A database of 1300 food items was available either through category browse

or free text search, aided by a spell check application or a copy meal function. A type-in format was available for foods not otherwise found through category browse or text search.

Amount consumed was estimated by selecting the closest portion size among four different digital images in 320 photo series. Before entering a main meal respondents were asked to indicate where the meal was consumed, where it was prepared and perception of time elapsed while eating. After entering every meal and after completing a whole day, participants were asked to check the list of reported food items, and WebDASC checked and prompted for frequently forgotten foods.

Besides dietary intake, participants were asked to report intake of dietary supplements and whether a day represented usual or unusual intake, including reasons for unusual intakes such as illness.

A food-meter displaying total amount of foods reported so far could be followed from every page. A Top 10 list of the most popular foods of the day, and a computer game with a high score list was accessible after completing a day.

If a participant failed to report a day, parents were reminded the next day by an e-mail. Failing to report a day within 48 hours automatically closed the day and opened a new day instead. To enhance memory of what was eaten during the day, and in case of technical problems, participants were provided with mini records, to note food type and amount eaten at the different meals during the day for later entering in the WebDASC.

At least 3 weekdays and 1 weekend day, in both periods, had to be completed for inclusion of participant's diet reporting's in the analyses. The EI and FJV intake was calculated for each individual using the software system General Intake Estimation System (Version 1.000 d - 2010-02-26) developed at the National Food Institute, Technical University of Denmark, and the Danish Food Composition Databank (version 7; Søborg; Denmark; 02-03-2009). Vegetables did not include potatoes which in Denmark are classified as a starchy staple rather than a vegetable. Fruit included fruit products such as jam, nuts and concentrated fruit syrups.

### **3.2.4 Energy expenditure estimated by accelerometry (Paper 2)**

During the OPUS *pilot study*, the children were instructed to wear Tri-Axis accelerometer 24-h a day for a continuous 7 days in an elastic belt on the right hip, including during sleep, and to remove it only during water activities as when showering or swimming. PAEE was estimated from mean counts per minute using Ekelund et al.'s modified prediction equation (Nilsson *et al*, 2008). TEE was then estimated as AEE plus BMR plus DIT which was assumed to account for 10% of TEE (Maffei *et al*, 1993). BMR was calculated from the equation published by Henry (Henry, 2005) based on age, sex, heights and weights. For more details about accelerometer data decisions and processing see Paper 2.

### **3.2.5 Definition of under-, acceptable-, and over-reporters of energy intake (Paper 2)**

Since there is random day-to-day variation in EI and in TEE, exact agreement between EI and TEE over 7 days in one individual is unlikely. Therefore the accuracy of the reported EI was assessed using the confidence limits of agreement between reported EI and TEE at the individual level as suggested by Black (Black, 2000b). For more details about the definitions of under-, acceptable-, and over-reporters see Paper 2.

### **3.2.6 User acceptability of WebDASC (Paper 2)**

During the background interview each child was asked to complete a questionnaire with assistance from one parent, and return it after the baseline recordings to gain qualitative feedback on the user acceptability of the WebDASC, and to evaluate if requirements were met. Questions were related to the daily use of WebDASC and included 18 (categorical multiple response and open ended) questions regarding the amount of help provided from parent's, used reporting time, preferred search facility by the child and by parent, relevance of the portion size pictures, usefulness of the information's given, acceptability of the reporting period, influence on dietary habits and suggestions for improvement and questions about the design and game.

### **3.2.7 Estimation of carotenoid intake (Paper 3)**

Carotenoid intake was estimated for each individual by coupling all foods reported (on databank level) to their carotenoid content. Thereafter GIES was used to estimate individual intake. Because a comprehensive database of the carotenoid content in Danish and Nordic foods does not exist, we chose to use the United States

Department of Agriculture USDA database for US foods (USDA National Nutrient Database for Standard Reference, Release 24, 2011) (U.S.Department of Agriculture, 2011).

### 3.2.8 Blood samples and determination of plasma carotenoids (Paper 3)

Venous blood was collected in EDTA tubes and stored at -80 C until further analysis.  $\alpha$ -Carotene,  $\beta$ -carotene,  $\beta$ -cryptoxanthin, lutein, lycopene and zeaxanthin in plasma were determined by high-performance liquid chromatography (HPLC). For more details about the plasma carotenoids analyses see Paper 3.

### 3.2.9 Observations of school lunch made by a digital photographic method (Paper 3)

Objective observations of school meals were conducted by the research team using a digital photographic method. Unpacked “packed lunches” and beverages were weighed before and after lunch and photographed by a digital method. When weighing the children’s food the researcher asked supplementary questions regarding previous eating from their packed lunches, and about receiving or giving foods away.

The digital images and weights were placed in the “survey” administration module together with the children’s lunch recordings in the WebDASC (Screenshot 1). An experienced dietician assessed the accuracy of the children’s diet records at lunch by scoring the items reported against the two images. Each item reported and observed eaten was classified as a match (item recorded eaten and observed eaten), intrusion (items reported eaten but not observed eaten), omission (item observed eaten but not reported eaten) and fault (item reported eaten does not describe the item observed eaten). Matches, omissions and intrusions also included assessment of the recorded serving size e.g. if there were two carrots eaten as seen from the school lunch image and there was only one carrot reported in the WebDASC (judged by WebDASC image weight), this was recorded as an omission, and e.g. if a raisin portion seen from the school lunch images were smaller than the reported raisin portion in the WebDASC (judged by WebDASC image weight) this was recorded as an intrusion. For more details about the observation method see Paper 3.

The screenshot displays a software interface for recording school lunch data. On the left is a table for item recording, and on the right are two photographs of a lunch plate.

Indtægnelse	Billeder	Vægt	Regt. serveret mængde	Andet tilføjet	Afhjælp fra billedet
Banan	2	59	1	1	Ingen afvigelse/match
Faldkornbrød	4	56	1	1	Ingen afvigelse/match
Ordnings	2	45	1	1	Ingen afvigelse/match
Lug, ristede	0	14	1	1	Ingen afvigelse/match
Pilægschokolade, mælk	3	4	1	1	Ingen afvigelse/match
Rensede, lige	1	7	1	1	Ingen afvigelse/match
Skinsmørsmælk	4	200	1	1	Ingen afvigelse/match
Smaar	1	6	2	2	Mangler(ommission)
Tørkerosin, pille	2	35	1	1	Ingen afvigelse/match
Vindruer, blå	2	80	1	1	Ingen afvigelse/match
Æble	4	115	1	1	Ingen afvigelse/match
Smag					Ingen afvigelse/match
Smag					Ingen afvigelse/match
Smag					Ingen afvigelse/match
Smag					Ingen afvigelse/match
Smag					Ingen afvigelse/match
Smag					Ingen afvigelse/match

Summary table below the main table:

	Vægt i gram registreret	Vægt i gram af fra billedet
Mælk	444	349
Drøkketarer	200	256

Additional fields: Søgefelt: [ ]

On the right, two photographs show a lunch plate. The top photo, labeled 'Før', shows a full plate with an apple, banana, grapes, carrots, raisins, a cookie, and a carton of milk. The bottom photo, labeled 'Efter', shows the same plate after eating, with only a few items remaining.

Screenshot 1. Scoring school lunch reportings in the Web-based Dietary Assessment Software for Children 8-11-year-old against digital images of eaten school lunch.

### **3.2.10 Statistical analyses (Paper 2 and 3)**

A number of statistical tests were applied in Paper 2 and 3 to assess the comparability of diet reported in WebDASC to more objective measures that was unlikely to have correlated errors with the WebDASC. Intake of fruit, juice and vegetables separately and the separate carotenoids plasma concentrations were not normally distributed, and not amenable to transformation, and for some analyses non-parametric tests were applied.

Chi-square analysis and independent t-test were used to describe the characteristics of the study population compared to a random sample of 8-11-year-old children from the DANSDA 2003-08.

Agreement between EI and TEE and between FJV intake and plasma carotenoid concentration was assessed by; Bland-Altman plots (EI vs. TEE); paired sample T-test (EI vs. TEE); and cross-classification into quartiles applying Kappa statistics and correlations (Pearson: EI vs. TEE and Partial and Spearman: FJV intake vs. plasma carotenoid concentration).

Furthermore the Intraclass Correlation was used to assess repeatability of EI and TEE between baseline and intervention.

Finally, Linear mixed models were used to assess the intervention effect (the period factor baseline; intervention) (Paper 2), a weekday and meal effect in FJV intake (Paper 3), the effect of background factors such as gender, parental education, BMI, age and illness and their mutual interactions on EI, TEE and FJV intake. The fixed factor effects in the model used in Paper 2 were gender, parental education, BMI, age, illness that affected eating and period and all their two-way interactions, and in Paper 3 gender, education, BMI, age, illness that affected eating and all their two-way interactions.

For both the EI/TEE and FJV intake analyses random effects were added for subject to adjust for dependency in repeated measures within subjects.

Homogeneity of variance and normality of the residuals were examined using graphical methods.

In all statistical analyses a significance level of 5% was applied. Data were analyzed using SPSS for Windows version 19. For more details about the statistical analyses see Paper 2 and 3.


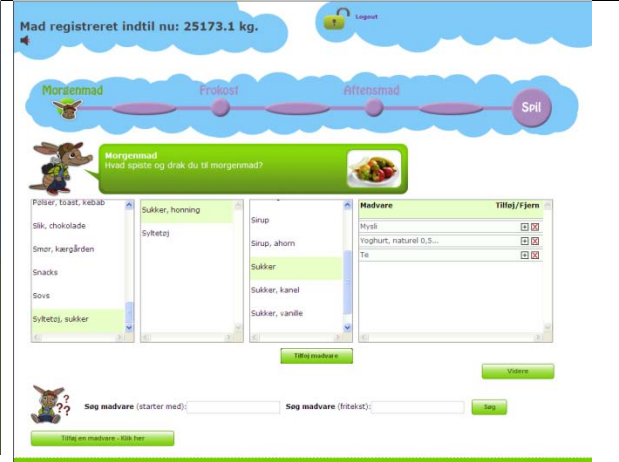
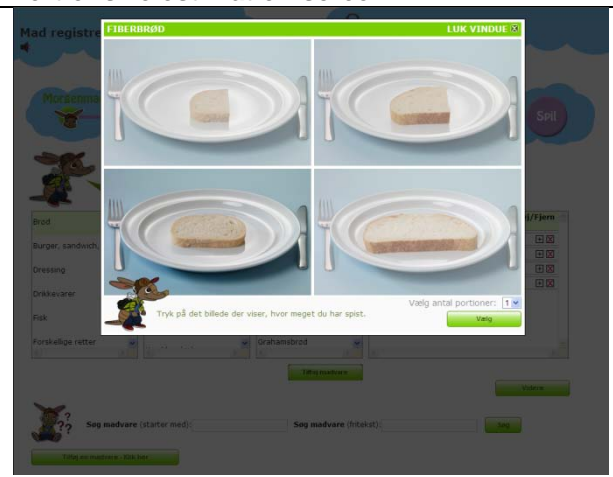

## 4. Results

In this chapter a summary of the main results from the three papers are summarized together with some unpublished findings. For a more detailed description of the results the reader is referred to the results section of the individual papers.

### 4.1 Web-based Dietary Assessment Software for 8-11-year-old Danish Children

The function of the final WebDASC developed is described in the method section, and in Paper 1. Screenshots from the final WebDASC are illustrated in Screenshot 2.

Screenshot 2. Screenshots from the Web-based Dietary Assessment Software for 8-11-year-old Danish Children

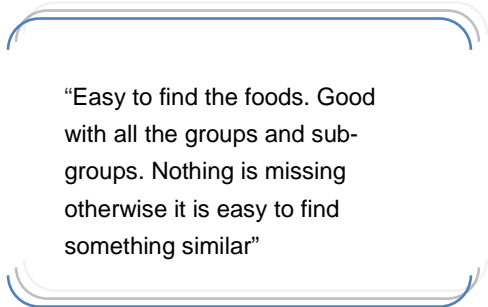
Frontpage	Registration screen – search in food groups
 <p>Mad registreret indtil nu: 17779.59 kg.</p> <p>Mad registreret indtil nu: 25173.1 kg.</p>	 <p>Mad registreret indtil nu: 25173.1 kg.</p> <p>Morgenmad: Hvad spiste og drak du til morgenmad?</p> <p>Frokost: Hvad spiste og drak du til frokost?</p> <p>Aftensmad: Hvad spiste og drak du til aftensmad?</p>
Portionsize estimation screen	Final approval screen
 <p>FIBERBRØD</p> <p>Vælg antal portioner: 1</p>	 <p>Mad registreret indtil nu: 25173.1 kg.</p> <p>Hvad har du spist i dag?</p> <p>Dine hovedmåltider:</p> <ul style="list-style-type: none"> <li>morgenmad: Myst, Yoghurt, naturel 0.5%, Te, Sukker, Høbrød</li> <li>frokost: Sandwich, fyldt, Høbrød, Gulerod</li> <li>aftensmad: Kødbrød, Pasta, Høbrød, Salat, blandede, kun grøntsager, Vanilje, postevand</li> </ul> <p>Dine mellemmåltider (snack):</p> <ul style="list-style-type: none"> <li>formiddagsnack: Appelsauce, banan</li> <li>eftermiddagsnack: Chokoladekage, kaffe, Mælk i kaffe</li> <li>aftensnack: Chokolade, fløde, nødder, Te, Mælk i te</li> </ul>

WebDASC is cross platform (Pc/MAC) and browser-based, and can be run on almost all home computers (95% of them as of November 2010) with Internet Explorer 7 or 8, FireFox 1.5, 2.0 or 3.6, Chrome 5, or Safari 4. It requires internet access and Adobe Flash player version 9 or higher, and displays best with the current standard screen resolution (1024 x 768 pixels). WebDASC is hosted on a standard web-hotel with a bandwidth that supports the use of databases and other tools that are likely to exceed the storage capacity of a typical home computer. Since many computers have a pop-up blocker, pop-up windows were avoided; instead, an overlay function is used to allow a second layer of information to be retrieved, e.g. at the time of estimating portion size. An uncompleted day is saved for 9 hours, otherwise the reporting is lost. This stresses respondents to complete their diet reports when first started. Longer saving time introduces the risk for overlapping days, and this is a problem with a consecutive data collection on the web.

Number of different foods and beverages reported per day in the WebDASC in the validation study was on average 15 (Standard Deviation (SD)=3) in the baseline period, and 14 (SD=3) in the intervention period. If the counting was extended to include the same foods/beverages occurring to different meals the average increased to 18 (SD=4) (baseline), and 16 (SD=4) (intervention) foods/beverages a day. The last figures are an expression of how many foods a day, the child on average had to search, estimate portion size, and report in the WebDASC. In top of this come the open answers. At baseline 28 persons entered on average 0.6 open answers per registration day. At the intervention period 26 persons entered on average 0.9 open answers per registration day.

#### 4.1.1 User acceptability (Paper 2)

All 81 participants in the *pilot study*, choose to complete the diet assessment on the web even though they were presented with a paper based food record method as an alternative at the information meeting. 74 out of 81 who completed the dietary assessment using the WebDASC at baseline returned the user acceptability questionnaire. The average time spend completing the WebDASC the first day was 35 min. and 15 min. the following days. 80% found the recording duration acceptable. 85-90% found the task of finding and reporting foods and portion sizes more or less easy. The children and their parents that experienced difficulties reported that difficulties arose due to unfamiliarity with the food grouping or the naming in the food list. It was suggested, from these children's parents, that the children should have some time to practice with the software before start e.g. in school. For the portion



“Easy to find the foods. Good with all the groups and sub-groups. Nothing is missing otherwise it is easy to find something similar”

size estimation, the difficulties were related to size estimation of specific foods e.g. milk on cereals, beverages (if own cup/glass size deviated from the illustrated one) and difficulties related to see the size difference among images which deviated too little or was not clear enough. Furthermore, it was also reported by some respondents that they needed the possibility to correct in previous days completed records, which was not an opportunity.

Technical problems were reported as well. These related

to failing web access in general, from different homes.

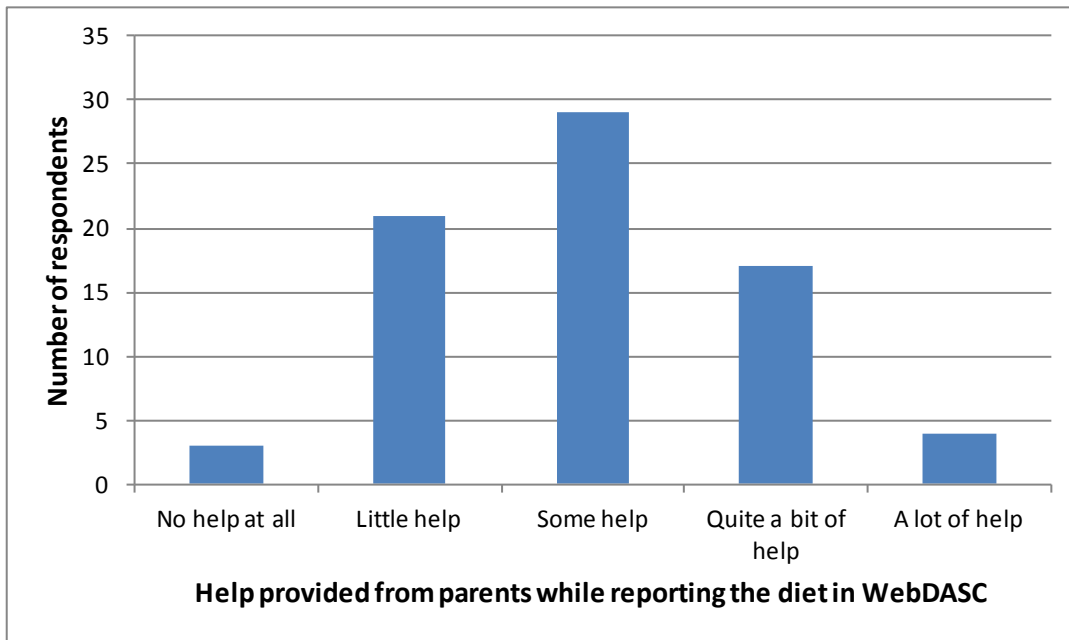


Figure 4. Number of participants getting help from parents while reporting their diet in the WebDASC (n=74).

No help at all = the child reported by him/her self.

Little help = the child reported predominantly by him/her self

Some help= the parents helped half of the time

Quite a bit of help = the parents reported predominantly

A lot of help = the parent reported the child's diet

90 % of the children received more or less help from parents to complete WebDASC (Figure 4).

Children preferred the category browse search, whereas parents preferred the free text search. All liked the user interface design.

Respondents also provided suggestions to improvement of the WebDASC. These improvements all related to the flexibility of the software e.g. wish for editing in recipes in relation to own recipes, commenting meals, and saving of foods entered in the open registration, to the food list terms, for future use.

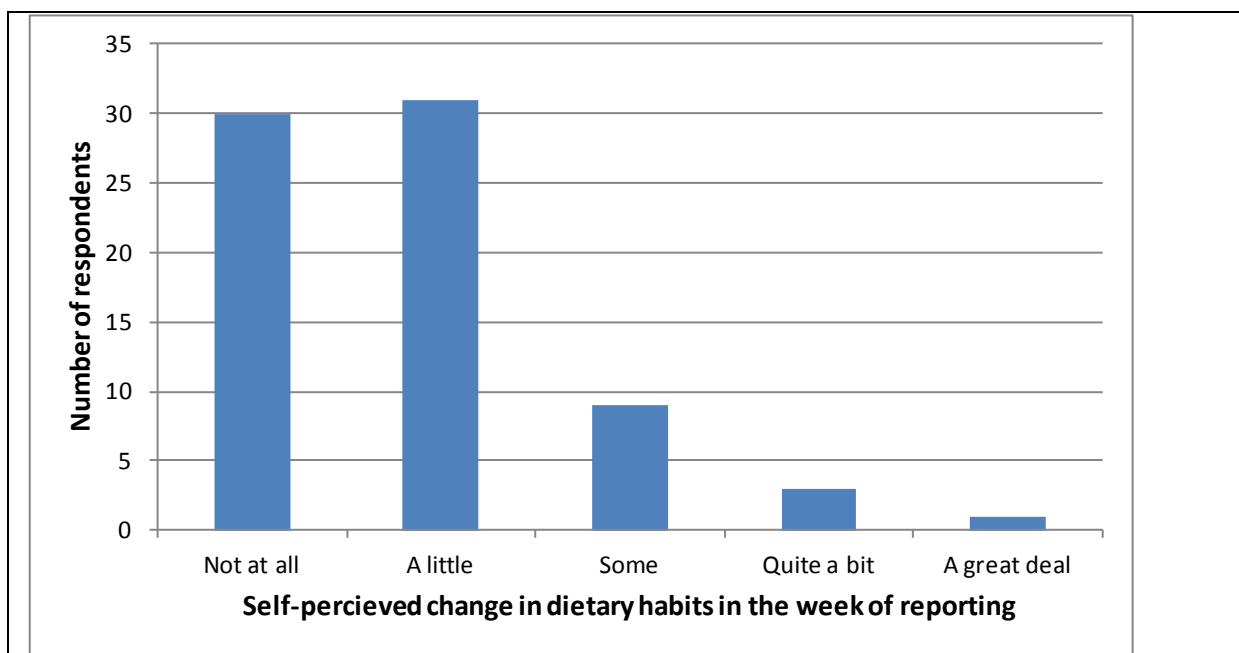


Figure 5. Number of participants experiencing a change in dietary habits in the dietary assessment period (n=74).



As illustrated in Figure 5, 59% of the study population felt that the recording period more or less influenced their eating choices. 88% of the children answered they played the computer game during the registration week. 57% thought it was fun or ok, the rest found it more or less boring. A look in the statistics at the web-hotel showed that the game was played on 55% of the reporting days.

## 4.2 Validation

Eighty one children (34 boys; 47 girls), with assistance from parents, reported their diet in the WebDASC and wore the accelerometer for 7 consecutive days. Seventy three of these had a blood sample taken after baseline reporting. At intervention 78 completed the food recording and 73 had acceptable accelerometer results giving 72 children (28 boys; 44 girls) at the intervention period with measures for both EI and TEE.

Seventy seven children had their lunch weighed and photographed during the diet assessment period at baseline, not all on all 5 days due to illness and vacation.

The volunteer study population was representative of the randomly selected population in the DANSDA 2003-8 with regard to gender, and use of supplements. But the study population consisted of a higher proportion of children with parents with a vocational education; Had a higher intake of vegetables; Had a greater part of parents that were unsatisfied with healthiness of own dietary habits; Had lower BMI's; Reported lower EI relative to BMR (EI/BMR). Furthermore, the parents answered to a higher degree, that vegetables characterized a healthy diet, when asked "What does in your opinion characterize a healthy diet (results not shown).

### 4.2.1 Energy intake vs. energy expenditure (Paper 2)

In the validation study described in Paper 2 it was found that on group level the EI estimated by the WebDASC was in agreement with TEE estimated from the accelerometer counts, BMR and DIT ( $-0.02$  MJ/d:  $P=0.788$ ). However, the differences between EI and TEE tended to be positive when intake was high and negative when intake was low, reflecting that 20% was classified as over-reporters, and 20% as under-reporters for both baseline and intervention. The 95% limits of agreement was  $-3.48$  and  $3.44$  MJ/d (Figure 6) for both baseline and intervention.

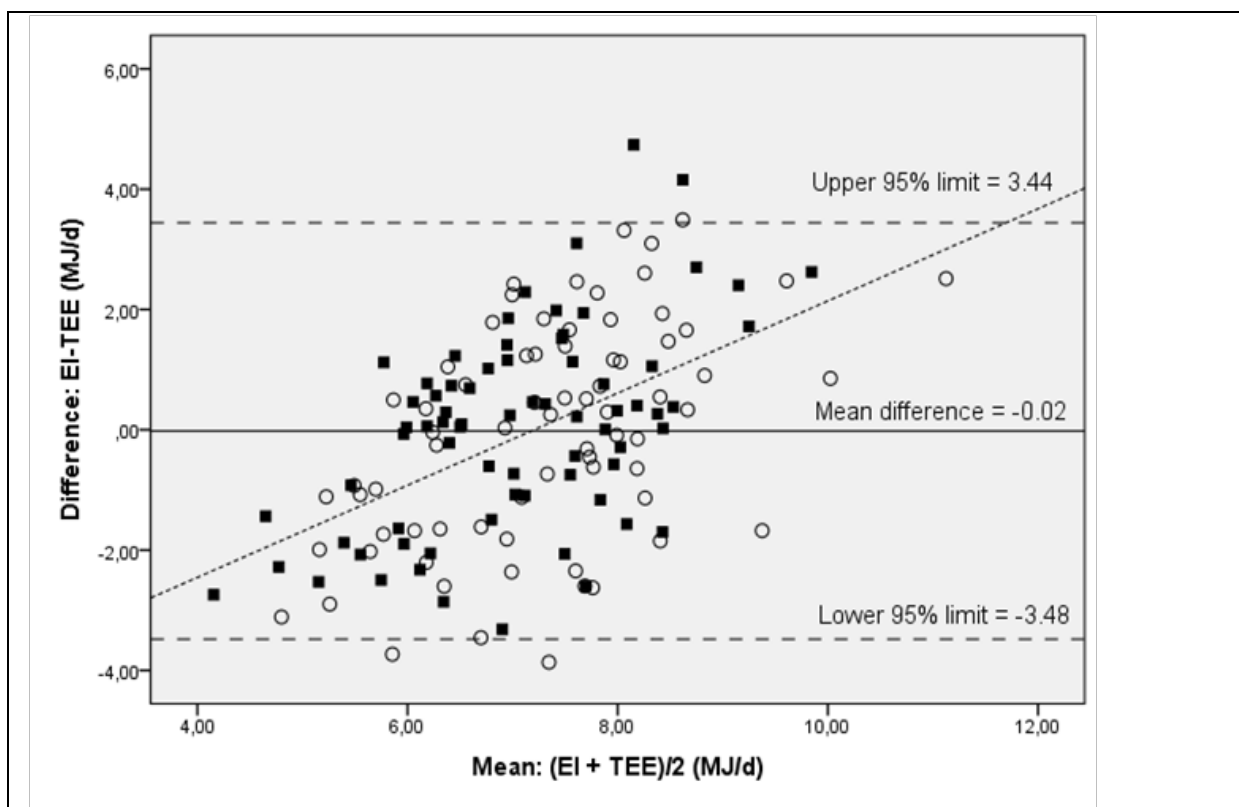


Figure 6. Bland-Altman plot of the differences between energy intake (EI) calculated from the WebDASC and accelerometer-estimated energy expenditure (TEE) plotted against the mean of EI and TEE (n=72). ■ = Baseline, and ○ = Intervention

In general, gender, illness, and BMI influenced reported EI. Boys had a 924 kJ (95% CI: 309 to 1540) higher mean EI, and a 1682 kJ (95% CI: 1472 to 1893) higher mean TEE compared to girls. Those reporting no unusual intakes due to illness in the study period overall had a 1233 kJ (95% CI: 732 to 1734) higher mean EI, and a 343 kJ (95% CI: 169 to 518) higher mean TEE compared to those who reported eating was affected by illness. EI was reduced with -145 kJ (95% CI: -255 to -11), and TEE increased on average 118 kJ (95% CI: 76 to 161) for every one unit increase in BMI.

During baseline 33% reported that illness affected eating, and during the intervention period 18% of the study population reported that illness affected eating.

As illustrated in Table 4 under-reporters had significantly higher BMI compared to acceptable-, and over-reporters. The diet of under-reporters was more likely to be affected by illness during the reporting periods and it contained more protein, more fruit and less juice compared to acceptable-, and over-reporters.

Over-reporters had significantly lower TEE and BMI compared to acceptable-, and under-reporters. The diet of over-reporters contained more fat, saturated fat, less protein compared to acceptable-, and under-reporters. More girls and fewer boys were over-reporting compared to acceptable-, and under-reporters.

Although not significant, the results demonstrated a trend towards that under-reporters were less involved in cooking compared to acceptable-, and over-reporters.

Pearson's correlation coefficient between EI and TEE was 0.31, and 73% was classified in correct or adjacent quartile for both baseline and intervention. Correlation and cross-classification was better for baseline than intervention when reporting unfamiliar foods. The repeatability of energy was moderate (0.45;  $p < 0.001$ ).

Table 4. Characteristics of under-reporters, acceptable-reporters and over-reporters of energy intake in the WebDASC<sup>\*</sup> validation study (Baseline and intervention n=153)

Subjects	Under-reporters (n=33)		Acceptable-reporters (n=89)		Over-reporters (n=31)	
		SD		SD		SD
Boys (%)	36 <sup>a</sup>		48 <sup>a</sup>		23 <sup>b</sup>	
Girls (%)	64 <sup>b</sup>		52 <sup>b</sup>		77 <sup>a</sup>	
Age (mean years)	10.4	0.5	10.3	0.6	10.2	0.6
Parental education <sup>§</sup> (%)						
Basic school and Vocational education	61		55		55	
Short, medium and long further education	40		45		45	
Use/non-use of supplements (%)	50/50		63/37		50/50	
Illness affected eating (%)	56 <sup>a</sup>		27 <sup>b</sup>		31 <sup>b</sup>	
BMI (mean kg/m <sup>2</sup> )	18.6 <sup>a</sup>	3.3	16.9 <sup>b</sup>	1.9	15.4 <sup>c</sup>	1.4
Overweight <sup>†</sup> (%)	27 <sup>a</sup>		6 <sup>b</sup>		0	
BMR (mean MJ/d)	5.2 <sup>a</sup>	0.5	5.1 <sup>a</sup>	0.4	4.8 <sup>b</sup>	0.4
Total Energy expenditure (mean MJ/d)	7.4 <sup>a</sup>	1.1	7.4 <sup>ab</sup>	1.0	6.7 <sup>c</sup>	1.0
<b>Dietary composition</b>						
Energy Intake (mean MJ/d)	5.0 <sup>c</sup>	1.0	7.4 <sup>b</sup>	1.1	9.0 <sup>a</sup>	1.3
Fat (E %)	31 <sup>c</sup>	4.2	32 <sup>bc</sup>	4.0	35 <sup>a</sup>	4.1
Saturated fat (E %)	12 <sup>c</sup>	2.0	13 <sup>bc</sup>	2.1	14 <sup>a</sup>	2.2
Protein (E %)	17 <sup>a</sup>	2.8	16 <sup>bc</sup>	2.1	15 <sup>c</sup>	2.4
Carbohydrate (E %)	52	4.7	52	4.8	50	4.2
Added sugar (E %)	10	4.1	11	4.9	11	3.6
Dietary fibre (g/10 MJ)	25	5.7	24	4.5	22	7.7
Vegetable intake (g/10 MJ)	194	115	175	85	177	139
Fruit intake (g/10 MJ)	278 <sup>a</sup>	188	188 <sup>b</sup>	117	201 <sup>b</sup>	138
Juice intake (g/10 MJ)	71 <sup>b</sup>	86	109 <sup>a</sup>	111	135 <sup>a</sup>	108
EI/BMR (mean)	1.00 <sup>c</sup>	0.17	1.46 <sup>b</sup>	0.21	1.90 <sup>a</sup>	0.21
<b>Dietary focus</b>						
Parental intention to eat healthy (%)						
Very often or often/once in a while and never	88/12		90/10		81/19	
Parental satisfaction with own dietary habits (%)						
Yes, very and to some extent/only partly or not at all	69/31		57/42		69/31	
Parental responsibility for cooking (%)						
Mother	69		59		68	
Father	25		15		13	
Mother/father or mother/father/children together or in turn or others	6		27		20	

Statistical analysis included independent t test, and  $\chi^2$  test.

Mean values within a row with unlike superscript uppercase letters were significant different between under-, acceptable-, and over-reporters ( $p < 0.05$ ).

\* Web-based Dietary Assessment Software for Children.

<sup>§</sup> Basic school: <12 years in school. Vocational education: 11-13 years total education, mainly practical. Short higher education: 11-13 years total education, mainly theoretical. Medium and long further education: at least 15 years total education, including academic education.

<sup>†</sup> Overweight is defined by Cole's standard definitions on child overweight (Cole *et al*, 2000).

#### 4.2.2 Reporting of fruit, juice and vegetables (Paper 3)

The validation of reported FJV intake is only based on baseline data. No differences in plasma concentrations of carotenoids between supplement users and non-users were found which may reflect that standard Danish vitamin supplements do not contain carotenoids.

The WebDASC estimated intake of FJV was significantly correlated with the biomarker (Figure 7), and the Spearman correlation between total plasma concentration of carotenoids and FJV intake were 0.58 ( $p < 0.01$ ). Partial correlation coefficients adjusted for gender, BMI, and TEE between total plasma concentrations of carotenoids and FJV intake were 0.49 ( $p < 0.01$ ).

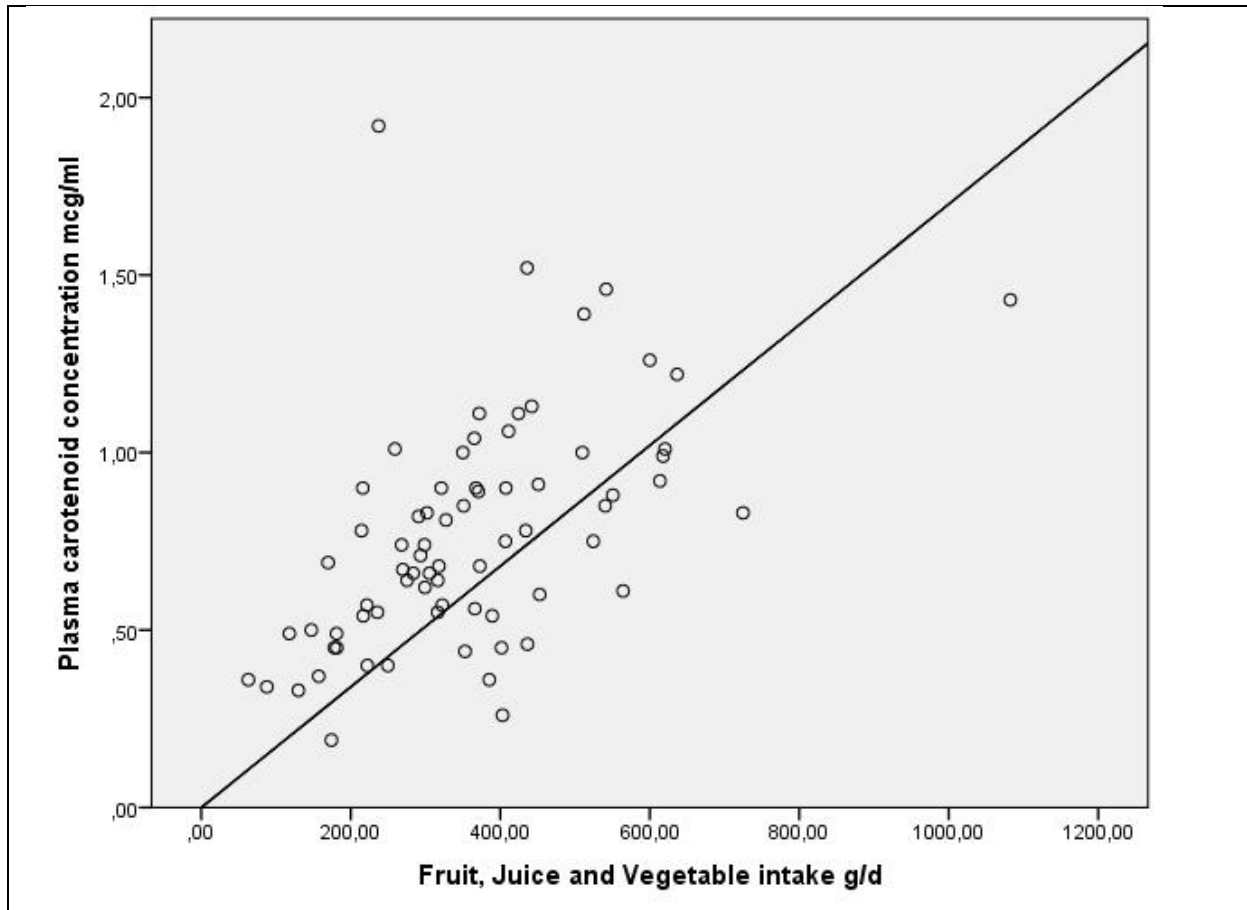


Figure 7. Fruit, Juice and Vegetable intake (g/day) illustrated against plasma carotenoid concentration ( $\mu\text{g}/\text{ml}$ ).

Fruits and juice showed higher Spearman correlation coefficients than vegetables with plasma carotenoid concentration (0.38 and 0.42 vs. 0.33). 82 % of the participants fell into the same or adjacent quartiles when classified by estimated FJV intake and carotenoids biomarkers.

The relative contributions of the single carotenoids to total plasma concentration reflected the relative contribution of the single carotenoid intake to total carotenoid intake ( $\chi^2$ :  $p = 0.220$ ) (Figure 8).

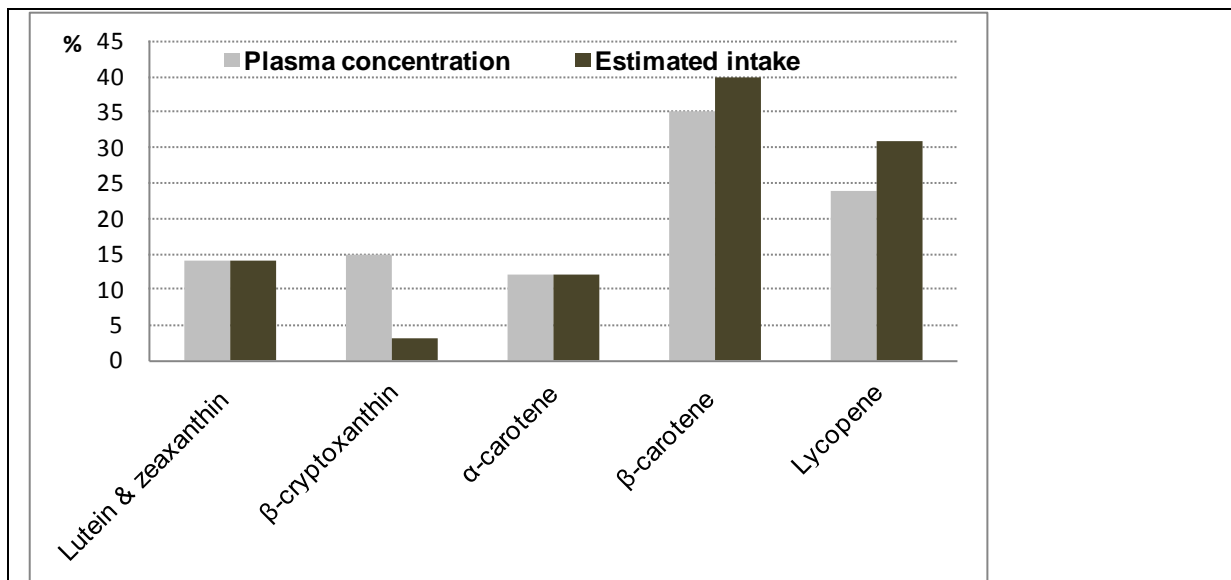


Figure 8. Relative contribution (%) of individual carotenoids to total carotenoid plasma concentration and total estimated carotenoid intake (n=81).

#### 4.2.3 Observations.

As seen in Figure 9 the largest intake of fruit, juice and vegetables occurred at lunch on school days. School lunch therefore, provided an obvious opportunity to observe fruit, juice and vegetable intake.

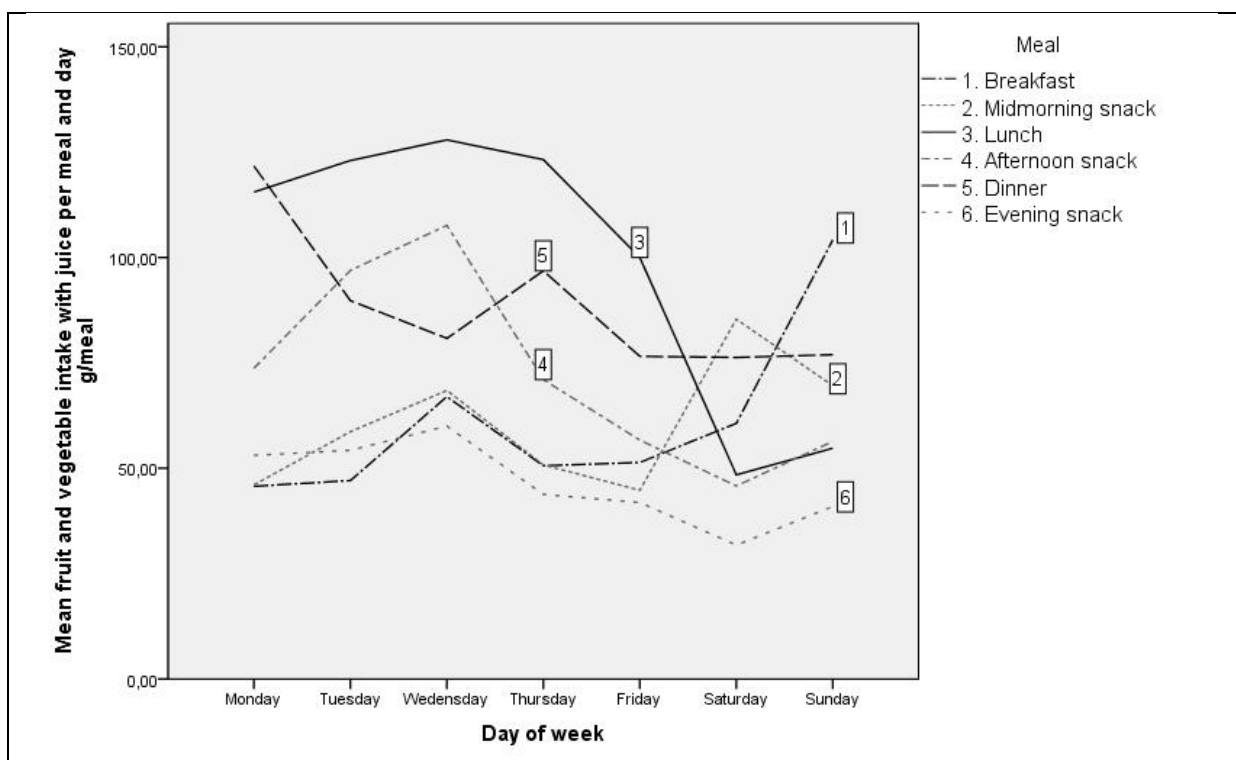


Figure 9. Intake of fruits and vegetables at different meals during the week (n=81)

For school lunch reporting's in general WebDASC obtained 82% matches, 14% intrusions, 3% omissions and 1% faults for total foods and beverages (results not shown).

As illustrated in Table 4 overall reporting accuracy for fruit, juice, vegetables and other foods were not significantly different. However, a higher percent match and a lower percent intrusion for fruit compared to beverages and lower percent omission compared to foods was observed.

Most (90% in total) reporting errors for FJV were intrusions e.g. reporting a portion size image illustrating a larger portion than the eaten portion size (35%) or reporting fruits and vegetables not eaten (65%).

Table 4. Relative reporting matches, intrusions, omissions and faults (%) of fruit, juice, vegetables, foods and beverages when comparing packed school lunch intake to school lunch reporting's in the WebDASC among 77 children.

	<b>Fruit (n=158)</b>	<b>Juice (n=27)</b>	<b>Vegetables (n=411)</b>	<b>Beverages excluding juice (n=255)</b>	<b>Foods excluding fruit and vegetables (n=1208)</b>
Match (%) <sup>*</sup>	89 <sup>a</sup>	89	82	77 <sup>b</sup>	81
Intrusion (%) <sup>†</sup>	10 <sup>b</sup>	11	16	22 <sup>a</sup>	13 <sup>b</sup>
Omission (%) <sup>‡</sup>	1 <sup>b</sup>	0	2 <sup>b</sup>	0	5 <sup>a</sup>
Fault (%) <sup>§</sup>	0	0	0	1	1

<sup>a,b</sup> Mean values within a row with unlike superscript letters were significant different (p<0.05).

\* Item recorded eaten and observed eaten including match of portion sizes.

† Items reported eaten but not observed eaten. If reported serving size was too large, this was also scored as an intrusion.

‡ Item observed eaten but not reported eaten. If reported serving size was too small, this was also scored as an omission.

§ Item reported eaten does not describe the item observed eaten

That intrusions were the most common reporting error was also reflected in the total weight of foods reported, which were higher than the total weight of food actually eaten at lunch. Mean reported weight of foods at lunch was 243g vs. actual weight of eaten foods: 209g (p<0.001). The same was true for beverages. Mean reported weight of beverages at lunch was 184g vs. actual weight of beverage intake at lunch: 147g (p<0.001).

# 5. Discussion

The present chapter discusses key issues emerging from 1. The development of a dietary assessment tools for Danish 8-11-year-old school children, and 2. The results of the validation studies. Finally the key issues are gathered in the overall concluding discussion.

## 5.1 Developing WebDASC (Paper 1).

WebDASC was developed as an intuitive, simple, cost-effective and engaging method to collect 8-11-year-old children's self-administered recalls, with an appropriate level of detail to obtain food intake estimates in the context of a school-based intervention study.

Development challenges included: choosing relevant food list terms and food categories covering the children's diet; accruing and selecting digital images for portion size estimation; providing a customized spell check function; and anticipating limitations in the available computer technology during development, which were not able to satisfy the needed flexibility within allocated resources.

The development of the WebDASC involved many issues, including those not directly related to nutrition as IT challenges and development of a spell check application. The next sections discusses key nutritional issues including the comparison of WebDASC with the more conventional paper and pencil method, level of detail, portion size estimation and how to motivate children to complete a dietary assessment.

### 5.1.1 Comparison with pencil and paper

The advantages of using the WebDASC compared to a self-administered paper and pencil method was the possibility to include a large and specified food list and corresponding many portion size images, to develop a child appealing interface, including sound, prompts and internal checks for frequently forgotten foods to enhance memory, and to provide skip patterns for ease of navigation. Furthermore, it was possible to include motivators like the game and some kind of immediately feedback such as the food meter and the top 10 list. Furthermore, the data demands less processing time (no need for scanning and/or entering) and are quickly accessible for researchers and thereby timesaving. During the *pilot study* we had close contact with the respondents, with respondents e-mailing or phoning about the WebDASC and the food reporting, e.g. parents felt that WebDASC did not always give the opportunity to report precisely enough especially when reporting mixed dishes. The major disadvantage, reported by respondents was the inability to correct in a completed previous record.

This seldom happens with paper and pencil methods. This may be because everything is visible with the paper and pencil method, the food list, the number of meals, the portion size images. The possibilities are what respondents see, and if they remember a mistake from the day before, it is easy to correct even 3 days after whereas the day would be closed for correction in the WebDASC. In a future version of the WebDASC it might be a good idea to have a "box", where respondents can enter comments to their specific meals. This might satisfy needs for clarification of own entered meals and useful for researchers in understanding respondents interaction with the dietary assessment tool.

### 5.1.2 Level of detail

One obvious dilemma in the dietary assessment of children is that the level of detail imposes a great burden on younger participants who are unable to provide accurate recounts.

Most dietary assessment is built around the answers that would be ideal obtaining in a study and not around the answers that the study population is able to provide. This obvious shortcoming also applies to the OPUS School Meal Study, and therefore, the WebDASC could not be fully adapted to match children's cognitive abilities. In WebDASC the children are requested to report details in their diet that they are not aware of. For instance the children in the focus groups wanted to report a "Leverpostejsmad" (liver pâté open sandwich) as a single food, but in the WebDASC they are required to report the bread, fat spread, liver paste, and condiments as cucumber separately with the risk of something being forgotten. It would be interesting to investigate the errors introduced when asking to report food items separately compared to a generic recipe. It should also be investigated if it would

be possible for respondent to create and save his own "Leverpostejmad" for later use in the food reporting. Generic recipes for mixed dishes are already used, as it would be impossible for a child (and also adults) to estimate e.g. the amount of canned tomato in a meat sauce if they did not prepare the dish themselves.

To the author's knowledge, other computer- or web-based self-administrated dietary assessment software's aim at different levels of detail. The web-based Synchronised Nutrition and Activity Program (SNAP) developed for 7-15-year-old English Children by Moore et al (Moore *et al*, 2008) applies a low detail level with a food list containing 40 food items and 9 beverages, with the goal to assess energy balance behaviours. In the computer based Young Adolescents Nutrition Assessment on Computer (YANA-C) developed for 11-18-year-old Belgian adolescents by Vereecken et al (Vereecken *et al*, 2008), the food list included 800 food items organized into 25 food groups. In YANA-C the respondents are also asked, if relevant, to provide additional information to the food item chosen e.g. about preparation method (cooked, baked, fried). In the Food Intake Recording Software System version 4 (FIRSSt4), based on FIRSSt (Baranowski *et al*, 2002), under redevelopment for 10-13-year-old American children by Baranowski et al (Unpublished results) the food list contains 1700 foods and contains multiple queries for each foods. The YANA-C and the FIRSSt aim to estimate the whole diet whereas SNAP aims at estimating one behaviour of diet intake.

The WebDASC which contains 1300 items in the food list is comparable to YANA-C and FIRSSt except it does not apply additional questions about related qualities; such as if the salmon was raw, baked or fried. This is handled in the nutrient calculation where the recipe for salmon consists of 50% baked and 50% fried salmon. By removing the last questions, it is expected to remove questions that the children would not always be able to answer anyway, with only minor influences of commonly analyzed nutrients.

### **5.1.3 Portion size estimation**

The computer interface makes it easier to inquire about portion size details than paper versions. Other computer based dietary assessment systems, like the Automated Self Administered 24 Hour Recall (ASA 24), use a sequence of three questions to obtain portion size of drinks (container type, container size, and percent volume). WebDASC does this in a single step by showing a standard glass with four different levels of fill up. It is not clear whether implementing additional portion size estimation tasks in WebDASC would achieve more precise estimation. Some of the respondents who found it difficult to estimate portion size mentioned especially beverages as hard to estimate from available portion size images. The observation of the children's school lunch showed that the difference in mean weight estimated with WebDASC and actually weighing the beverages was 37g (corresponding to 25% misreporting by weight) whereas for foods it was 35g (corresponding to 17% misreporting by weight). This indicates that the errors associated with estimating beverages were larger, but at the same level as the errors associated with food estimation. A lot of the children brought beverages in an opaque water bottle which made the amount difficult to estimate as it was filled up during the day.

Foster and co-workers underlines the importance of using age appropriate food portions when estimating portion size by images (Foster *et al*, 2006). In WebDASC the use of age appropriate portions could not be fully accomplished because food pictures were obtained from more than one source. How portion size can be more easily estimated without sacrificing precision remains to be investigated. A 3D image or an image rotating to be viewed from different sides when "scrolled over" might be future improvements. Or a novel approach where the respondent does not have to perform that task of portion size estimation. These approaches are using either PDA or camara-enebled cell phones with data transfer capability where participants take and transmit photographs of foods selection and plate waste to researcher for analysis using automatic or dietician conducted food image analyses (Woo *et al*, 2010; Martin *et al*, 2009b; Martin *et al*, 2009a; Six *et al*, 2010; Zhu *et al*, 2008; Mariappan *et al*, 2009).

### **5.1.4 Motivators**

All participants choose to use WebDASC even though they had the possibility to use a paper version instead. This indicated a high level of computer ownership amongst participants and overall acceptance of the technology.



Three motivators were included in the WebDASC, a food meter, a top 10 list, and a computer game. The food meter is displayed at every screen so the respondent can see that others are participating as well. The main goal with the food ranking was to offer the children the possibility of comparing their own diet to that of others, without influencing the food reporting. The game was provided as an incentive to persuade children to complete the WebDASC every day. The computer game was a simple low cost game, and in comparison with the graphics, and possibility for interactions with friends and the interface designs of what children in that age group plays normally (e.g. World of Warcraft) the game was basic. 88% of the participating children answered that they played the game, and of these 31% found it a little boring. The statistics on the web-hosting showed that the game was played on 55% of reporting days. It is not known whether the game and the high score list motivated the children to report their diet. But the statistics indicate that it had some success and if it did motivate some, it was a little once-and-for-all expense. It could also have been considered giving access to different already developed games, instead of developing a new game, but this might not be the same as playing an exclusive game.

Lu et al. has discussed the matter of motivation and suggests that the field of dietary assessment uses some of the same strategies known from media and communication when designing dietary assessment tools for children. These strategies include the use of animated customizable agents, embedding the dietary assessment process into a computer game, adding of narratives to the dietary assessment programme, recreation of virtual intake environment, interspersing of training sessions to improve portion estimation etc. (Lu et al, 2012). The customizable agent was also used in the WebDASC, and he was well accepted by children although for some of the older children he appeared childish. This is another challenge for making design for an age group of children. Their development is fast, and therefore it is difficult to target all even in a narrow age group. The suggestion of game embedment can also be discussed. It has to be thought of very carefully in order to avoid confusing the children with the goal of the dietary assessment. But the possibilities of interaction with friends should be investigated further.

## **5.2 Validating WebDASC (Paper 2 and 3).**

The validation process relates to both the method from which the measurement was derived, and the context within which the method was used. Therefore the context of the OPUS School Meal *Pilot study* is included where relevant in the following sections.

### **5.2.1 Energy intake vs. energy expenditure (Paper 2)**

At the group level WebDASC was found to give an EI which was in agreement with the measured TEE (-0.02 MJ/d:  $P=0.788$ ), and the repeatability of EI was moderate. The WebDASC's ability to rank participants according to EI was fair ( $r=0.31$ ) and 73% was classified into the same or adjacent quartile with EI and TEE. The correlations were higher than what was obtained in an American study validating 3 x 24hR among 4-11 year old children against doubly labelled water (Fisher et al, 2000), but slightly lower than the correlation observed in a comparable Norwegian study among 13 year old children (Andersen et al, 2005). In the present study correlation and cross classification showed better results at baseline period compared to intervention period. This difference may be due to greater difficulties when reporting the unfamiliar NND foods in the WebDASC (Livingstone & Robson, 2000; Warren et al, 2003).

#### *Methodological considerations: under-reporting and over-reporting*

Although the WebDASC provided an acceptable estimation of EI at group level compared to accelerometer-estimated TEE, 20% were classified as over-reporters, and 20% as under-reporters in both the baseline and intervention period. This is different from other studies using motion sensors to assess TEE in children showing that under-reporting is a larger problem than over-reporting and where between 19 – 52% were classified as under-reporters (Noel et al, 2010; Lillegaard & Andersen, 2005; Andersen et al, 2005). Additionally, the underreporting seemed to be relatively low in the present study when considering impact from illness (see below). There is not much data on over-reporting, and in her review Forrestal only found two studies showing over-reporting of 25- and 46% in 9-year-old and 4-11-year-old children respectively (Forrestal, 2011).

Over half of under-reporters reported that illness affected eating during the reporting period, and results from the linear mixed models showed that illness significantly influenced energy intake with a mean of -1233 kJ. This is also seen in a study on an adult population, where illness during the recording period had significantly impact on under-reporting (Rennie *et al*, 2007), and a German study including children and adolescent found that acceptable-reporters had a higher percentage of “no unusual recording days” (Forrestal, 2011).

Using TEE as a reference measurement for EI is based on the principle energy balance concept, i.e. EI equals TEE in the recording period. In the present study 22 out of 81 school children reported a lower EI than their estimated BMR, half of them due to illness. Using TEE estimated from PAEE, BMR and DIT as a comparison measure to EI under these circumstances may be a problem as BMR is a major constant component of TEE (BMR~ 70% of TEE in the present study). TEE will always be minimum the BMR, whereas EI may vary from a zero-intake during illness and upwards. This affects comparison analysis because the underestimated variation in TEE may have exaggerated the difference between EI and TEE. The consequence is that the observed correlation between EI and TEE is likely to be less than the true correlation. However, exclusion of respondents, reporting illness affected eating, from analyses did not change the overall results and therefore they were kept in the analyses. Furthermore, the influence of illness on dietary habits is a part of everyday life, and this will also be true for the OPUS School Meal Study where days lost through illness will dilute the effect of the NND.

Under-reporters in the present study had higher BMI, and reported less EI and more protein compared to acceptable-, and over-reporters. Other studies also demonstrate that 7-11-year-old children that under-report their dietary intake have higher BMI's and are more weight concerned compared to acceptable-reporters, and over-reporters (Lanctot *et al*, 2008; Ventura *et al*, 2006). It was expected that the unhealthy foods and beverages would be under-reported. However, only protein intake among under-reporters was significantly higher than acceptable-reporters. Moreover, there was a trend towards reporting a lower intake of fat, saturated fat and a higher intake of dietary fibre compared to acceptable-reporters. This is in contrast to what others have observed (Rasmussen *et al*, 2007; Samuel-Hodge *et al*, 2004; Goris *et al*, 2001b). Over half of the under-reporting children reported illness, and illness is not necessarily accompanied by a healthier diet – but with a generally low food and EI. This can also have contributed to the small difference in macronutrient distribution between under- and acceptable-reporters as can the small study sample. Furthermore, selective mis-reporting might have taken place in both under-, acceptable- and over-reporters, and the intake of unhealthy foods are underestimated and the intake of healthy foods is overestimated, and it is well known that the sales of sugar are much higher compared to what is reported in national dietary surveys (Fagt *et al*, 2008). Based on an evaluation of the macronutrient distribution of under-reporters and over-reporters compared to acceptable-reporters, it looks like it would be acceptable to keep under-reporters and over-reporters in the sample for e.g. analysing associations to biomarkers – but, a comparison on food and nutrient level would be necessary as well in making the final decision. However, it may be necessary to exclude under-reporters and over-reporters before relationships between diet and obesity can be investigated.

Children characterized as over-reporters had a low TEE and BMI and reported higher intake of fat and saturated fat compared to acceptable-reporters. Over-reporting may be a result of general over-estimation of portion sizes and also of high fat/energy-dense foods as fat spread as indicated by the relatively higher fat content in over-reporters diet. The lower BMI among over-reporters is also seen in a study among 4-11 year-old children (Fisher *et al*, 2000). Huang *et al* (2004) found that over-reporting was more likely to occur among younger children who received more parental assistance. The over-reporting can be guided by parents who wish for their children to increase growth, eat more, and therefore instinctively help the child report larger portion sizes. Maternal pressure to eat has been shown to be inversely correlated to children's BMI (Matheson *et al*, 2006).

Accelerometers are often attached to the waist, and do not capture upper body movement or cycling, and underestimate heavy load carrying as weight lifting. Furthermore, accelerometers are not waterproof, and hence do not measure water-based activities as bathing and swimming. This may lead to an underestimation of AEE (Armstrong & Welsman, 2006). Activities such as cycling, swimming and horseback riding is relevant in 8-11- year-old Danish children. However, analyses of the log books where time used for cycling, swimming and horseback riding noted by respondents, showed that only 14 min/day was used on such activities. Unaccounted time for

these activities can therefore not explain the low level of accelerometer counts and PAEE. This point is that the low level of TEE is caused by de facto lower activity due to weather conditions and illness.

Errors most likely have been introduced in estimating the different parts of TEE, which would have affected the number of under-reporters and over-reporters. There is no consensus about the most appropriate energy expenditure prediction equation from accelerometer data, including how to distinguish between periods of non-wear time and bouts of sedentary behaviour (Corder *et al*, 2008). The prediction equation used in the present study to estimate TEE is based on a small number of participants, but it is derived from doubly labelled water measurements, and to the authors knowledge, it is the only equation based on free-living European children of the same age-group as in the present study (Nilsson *et al*, 2008). In contrast Laboratory-derived prediction equations have been found to overestimate free-living energy expenditure by 47% in one study using doubly labelled water (DLW) (Ekelund *et al*, 2004).

A 7-day record/recall method to be completed in the evening was chosen in the present study to minimize a change in dietary behaviour, which have shown to occur with the diet record method if the record is filled in when eating (Thompson & Subar, 2008). However, the overall results from assessing over- and under-reporting demonstrated that the reported EI was associated with the child's weight status, and the results from the acceptability questionnaire showed that respondents themselves felt a change in dietary habits during the reporting period. This indicates that the diet reporting most likely did influence dietary behaviour.

#### *Methodological considerations: Socially desirable answers*

Participating in the OPUS School Meal *pilot study* most likely has influenced the results of the dietary assessment. First of all, all participants had to attend an introduction meeting before acceptance to participate. At this meeting they were introduced to the aim of the study, the measurements taken and they were introduced to and tasted the NND. Furthermore, they took part in a two hour long background interview, where focus was e.g. weight and lifestyle behaviour. This may have introduced a risk for dietary behaviour changes when entering the study. Minimizing the influence of these factors on the dietary assessment is important. Maybe it would be better if the study is presented as a study of acceptance, taste and implementation of NND in schools. These parameters are already important parts of the study but not main focus. Furthermore, the background interview could be divided into two parts, so only demographic questions were asked in advance and the health related questions could then be asked after the study period.

The home setting for completing the diet reporting was chosen to reduce risk of social desirable answers. The focus groups showed that the children were very judging about the food intake of their friends when talking about it (Biltoft-Jensen, 2009). In the home setting they also would have the advantage of getting help from their parents. Children and parents were instructed to report the children's diet together, and this was followed in 90% of the cases. However, getting help from parents, may have introduced socially desirable answers given by children to conform to what parents think is an appropriate diet, or parents may have provided socially desirable answers on behalf of their children (Livingstone *et al*, 2004). Measures of social desirability were not included in the present study (Baxter *et al*, 2004a). However, the background interviews showed that the parents had high intentions to eat healthy, but were not satisfied with own dietary habits. It is likely that the OPUS study and the food reporting might have provided an opportunity for parents to demonstrate that they could eat the healthy diet they were aiming for. The timing was also "perfect" because in January every newspaper and magazine sets the agenda by launching their "New year" diets.

The parents in the present study were generally more overweight than parents for the same age group in the DANSDA (54% vs. 42% both based on self-reported weight and height). It has been shown that groups wanting to purvey a socially desirable image tend to include overweight women (Macdiarmid & Blundell, 1998). It is very likely that overweight parents in the OPUS School Meal *pilot study* have wanted to appear with healthier diets than they normally eat and therefore changed their own and children's diet in the study period. Hence 59% of the study population felt that they changed their diet more or less during the study period. How much was due to the actual recording and how much was due to entering the study is unknown. Most likely it is a combination of both.

Overall the diet reporting in WebDASC was probably influenced by a change in dietary habits as a result of the diet reporting itself in combination with the study factors which, all together, placed a lot of focus on the respondents eating habits. This diet focus may have been reinforced by overweight parents that wished for a healthier diet for themselves and their heavier children, and parents of small children who wished for their children to grow resulting in that the diet reports was associated to the children's weight status.

### **5.2.2 Reported fruit, juice and vegetable intake vs. plasma carotenoid concentration and lunch observations (Paper 3)**

#### *Ranking of respondents according to intake of fruit, juice and vegetables*

When evaluating reported FJV intake against plasma carotenoid concentration it was found that the ability of the WebDASC to rank participants according to FJV intake was quite good (Spearman correlation:  $r = 0.58$ , Partial correlation:  $r = 0.49$ ). Moreover, 82% of respondents FJV intake was classified into the same or adjacent quartile according to plasma carotenoids concentration. Furthermore, the relative contributions of the individual plasma carotenoids to total plasma concentration reflected the relative contribution of the individual carotenoid intake to total carotenoid intake. The Spearman correlations between plasma concentrations of the individual carotenoids and respective dietary intakes were higher in the present study compared to a study by Neuhauser of adolescents aged 12-17 years (Neuhauser *et al*, 2001). In the study of Neuhauser, however, the dietary assessment used was a FFQ, which is known to be less accurate than a 7-day record as used in the present study (McPherson *et al*, 2008).

The Partial correlation between FJV intake and plasma carotenoid concentrations in the present study was higher than found in other studies among adolescents and adults validating FFQ, FD and 24hR. In one study of adolescents (5th and 8th grade) the correlations found were FFQ= 0.24 and 24hR= 0.14 (Slater *et al*, 2010) and in two studies of adults it was FFQ=0.13; and FD= 0.20 (Brantsaeter *et al*, 2007) and FFQ= 0.32 to 0.42 (Toft *et al*, 2008).

Fruits and juice intake showed higher correlations than vegetables with plasma carotenoid concentration which might reflect a better reporting of fruit and juice or a higher availability of carotenoids from fruit and juice compared to vegetables.

#### *Observed reporting of fruit, juice and vegetables*

The direct observation of school lunches showed that the reporting accuracy for fruit, juice and vegetables eaten for lunch was comparable to the accuracy for all foods and beverages. Overall, the study showed 82% matches. It was found that the children were better at reporting fruit intake than beverages at school lunch. This might be explained by the fact that fruit is very visible foods easy to count and the size is well known, opposed to beverages which are often brought to school in opaque water bottles of various sizes and refilled during the day. In the WebDASC this should be compared to different fillings of a standard glass, which would be difficult. How to estimate portion sizes of beverages from waterbottels remains a challenge.

There is probably no simple solution to improve the reporting of vegetables in mixed dishes, but for individual vegetables it might be a possibility to have more preparation types to choose among in the food list. These issues should be investigated further.

School meals seemed to provide a good opportunity to evaluate the reporting accuracy of FJV intake in the present study, since school meals contributed with the highest intake of FJV (101 g/day and higher during school days). In the present study a modified observation technique was used, including a digital photographic method, weighing and questioning. In a number of previous studies investigating accuracy of reported school meals researchers or dieticians have been observing 1-3 children at a time and recording items and amount eaten for each child (Baxter *et al*, 2002; Baxter *et al*, 2003a; Baxter *et al*, 2003b; Baxter *et al*, 2004b). Photographing the children's school lunches gave, in addition, the opportunity and time to evaluate the reported serving sizes more thoroughly by comparing them to food images and known weights of these.

The use of direct observation as a validation tool is based on the assumption that what is observed is a reliable and valid measure of actual dietary intake. But direct observation is not a complete “perfect” measure of dietary intake, and observation may alter respondents usual intake (Sherwood, 2008). However, using a digital photographic method is less sensitive to observer bias, because the same dietician is able to evaluate all the images. It can be argued that the evaluation of portion sizes from images by a trained analyst is subjective. However, a study have shown that accurate estimates of portion sizes of foods from digital images can be made by trained analysts, and that having the total weight of the food on the plate increased accuracy of estimated weight of the separate meal items (Lassen A.D. Unpublished paper).

Other American studies of the same age group have found intrusion rates ranging from 16-54 % and omission rates from 32-67% when reporting school meals in general (Baxter *et al*, 2002;Baxter *et al*, 2003a;Baxter *et al*, 2003b;Baxter *et al*, 2004b). This is higher than in the present study finding 14% intrusions and 3% omissions when reporting school meals in general. It should be noted that in the American studies of Baxter et al a statistical weight was assigned to each item according to importance by meal component so that errors regarding reporting main components counted more than errors for condiments. Furthermore, in some cases the observation validated 24hR obtained the day after the observation and not on the same day as in the present study. The results from these studies are therefore not directly comparable to the present study, where only the FJV part of the meal is evaluated. The higher accuracy observed in the present study might be explained by the parent assistance. Parents probably had prepared or assisted preparing the packed lunches, and therefore were able to assist their children in reporting their lunch intake. In contrast, in the studies of Baxter et al. no parent assistance were provided, and in addition the children had school meals prepared by a school cater which may contain unfamiliar foods compared to packed lunches from home as validated in the present study. Previous studies have shown that it is more difficult for children to record unfamiliar foods compared to familiar foods (Livingstone & Robson, 2000;Warren *et al*, 2003).

Preliminary results from the school lunch observations under the intervention period in the present study indicate that it is more difficult for children and parents to report the NND foods than the packed lunches. In the intervention period approximately 70 % matches, 20 % intrusions, 3 % omissions and 7% faults when reporting school meals in general was obtained. The 10 percent lower matches for the intervention is probably due to reporting unfamiliar foods with unfamiliar names. Furthermore, parents were less able to assist when reporting what and how much was eaten since they did not participate in preparing- or providing for school lunch. However, the percent matches for beverages increased (to 88% matches) during the intervention with the NND. This probably was a result of the children using a cup (as a part of the OPUS tableware and meal concept) for their beverages, during the intervention period. Finally a greater part of the intrusions during the intervention period was due to the reporting of a too large portion size (48% of mis-reportings) compared to baseline (35% of mis-reportings) probably as a result of children only tasting the unfamiliar NND, but reporting it as a full portion. This indicates that intrusions might be diminished if the portion size images include very small portions for the NND foods.

The clarity of displaying NND foods in the browse search was improved after the *pilot study*. All NND foods were displayed after the weekly menu. In the browse search it was possible to choose the menu of the day under subgroups. Thereafter all the foods contained in the menu was displayed in the food items list for reporting, sparing respondents to search after each food item and minimizing reporting errors for the foods included in the daily menu.

The percent obtained matches of FJV recordings in the WebDASC can be viewed as a form of ranking, showing that children, assisted by parents, are able to report the correct food item and choose the correct portion size among 4 images in the WebDASC, and there by ranking them self according to quantity of intake.

Overall the validation of FJV intake against plasma concentration and by direct observation showed that in general the WebDASC was able to produce a good ranking of the reported FJV intake when compared to respondent's

plasma carotenoid concentration. Furthermore, the WebDASC was also able to produce a good ranking of reported FJV intake when compared to photographic observations at school lunch. Fruit obtained higher correlations to plasma carotenoid concentration than vegetables and higher percent matches than beverages at school lunch. This might indicate that fruit is easier to report correctly compared to vegetables, beverages and other foods. It remains a challenge to increase accuracy of reporting vegetables, NND foods and beverages from water bottles in the WebDASC.

### **5.3 Overall concluding discussion**

The project all together showed that there were good acceptance of the technology and the WebDASC. The validation showed agreement (-0.02 MJ/d:  $P=0.788$ ) between EI and TEE on group level, and an acceptable ranking of individuals on individual level. Even if there was both under-reporting and over-reporting, the WebDASC ranked individuals according FJV intake quite good and a produced a high percent matches of reported fruit, juice, vegetables and other foods at school meal level when compared to photographic observations. This is promising because the intake of FJV is both important diet indicators for health and the development of lifestyle diseases, and important ingredients in the NND. Fruits and vegetables are energy-poor foods and their intake only influence EI with 10% in a normal Danish diet (Pedersen *et al*, 2010), and therefore it is possible to obtain a higher ranking of reported FJV than the ranking of EI. Under-reporters, who were those most affected by illness, had a higher content of fruits in their diet, and at the same time the analyses showed that FJV intake went down when reporting illness affected diet. This is probably due to a decreased intake of vegetables during illness, while fruit may still be consumed, because it is fresh and sweet.

Parent assistance is indispensable for the good results obtained reporting the school lunches and the diet. However, parents are also the gatekeepers of the family's eating habits, and if they have been inspired by the focus of the OPUS study to implement more favourable eating habits during the study period, it has most probably also influenced the reported diet of the children. The effect of changing diet in response to the health focus, information meeting, and background interview in the present study may be compared to the placebo effect known from medicine, where a measurable, observable, or felt improvement in health or behaviour is not attributable to a medication or invasive treatment that has been administered, but to what is told before the treatment was given. If this is true one should carefully consider the information and signals given in advance and during the study period.

### **5.4 Strengths and limitations**

#### **5.4.1 Strengths**

The strength of the present study was that a combination of formative research and professional judgement was used to guide the development of WebDASC. This ensured that WebDASC is based on sound research combined with professional experience.

A further strength was that 7 days of dietary assessment in the *pilot study* was aimed at giving optimal possibilities for measuring the whole diet and the influence of the NND on the whole diet. Further, 7 days of diet assessment did not represent a low respondent burden, which was one of the foreseen challenges as 98% of participating children completed all 7 days. This shows, that the same, and the optimal number of days can be aimed at in the main study.

Another strength was that, several different and non-correlated objective methods were used to evaluate different aspects of the children's report in the WebDASC.

The results from the qualitative questionnaire showed that the WebDASC method was well accepted by participants, and they provided useful feedback for improvements. This together with the lower and non-academic educational level in the present study compared to the general population implies that the web-based method does not require a high educational level. A further strength of this study is that the validation of the WebDASC

was performed under exactly the same circumstances as it is intended to be used in the OPUS school meal intervention study including same procedures, same setting, same age group, and a baseline and intervention period with the NND although not representing all seasons.

#### **5.4.2 Limitations**

The *pilot study* sample was composed of volunteers with little ethnic, social and cultural diversity which probably have influenced the generalizability and external validity of the results. The study sample was recruited from one school and the study was conducted during one time period, which made the study vulnerable to a flu epidemic, resulting in 33% and 18% during baseline and intervention respectively reported different eating due to illness. Furthermore, the study was vulnerable to weather conditions with heavy snow and frost resulting in low levels of accelerometer counts in the participating children and following low estimated AEE. The relative small sample size made comparisons between under-reporters, acceptable-reporters and over-reporters uncertain and the results should be interpreted with this in mind.

Furthermore, when validating EI, the accelerometer derived TEE had limitations as reference method, as already discussed in section 5.2.1.

## 6. Conclusion

The thesis demonstrated that it is possible to develop a child appealing web-based dietary assessment tool that can be used in intervention studies at home on the family's home computer. The developed WebDASC was acceptable to use for both 8-11- year-old children and their parents, and feasible to use in the OPUS School Meal *pilot study*.

The WebDASC provides good estimates of average EI compared to the estimated TEE. Moreover a moderate repeatability of EI was observed. The ability of the WebDASC to rank participants according to energy intake was fair. The validation study demonstrated that under-reporting and over-reporting was associated to the weight status and BMI of the children. Possible causes may be the weight and health focus of the study, social desirability and the diet reporting itself.

When using plasma carotenoid concentrations as a reference, the WebDASC's ability to rank participants according to FJV intake was good and the WebDASC obtained a high percent matches for FJV intake and overall intake at school lunch.

In conclusion the WebDASC is both acceptable and feasible to use to collect dietary data from 8-11-year-old children in intervention studies. This project demonstrated that, in the study population, data could be used to estimate energy intake on group level and to rank individuals according to EI, and to rank FJV intake both overall and on school meal level, and thereby contribute to the understanding about associations of fruit and vegetable intake, which is an important nutritional indicator for healthy eating habits, and the development of lifestyle diseases.



## 7. Perspectives

Dietary assessment is a difficult measure to obtain accurately, because it requires a lot of interaction from and with the participant, but they are necessary for investigating the influence of dietary behaviour on health and disease. In this project effort was made to develop a more simple, engaging, age appropriate and at the same time accurate method. The WebDASC was developed to be used by 8-11 year-old children and is currently in use in the OPUS School Meal Study. It is the first Web-based comprehensive dietary assessment tool developed in Denmark for research purposes.

If the WebDASC should be further developed and refined, it would be important to work with the following issues:

- Adaption to the spelling competence's of children (and adults). It might be the inclusion of a speech search facility as known from advanced mobile phones.
- The portion size images and portion size estimation. It should be investigated if 3D images or images rotating to be viewed from different angles when "scrolled over", would improve estimation.
- The flexibility of moving around in WebDASC should be improved by including the ability to use the browser "back arrow".
- A type in field should be available at the registration screen giving respondents the possibility to add notes to their reports.
- It should be investigated which motivators best back up corporation from children and motivate them to complete the diet assessment without impairing the accuracy of reports.
- An image supported food list, and a synonym list.
- A personal and professional instruction was seen as important for the quality of the reporting and the response rate. It should also be investigated if the social component and the face-to-face interaction are vital to the corporation of the respondent, and the quality of the answers or if the software itself represents the key to accurate dietary assessment.
- In the present study there was a learning effect by repeated use which was reflected in the time used for reporting the first day and the following days. How training could be incorporated, and results of training compared to no training, should be further investigated.

In the future the WebDASC might be further developed for use in other studies and intervention studies. It can easily be adapted to other age- and target groups by making a reskin of the visual design, updating the food list, portion size images and recipes, and changing the context questions to the meals.

A version with a feedback application on the reported diet and nutrient composition could be useful in dietary interventions as a self-evaluation tool. Furthermore, the WebDASC can also be developed to fit android mobile phones which add other possibilities to the diet reporting and the WebDASC as the camera function.

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# Papers

## Paper 1:

Biltoft-Jensen A, Trolle E, Christensen T, Islam N, Andersen LF, Egenfeldt-Nielsen S, Tetens I. A Web-based Dietary Assessment Software for 8-11 Year Old Danish Children. *Journal of Human Nutrition and Dietetics*, 2012 (Accepted).

## Paper 2:

Biltoft-Jensen A, Hjorth MF, Trolle E, Christensen T, Brockhoff PB, Andersen LF, Tetens I, Matthiessen J. Comparison of estimated energy intake in children using Web-based Dietary Assessment Software with accelerometer-estimated energy expenditure. February 2012 (Submitted).

## Paper 3:

Biltoft-Jensen A, Bysted A, Trolle E, Christensen T, Knuthsen P, Damsgaard CT, Andersen LF, Brockhoff P, Tetens T. Evaluation of a Web-based Dietary Assessment Software for children: comparing reported fruit, juice and vegetable intake to plasma carotenoid concentration and lunch intake observation. April 2012 (Submitted)

## Paper 1

### **WebDASC: A Web-based Dietary Assessment Software for 8-11 Year Old Danish Children**

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## **Abstract**

This paper describes the development and formative evaluation of the Web-based Dietary Assessment Software for Children (WebDASC). WebDASC is part of the OPUS<sup>1</sup> project (“Optimal well-being, development and health for Danish children through a healthy New Nordic Diet”) and was intended to measure dietary change resulting from a school-based intervention. WebDASC is a self-administered tool that can be used by 8-11 year old children with or without parent’s aid. The development of WebDASC followed a prototyping approach: focus groups, informal interviews, literature review, and usability tests preceded its release. Special consideration was given to age-appropriate design issues.

In WebDASC an animated armadillo guides respondents through six daily eating occasions and helps them report foods and beverages previously consumed. A database of 1300 food items is available either through category browse or free text search, aided by a spell check application. A type-in format is available for foods not otherwise found through category browse or text search. Amount consumed is estimated by selecting the closest portion size among four different digital images. WebDASC includes internal checks for frequently forgotten foods, and the following features to create motivation: a food-meter displaying cumulative weight of foods reported, a most popular food ranking, and a computer game with a high score list.

WebDASC was developed as an intuitive, cost-effective, and engaging method to collect detailed dietary data from 8-11 year old children. Preliminary testing demonstrated that it was well accepted among children.

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## **Introduction**

Children's lifestyle and behaviour have increasingly become a focus of research, since obesity and other life-style related diseases begin in childhood (Koplan *et al*, 2005).

The OPUS Centre was established in 2009 to advance public health and prevention among children. OPUS promoted the concept of the New Nordic Diet, that draws on sustainable food items such as whole grains, berries, herbs and plants that are native to the Nordic region (Meyer *et al*, 2010). These principles will be applied to the school lunch menus of selected public schools in a large Danish intervention study.

Valid and reliable dietary assessment methods are critical for identifying the impact of children's dietary habits on their health and weight status. To be sensitive to dietary changes resulting from school interventions, dietary intake must be measured with a relatively high level of detail and using repeated measures. The dietary assessment method selected should be able to identify type of foods consumed, weekday versus weekend patterns of consumption, meal specific patterns, etc. A web-based, self-administered method - ideally a 7-day record/recall- is likely to be both feasible and cost-effective to achieve such goal (Biltoft-Jensen, 2010).

One of the advantages of a web-based program is that it allows data collection from thousands of children for multiple days over different time periods, and minimizes data scanning/entering efforts. Such method appears to be feasible in Denmark since the majority of Danish families, and especially families with children have a computer and internet access at home (Tassy, 2009). Additional advantages are the ability to standardize the dietary interview, provide a child-friendly interface with prompts to facilitate food intake recall, and customize food and nutrient databases to the requirements of children. Disadvantages, compared to a dietitian conducted interview, are the lack of personal guidance, the typing/spelling skills and computer literacy required, and the inability to anticipate and/or tackle impromptu technical difficulties during self-administration (Probst & Tapsell, 2005).

A number of technology-based dietary assessment (TBDA) methods have proven to be both feasible and acceptable when administered to children (Vereecken *et al*, 2009; Vereecken *et al*, 2008; Moore *et al*, 2008; Baranowski *et al*, 2002). This paper describes the development effort and related formative research of a self-administered daily recall system called WebDASC, to be used by 8-11 year olds with or without parents' aid.

## **Developing process**

WebDASC was developed as a data entry application. Data output consists of food and food group totals for each eating occasion. Nutrient calculations are performed by the GIES (General Intake Estimation System). WebDASC was developed using evolutionary prototyping (Tate, 1990), which included:

- Identifying the elements needed to perform a self-administered dietary assessment with children and the problems likely to occur; informal meetings/interviews with experts in different research areas; focus groups with children 8-10 years old (a total of four); and review of the literature.
- Formulating requirements based on the results of the formative research.
- Developing small-scale mock-ups, followed by a functional prototype, with special attention to interface design and functionality.
- Testing the functional prototype.
- Developing a full functional system, including administrative modules.

The development process is graphically depicted on figure 1.

### **1. Formative research**

#### *Informal interviews/meetings with experts*

Four experts with diverse perspectives on children, dietary assessment, and the internet (an ethnologist, a sociologist, a child psychologist and an information technologist) were interviewed. In addition, input was sought from research groups involved in TBDA with children, namely, those from Newcastle University (UK), Durham University (UK), Baylor College of Medicine (USA) and Ghent University (Belgium). The results from these informal interviews/meetings indicated that WebDASC should:

- Target children, because they would want to or have to complete the dietary assessment by themselves.
- Clearly indicate the purpose of completing WebDASC and give children the opportunity to compare their intake to that of their peers.
- Be intuitive, simple, clear, and fast paced (completed in 20 minutes or less).
- Involve and engage children (children should not be passive viewers of a tutorial).
- Use animated guides or avatars, games, stories, treasure hunts, and different virtual worlds to engage and motivate children without shifting the focus away from the goal of dietary assessment.
- Provide context to help children remember what they consumed.
- Stimulate children's senses (through reading, hearing, writing and viewing).
- Be credible (otherwise children would see through it).
- Make it easy for children to find and report food items (or they may just select items randomly).

- Facilitate portion size estimation by using few and clear response alternatives; and
- Avoid dull design elements such as drop down lists, check boxes and too much text.

### *Focus groups*

Four focus groups were conducted to get insight into children's understanding and use of the elements included in the dietary assessment. Each focus group consisted of five 8-11 year olds of different gender, ethnicity and background. The groups focused on four aspects of dietary assessment:

- Memory in relation to foods and meals consumed.
- Understanding of eating occasions (meals and snacks).
- Understanding of food groupings; and
- Preferred way to estimate portion size: images or models.
- 
- The focus groups showed that children:
  - Were unfamiliar with having to remember their dietary intake and needed help with details such as condiments, beverages and unstructured snacking; however, they remembered the content of structured main meals with confidence.
  - Categorized foods in a “food group” based way (fruits, vegetables, bread, beverages), a “meal” based way (breakfast, lunch, dinner) and a “complementary food” based way (cereal + milk, burger + french-fries), but had difficulties categorizing mixed dishes and condiments. Food pictures made the categorization process much easier.
  - Expected to report food items and portion sizes exactly as they had eaten them.
  - Equally liked images and food models as portion size aids.
  - Liked feedback such as the ability to compare themselves against their peers (Biltoft-Jensen, 2009).

### *Literature review*

The literature review in preparation for WebDASC was reported elsewhere (Biltoft-Jensen, 2010) and included among other several recently published, comprehensive reviews (Ngo *et al*, 2009); (McPherson *et al*, 2008); (Sherwood, 2008); (National Cancer Institute, 2007); (Livingstone *et al*, 2004); and studies (Thompson *et al*, 2010; Baranowski *et al*, 2010; Subar *et al*, 2010; Vereecken *et al*, 2010).

Key points emanating from the literature review are:

- 8-11 year old's spelling, memory, and reading competencies are not yet fully developed to self-complete a dietary assessment, and they may need help from their parents (Baxter *et al*, 2009; McPherson *et al*, 2008; National Cancer Institute, 2007; Sherwood, 2008; Baxter *et al*, 2003; Baxter *et al*, 2002; Larsen, 2002); age-appropriate prompts are likely to help the process of memory retrieval (McPherson *et al*, 2008; Baxter *et al*, 2002; Haraldsen & Dale, 2002).

- To minimize misreporting and intrusions, it is best if the reporting is done in the evening of the day of consumption (Baxter *et al*, 2009; Baxter *et al*, 2008; Baxter *et al*, 2004).
- A meal based recall is preferred by adults (Subar *et al*, 2007) and enhances recall in children (Moore *et al*, 2008).
- The naming of categories in a category-based type of food search should be carefully made; professional names (e.g. poultry, fats) ought to be avoided, especially if not used by children or their families (Baranowski *et al*, 2010; Sepulveda *et al*, 2009; Beltran *et al*, 2008a; Beltran *et al*, 2008b; Beltran *et al*, 2008c); foods terms should be easy to locate (Zimmerman *et al*, 2009); and
- Food images depicting increasing portion sizes are preferred over food models (Foster *et al*, 2008). Portion sizes should be age-appropriate (Foster *et al*, 2009; Foster *et al*, 2006); and simultaneous presentation of food images is preferred over a sequential presentation (Subar *et al*, 2010).

## 2. Requirements

40-50% of the daily energy intake of Danish children occurs during school hours, which limits the help that parents can provide as informants. WebDASC was designed to allow children to self-complete their dietary recall on multiple days over different time periods. Since the task of self-reporting is burdensome for children, the software needs to be appealing. The full list of requirements appears in Table 1. The elements needed to perform dietary assessment, the problems likely to occur, and the methods to handle them were drawn from the formative research and are shown on figure 2, which represents the “tool box” of relevant principles and research that guided the development of WebDASC.

## 3. Design considerations – description of the functional prototype

When children interact with software in general, and WebDASC in particular, they look at:

functionality (e.g. is it fast paced and to the point?)

content (e.g. does it have relevant food terms and images? )

interface elements and motivators (e.g. are the questions and instructions relevant and understandable?; is the graphic user interface (GUI) clear and child-appealing?).

### *Functionality*

To ease navigation and aid recall, WebDASC uses a meal-based approach, namely six eating occasions, since most Danish children have between 3-6 eating events per day (Fagt *et al*, 2007).

To provide context and enhance memory, WebDASC shows pictures of foods customarily eaten at a given meal, and inquires about sports and social activities at snack time. It also has internal checks for capturing

the intake of frequently forgotten foods, such as spreads, sugar, sauces, dressings, snacks, candy, and beverages.

To facilitate the search and selection of foods reported as eaten, WebDASC offers five search strategies: (Screenshot 1)

1. A three-level category approach to locate items by browsing 23 main food categories (level 1), approximately 160 sub-categories (level 2) and about 1300 food list terms or FLT's (level 3).
2. A "copy meal" function to allow the selection of foods previously reported for a meal entered the day before.
3. A "free text" search; to locate FLT's containing the words supplied by the user.
4. A "starts with" search to locate FLT's with the same spelling; and
5. A "type-in" answer to report type and amount of items not found in the food list.

WebDASC applies a spell check program that uses Constraint Grammar Parsing (Bick, 2006) to streamline the search process by quickly matching typed-in search terms to the FLT's in the database.

#### Content

The FLT's in WebDASC are based on actual intake data collected by the Danish National Survey of Diet and Physical Activity (DANSDA) 2003-08. The food list was supplemented with a combination of purchase data from a Danish Household Panel (GfK, 2007) and trademark items sampled and analysed by the Danish Food Composition Databank ([www.foodcomp.dk](http://www.foodcomp.dk)). Furthermore, it includes foods commonly eaten by ethnic minorities living in Denmark (Uggerly *et al*, 2002).

To facilitate food search and selection, the WebDASC database provides aliases (descriptive information) such as "wholegrain" and "dark", in addition to "rye bread". In other instances, the descriptive information is part of the food name, e.g. a Danish type of bread is referred to as "franskbrød". The database also contains generic descriptions for items consumed away from home and hard to characterize, such as . a glass of milk or milk added to tea..

For categorical searches, "food groups" are defined on a broad basis, for example: "vegetables"; "fruit"; "breakfast products"; "condiments" (which includes garnishes, gravies and dressings), and "different dishes" (which includes multi-ingredient preparations).

In WebDASC, simple terms are prioritized over professional designations, e.g. "chicken" is used instead of "poultry". Food categories were reviewed by school teachers and child psychologists used to working with children .



The images for portion size estimation include those developed for the DANSDA 2011 (n=75 photo series) and those produced at the Children's Nutrition Research Center, Baylor College of Medicine, Houston, Texas (n=245) for use in two web-based, self-administered 24-hour dietary recall systems: the Food Intake Recording Software System (FIRSS) (Baranowski *et al*, 2002), and the Automated Self-Administered 24-hour dietary recall (ASA 24) (Subar *et al*, 2010). Since our formative research indicated that children preferred clear and fewer answer choices, each portion size series consists of four digital images. In those instances where multiple digital photos were available, the best four images depicting children-sized portions (for ages 4-14) were selected. Small pre-packed food items, e.g. a piece of chewing gum, are depicted as such (n=25).

Other relevant information collected with WebDASC includes:

School day or non-school day (which controls subsequent prompts).

Meal location: home meal, away from home meal, or a combination of both.

Perception of time elapsed while eating.

Intake of dietary supplements (closed-ended question with eleven possible answers based on brands representing 90% of the market share); and

Total amount of food consumed: normal versus different than normal, with the purpose of validating unusual intakes due to illness, special social events, etc. Answers choices are those in DANSDA 2003-2008.

WebDASC uses cartoon-like speech balloons and sounds during the recall process; e.g. when children select foods. The purpose is double-fold: to perk up the recall process, and to increase the likelihood of participation among slow readers. Text and audio emulates the brief communication style used on mobile phones and Facebook, which limits the number of keystrokes to a maximum of 140 (Høgh, 2009).

### *Interface elements and motivators*

To make the GUI more intuitive and appealing, visual elements were carefully selected. For example, the six eating occasions are displayed within the confines of a blue cloud that appears at the top of every screen. The avatar or guide is an animated armadillo (Screenshot 2) purposely chosen as a "neutral" figure, distant from the day-to-day life of Danish children.

Colors were also used to reinforce the meaning of the text, features and elements, e.g. green is used for "yes" buttons and red for "no" buttons.

Upon completion of the food recall, respondents are exposed to a ranking of the most popular foods reported for that day, and can also play a computer game as a reward. The main goal of the food ranking is to offer children the possibility of comparing themselves against others. The video game is provided as an incentive

to persuade children to complete the WebDASC every day. The game features conveyor belts on which food is transported. At the end of the conveyor belt, the player controls the animated armadillo that has to catch the correct food in the correct basket or food category. The purpose of the game is to train children to accurately report foods by means of the food category search available in the program. The game includes different levels of game difficulty, involving speed, number of conveyor belts, and food types. If a child plays the game successfully and attains a high score, his/her name as well as the score is displayed at the opening screen for others to view. Another element intended to motivate kids to record their intake regularly is the “food meter”, which advertises the total amount of foods reported so far in the project.

#### **4. Prototype testing**

A functional prototype was tested to identify and address acceptance, performance and usability issues. The following tests were performed:

##### *Acceptance test*

This test was meant to evaluate acceptance, flow and functionality. Five eight year old children together with one of their parents participated in the test. Minimal instructions were provided and a “think aloud” method was encouraged. Participants were asked to verbalize what they were thinking while interacting with the functional prototype to record their intake (Rasmussen & Fischer, 2008).

##### *Initial performance and usability tests*

Four nutrition graduates entered weighed food records from 22 children (8-10 years old), to evaluate the suitability of the food list, the search function, and to uncover programming bugs.

Five hundred food spelling errors were identified from children’s own report of a school lunch, and subsequently tested with the Methaphone algorithm, the GoogieSpell, and the Google’s search engine to find out which method was better suited to match the misspelled term with the correct food item.

The final prototype was tested among seventy 8-11 years old children. Usability was assessed in terms of: Children’s perception of the animated guide.

Design elements that could cause disruptions in the flow (e.g. icons and buttons), and Cognitive appropriateness of the search strategy.

#### **Main results of the performance and usability tests**

Usability tests showed that participants benefited from all five food search strategies, including the open answer option. Intuitively, participants gravitated towards the category search first, but were not always able

to pick the right category to search for a particular food. Visual elements such as text outside the animated guide's speech balloon were not noticed. Children's focus was geared towards the "touch" graphics (e.g. start-, yes/no-, meal location-, and continue buttons). Long food lists were counterproductive in the sense that required longer time to browse, and frustrating whenever the food searched for (e.g. a brand-name item) was not found.

Metaphone algorithm and Google Spell found the correct food item for 30% of children's misspellings, whereas Google correctly identified 85% of them. However, the Google Spell Check Web API (Application Programming Interface) is more likely to return false positive answers because Google searches websites, not FLT's (e.g. common misspelling of "rye bread" returns "robot" with Google's spell check). None of these free spell check services were found to be suitable for use in the WebDASC.

The animated guide was perceived as being younger (7 years) than the participants themselves (9 years), and also as a "friend". Some older children described it as "childish". Almost all the children (92 %) found the icons and the questions about where they ate, and where the food came from, easy to answer. 56% of respondents found the question on duration of the meal easy to answer; 61% characterized the search and selection of foods as easy. Overall, 67% easily navigated the program, whereas the remaining (respectively 8, 44, 39, 33 %) experienced more or less difficulty.

Major improvements resulting from this testing, such as the re-design of the avatar, the introduction of a "copy meal" function to expedite data entry, a spell check function that prioritizes FLT's, and simplification of the food list are listed in Table 2.

Observations made during the prototype testing were useful for the development of content-specific help in WebDASC.

## **5. Full functional system and technical specifications of the software**

WebDASC was designed and programmed in Danish by a computer-gaming company (Serious Games Interactive) experienced in creating user-friendly interfaces for children.

WebDASC is crossplatform (Pc/MAC) and browser-based, and can be run on almost all home computers (95% of them as of November 2010) with Internet Explorer 7 or 8, FireFox 1.5, 2.0 or 3.6, Chrome 5, or Safari 4. It requires internet access and Adobe Flash player version 9 or higher, and displays best with the current standard screen resolution (1024 x 768 pixels). WebDASC was written using PHP5 and MySQL5, and is hosted on a standard web-host with a bandwidth that supports the use of databases and other tools that are likely to exceed the storage capacity of a typical home computer. Since many computers have a pop-up blocker, pop-up windows were avoided; instead, an overlay function is used to allow a second layer of information to be retrieved, e.g. at the time of estimating portion size.

If a dietary assessment is not completed by midnight on a given day, a reminder e-mail is sent out to the parents the next morning. The opening screen and a flowchart of the WebDASC software are illustrated in screenshot 2 and figure 3.

WebDASC includes two administrative modules: a “web site” application and a “survey” application. The “web site” application allows:

- Project set up
- Participants search and logon
- Setting number of reporting periods
- Defining project parameters, such as number of recalls to be completed and number of add-on questions to be answered
- Add food groups and FLTs
- Hide FLTs
- Change the category to which an FLT belongs
- Add and modify the digital photo series used for portion size estimation
- Export data files

The “survey” application provides an overview of:

- Existing projects and periods
- Participant’s logon and progress
- Participant use of FLTs
- Coding of open answers

## **Discussion**

WebDASC was developed as an intuitive, simple, cost-effective and engaging method to collect children’s self-administered recalls, with an appropriate level of detail to obtain accurate food intake estimates in the context of a school-based intervention study. Development challenges included: choosing relevant FLTs and food categories; selecting and accruing digital images for portion size estimation; providing a customized spell check function; and anticipating limitations in computer technology during development.

One obvious dilemma in the dietary assessment of children is that the level of detail often required imposes a great burden on younger participants who are unable to provide accurate recounts. For that very reason, self-reported dietary assessment software should be intuitive, simple and clear. This has seldom been the case. Most dietary assessments programs are built around the answers that a study is expected to obtain and not around the answers that the study population is able to provide. This obvious shortcoming applies to the OPUS study, and therefore, the WebDASC could not be fully adapted to match children’s competencies.

Building a food database with meaningful FLTs, food sub categories and categories is essential for children to be able to find and select foods when browsing. In WebDASC the two naming strategies (general name plus descriptor and “name as spoken”) are not very precise. In a foreseeable future, improvements on this arena are expected after the search logs and open answers are carefully scrutinized.

Since children are visually skilled, the initial idea was that all food searches should be geared towards the display of a food image (digital photography) as a visual reinforcer (Biltoft-Jensen, 2009). This effort would require an image of every item in the food list, and ideally, one that closely matches a kid’s mental representation of the item. Regrettably, shooting all the images needed to accomplish that goal was way beyond the scope of this project.

The computer interface makes it easier to inquire about portion size details. Other computer based dietary assessment systems, like the Automated Self Administered 24 Hour Recall (ASA 24), use a sequence of three questions to obtain portion size of drinks (container type, container size, and percent volume). WebDASC does it in a single step by showing a standard glass with four different levels of fillup. It is not clear whether implementing additional portion size estimation tasks in WebDASC would achieve more precise estimation. An English study underlines the importance of using age appropriate food portions when estimating portion size by images (Foster et al, 2006). In WebDASC the use of age appropriate portions could not be fully accomplished because food pictures were obtained from more than one source. How portion size can be more easily estimated without sacrificing precision remains to be investigated.

A system developed using evolutionary prototyping is continually refined allowing the developer to add features or make changes that could not be conceived during the requirement formulation and design phase. The focus on testing prototypes with limited functionality ends up limiting the number of functionalities that can be implemented in the final deliverable, e.g. instead of giving the respondent the choice of a “copy meal” feature, it might have been better to allow the user to create his own list of “top ten favorites” for each meal. Due to time and budget constraints, implementing alternative strategies was not attainable at the end.

A rule of thumb is that even an “intuitive” TBDA tool has to be explained to participants. However, the method chosen to do that may also have a substantial impact on response rate and quality of the answers obtained (Kiezebrink et al, 2009; Yu & Cooper, 1983). This issue should be further investigated.

## **Conclusion**

Computer technology provides countless opportunities to obtain information on dietary intake. WebDASC was developed for use by 8-11 year old children, with the principles of formative research and a prototyping approach guiding its development. Preliminary testing demonstrated that it was well accepted by both children and their parents. The validity of WebDASC remains to be documented.

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[http://www.foodcomp.dk/v7/fcdb\\_default.asp](http://www.foodcomp.dk/v7/fcdb_default.asp)

Table 1. Overall requirements set forth before the development of the WebDASC

**The WebDASC should:**

- Facilitate food intake report among school children
- Motivate children to complete daily recalls
- Have a child appealing design
- Use visuals to engage young respondents
- Have a guided meal-based approach
- Provide context-driven help
- Be easy to navigate (simple, fast-paced, and intuitive)
- Have internal checks for frequently forgotten eating occasions (e.g. snacks), foods, and beverages
- Use food photography to illustrate portion size
- Use a combination of search methods: browse, type-in aided by an adapted spell check and open-ended
- Allow multiple-day reporting in several periods for each respondent
- Be able to locate and display reports per respondent, per day, per session and per meal
- Have an administrative module to facilitate project registration, and to manage respondent's data as well as food list terms, probes, and portion size photography
- Be able to run on almost every home computer
- Handle up to a maximum of one thousand respondents at a time

Table 2. Major improvements resulting from the prototype testing of WebDASC included:

- Improved timeline or flow indicator, e.g. colour changes as respondent progresses through the recall
- Bug fixing
- Less text in the avatar's speech bubbles
- Increased use of food images as prompts
- Question about "duration of the meal" was changed to "time perception of the meal"
- Redesign of the avatar to improve respondent's perception from "childish" to "older" looking
- A spell check function that was modified to prioritize food list terms was implemented
- Many brand names and taste varieties were removed from the long food list to make the search and selection of items simpler
- Introduction of a "copy meal"-function
- Implementation of a context-driven help

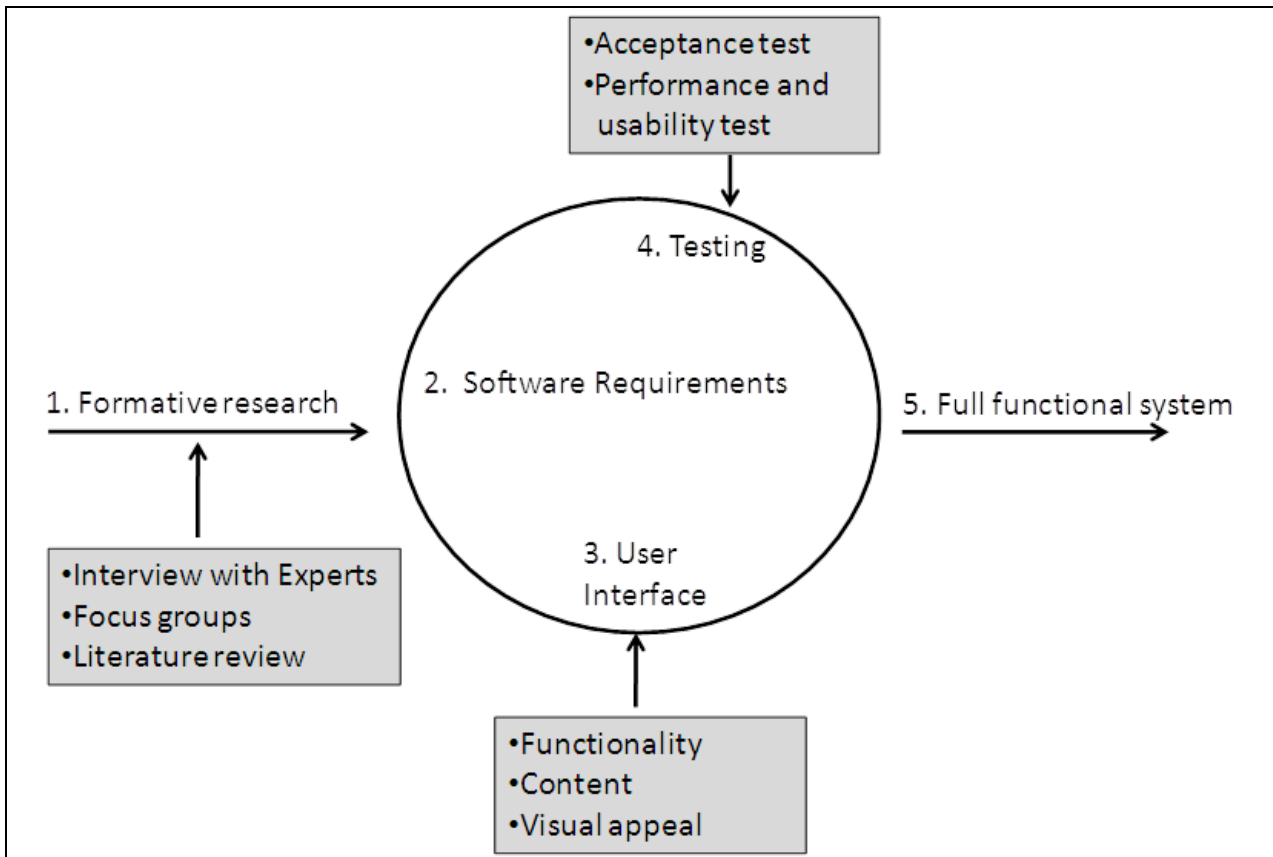


Figure1. Diagram illustrating the prototyping approach used to develop WebDASC

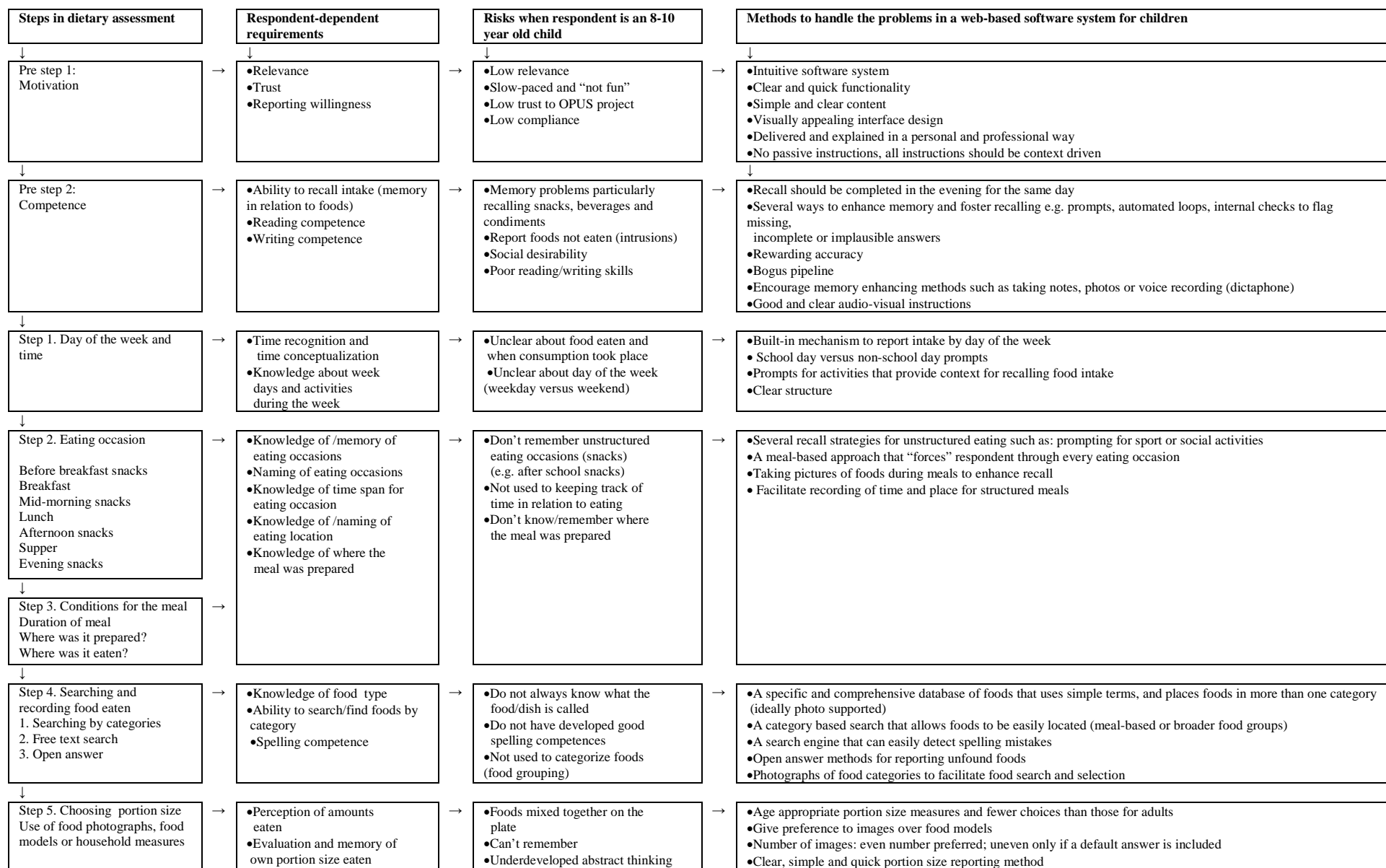


Figure 2. The elements needed to perform dietary assessment, the problems likely to occur, and the methods to handle them, based on the formative research preceding the release of WebDASC

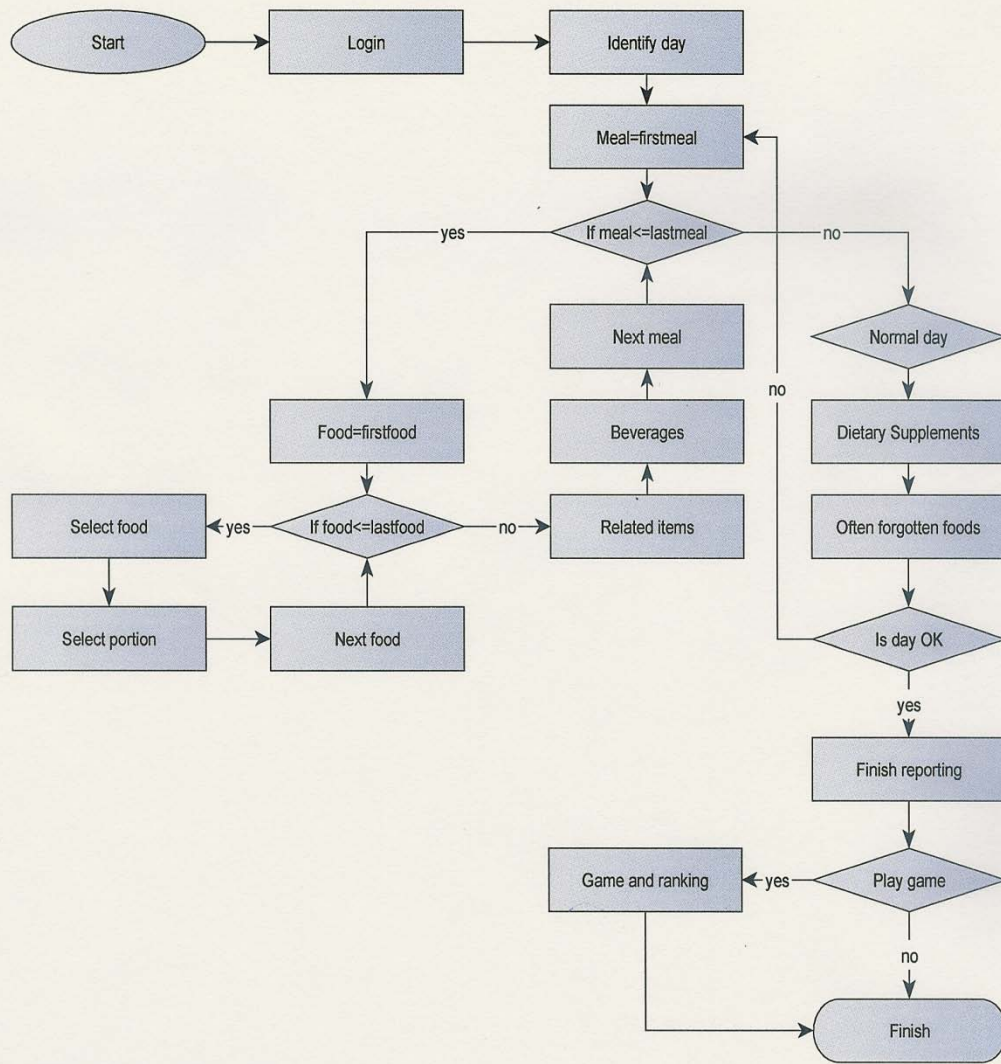


Figure 3. Flowchart of WebDASC

Mad registreret indtil nu: 2325.22 kg. Logout

Morgenmad Frokost Aftensmad Spil

**Morgenmad**  
 Har du spiste og drak du til morgenmad?  
 Se hvad du spiste i går - [klik her](#)

<ul style="list-style-type: none"> <li>Brod</li> <li>Burger, sandwich, pita</li> <li>Dressing</li> <li><b>Drikkevarer</b></li> <li>Fisk</li> <li>Forskellige retter</li> <li>Frugt, bær, nødder</li> <li>Grøntsager</li> </ul>	<ul style="list-style-type: none"> <li>Drikkeyoghurt, milkshake</li> <li>Fløde i kaffe</li> <li>Iste, cider</li> <li>Juice</li> <li>Kaffe</li> <li>Kakaomælk</li> <li>Mælk</li> <li>Mælk i te, kaffe</li> </ul>	<ul style="list-style-type: none"> <li>Appelsinjuice</li> <li>Grøntsagsjuice</li> <li>Gulerodjuice</li> <li>Juice</li> <li>Juice, blandet</li> <li>Tomatjuice</li> <li>Æblejuice</li> <li>Æblemost</li> </ul>	<p><b>Madvare</b> <span style="float: right;">Tilføj/Fjern</span></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td>Bolle, grov</td> <td style="text-align: right;">+</td> <td style="text-align: right;">-</td> </tr> <tr> <td>Cornflakes</td> <td style="text-align: right;">+</td> <td style="text-align: right;">-</td> </tr> <tr> <td>Minimælk på morgenma...</td> <td style="text-align: right;">+</td> <td style="text-align: right;">-</td> </tr> </table>	Bolle, grov	+	-	Cornflakes	+	-	Minimælk på morgenma...	+	-
Bolle, grov	+	-										
Cornflakes	+	-										
Minimælk på morgenma...	+	-										

[Tilføj madvare](#) [Videre](#)

Søg madvare (starter med):  Søg madvare (fritekst):

[Tilføj en madvare - Klik her](#)

Screenshot 1. WebDASC: Search and selection screen showing the available typ-in and copy meal search strategies (circled) and the browse by category alternative.



Mad registreret indtil nu: 2211.57 kg.



Brugernavn:

Kodeord:

Login

[Glemmt din adgangskode](#)

Hej jeg hedder Sniffel

Tak fordi du vil være med i min undersøgelse. Du skal fortælle alt, hvad du spiser og drikker i den næste uge. Jeg hjælper undervejs.

Du skal logge ind for at starte.



DTU Fødevareinstituttet

Danmarks Tekniske Universitet



Screenshot 2. WebDASC: Opening Screen.

## Paper 2

### **Comparison of estimated energy intake in children using Web-based Dietary Assessment Software with accelerometer-estimated energy expenditure.**

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February 2012 (Submitted).

**Abstract:**

A Web-based Dietary Assessment Software for Children (WebDASC) was developed for use in a school-meal study where children were served a New Nordic Diet (NND). The present study investigates energy intake (EI) estimated with WebDASC against accelerometer-estimated energy expenditure, the repeatability and acceptability of WebDASC.

Eighty-one 9-11 year-old school children, assisted by parents, recorded their diet in the WebDASC and wore an accelerometer on the same 7 consecutive days twice: at baseline, and at intervention with the NND. EI was estimated from WebDASC, and total energy expenditure (TEE) was estimated from accelerometer-estimated activity energy expenditure, calculated basal metabolic rate, and diet induced thermogenesis. The acceptability of WebDASC was assessed with questionnaires.

The mean difference between EI and TEE was 20 kJ/day indicating agreement. The differences tended to be positive when intake was high and negative when intake was low, reflecting that 20% was classified as over-reporters, and 20% as under-reporters. The 95% limits of agreement was -3.48 and 3.44 MJ/d. Pearson's correlation coefficient between EI and TEE was 0.31 and 73% was classified in correct or adjacent quartile. Correlation and cross-classification was better for baseline than intervention when reporting unfamiliar foods. The repeatability was moderate. Gender, BMI and illness influenced reported EI. Participants found reporting in WebDASC acceptable.

This study showed acceptable estimation of EI with WebDASC at group level compared to TEE in 9-11 year-old schoolchildren. Misreporting indicates that the weight and health focus of the present study may have influenced diet intake to reflect the child's weight status.

## Introduction

Eating behaviour is likely to be established already in childhood to be increasingly rooted in adolescence and adulthood (Koplan et al. 2005). Consequently, it will be expected that healthy eating habits acquired early in life will have higher chance of being maintained and in the long term cause reduced risk of obesity and other life style diseases. Several intervention studies have been conducted within the framework of the school with the purpose of changing unhealthy eating habits among children (Foster et al. 2010; Lien et al. 2010). One of the advantages of using a school-based approach is that children attending public schools constitute a population across all ethnic and socioeconomic groups. This makes it possible to reach also socially disadvantaged whom are likely to benefit most from an intervention with a healthy diet.

A large multidisciplinary centre, the OPUS<sup>1</sup> Centre, was established in 2009 to advance public health and obesity prevention among children. OPUS promoted the concept of the New Nordic Diet (NND), that draws on sustainable food items native to the Nordic region (Mithril et al. 2012). These principles will be applied to the school lunch menus of 9-11 year-old school children in a large Danish intervention study in order to investigate the influence of NND on BMI, body composition, sleep, and risk markers for lifestyle diseases.

To identify the impact of diet interventions on children's dietary habits and their health and weight status it is critical with a valid dietary assessment method able to identify type of foods consumed, patterns of consumption etc. Since not all 9-11 year-old school children will be capable to self-report their own diet, the parent needs to assist the children about the diet reporting. Therefore the method needs to appeal and be acceptable to both the children and adults.

It was considered that a web-based, self-administered method, ideally a 7-day food diary/recall, is likely to be both feasible and cost-effective to achieve such goal (Biltoft-Jensen 2010), and a Web-based Dietary Assessment Software for Children (WebDASC) was developed for this purpose.

To know the extent of misreporting, evidence of the validity of the WebDASC is required, preferably against an objective measure, to ensure that the survey instrument does not introduce errors that distort true associations between dietary intake and health. Data on a person's total energy expenditure (TEE) can be used to estimate under- and over-reporting of energy intake (EI) in

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<sup>1</sup> Optimal well-being, development and health for Danish children through a healthy New Nordic Diet.

conditions of energy balance. The use of doubly labelled water as the golden standard method to measure TEE was not regarded as feasible in the OPUS pilot study which already placed heavy burden on participants with measurements and questionnaires. Less invasive measurements, useable for more than one purpose, were preferred. Since accelerometers can provide measures for both physical activity and sleep, and at the same time can be used with little disruption to everyday life, these were chosen. It was considered that prediction equations to estimate energy expenditure from accelerometer output could serve as a feasible, participant friendly and cost-effective validation method of reported energy intake (Goris et al. 2001a). TEE estimated from motion monitors has previously been used to evaluate EI in children and adults (Andersen et al. 2005; Biloft-Jensen et al. 2009; De Keyzer et al. 2011; Gigante et al. 2010; Lillegaard & Andersen 2005).

This paper reports the evaluation of the WebDASC specifically to be used by 9-11 year-old school children, assisted by parents, by comparing WebDASC-estimated EI against accelerometer-estimated energy expenditure, and the repeatability and acceptability of the WebDASC.

## **Method**

### *Study design*

The study is a part of the OPUS pilot study, and the data collection was performed in January (baseline) and February/March (Intervention) 2011. The full study design is illustrated in figure 1. The participating schoolchildren had their normal packed lunches during the baseline period, and during the intervention period, the children were served NND for lunch and snacks in school. Participants reported their diet in the WebDASC each day for 7 consecutive days during two periods: at baseline and at the intervention with the NND, resulting in two measures of EI. On the same 7 consecutive days as the WebDASC was completed the participants wore an accelerometer, an electronic device that measures physical activity, in order to estimate energy expenditure. After the baseline measurements participants completed an acceptability questionnaire about the diet recording in the WebDASC. All the participants' parents were interviewed, in person, about social background, health issues, involvement in cooking, attitudes and knowledge about food and health. Body weight and height was measured once by trained personnel during the week after the baseline food reporting and activity recording. Detailed instructions on how to report food intake and how to use the accelerometer were provided individually to all participants by the research team. Written

instructions were given as well. The procedures followed were approved by the Committee on Biomedical Research Ethics in the Capital Region of Denmark.

### *Participants*

3<sup>rd</sup> and 4<sup>th</sup> grade children (9-11 years) in one school situated in the Northeastern part of Denmark were recruited for the pilot study. 105 pupils and their families were invited to participate and 81 gave written consent to participate. A random sample of 250 children from the Danish National Survey of Diet and Physical Activity (DANSDA) 2003-8 were included for comparison of background characteristics.

### *WebDASC*

Participants recorded their diet in WebDASC for 7 consecutive days in the evening for the same day. For inclusion of participants in the analyses, the WebDASC had to be completed for at least 3 weekdays and 1 weekend day.

In the WebDASC special attention was given to age appropriate design issues. An animated armadillo guided respondents through six daily eating occasions (breakfast, morning snack, lunch, afternoon snack, dinner, and evening snack) and helped them report foods and beverages previously consumed. A database of 1300 food items was available either through category browse or free text search, aided by a spell check application. A type-in format was available for foods not otherwise found through category browse or text search. Amount consumed was estimated by selecting the closest portion size among four different digital images in 320 photo series. WebDASC included internal checks for frequently forgotten foods (spreads, sugar, sauces, dressings, snacks, candy and beverages) and the following features to create motivation: a food-meter displaying total amount of foods reported so far, a most popular food ranking, and a computer game with a high score list. The rank list and game was accessible after completing a day. Furthermore, participants reported intake of supplements, and if a day represented usual or unusual intake and reasons for unusual intakes as illness. If a participant failed to report a day, parents were reminded the next day by an e-mail. Failing to report a day within 48 hours automatically closed the day and opened a new in the end. The EI was calculated for each individual using the software system GIES (Version 1.000 d - 2010-02-26) developed at the National Food Institute, Technical University of Denmark, and the Danish Food Composition Databank (version 7; Søborg; Denmark; 02-03-2009).

### *Accelerometry*

The accelerometers used (ActiGraph™ GT3X, Tri-Axis Accelerometer Monitor, Pensacola, FL) are one of the most extensively validated monitors on the market and have been shown to have good agreement with the doubly labelled water technique (Plasqui & Westerterp 2007).

The children were instructed to wear the accelerometer 24-h a day for a continuous 7 days in an elastic belt on the right hip, including during sleep and to remove it only during water activities as when showering or swimming. At the end of the observation period, the children returned the monitors and the data were downloaded to a pc for further processing. The freely available software Propero Actigraph Data Analyzer (version 1.0.18; <http://sourceforge.net/projects/propero/files/>) was used to analyze the accelerometer data. Time periods of at least 20 consecutive minutes of zero counts were considered to represent periods when the monitor was not worn or when the child was sleeping and were thus disregarded before analysis as recommended by Treuth and colleagues (Treuth et al. 2004). The epoch was set at 30 Hz and re-integrated to 1 min. Derived variables were mean counts per min (cpm) based on the vertical axis. Criteria for a successful recording were a minimum of 4 days of 13 hours per day including at least 3 weekdays and 1 weekend day.

Activity-estimated energy expenditure (AEE) was estimated from mean cpm using Ekelund et al.'s modified prediction equation (Nilsson et al. 2008):  $AEE \text{ (kcal/day)} = 66.847 + (\text{cpm} \times 0.953) - (176.91 \times \text{gender})$ . TEE was then estimated as AEE plus basal metabolic rate (BMR) plus diet induced thermogenesis (DIT) which was assumed to account for 10% of TEE (Maffeis et al. 1993). BMR was calculated from the equation published by Henry (Henry 2005) based on age, sex, heights and weights.

### *Anthropometric measurements*

Participants were weighed, fasting overnight, without shoes in light indoor clothing to the nearest 0.1 kg on an electronic digital scale (Tanita BWB-800S, Tokyo, Japan). Height was measured without shoes to the nearest 0.1 cm with a stadiometer (CMS Weighing Equipment LTD, London, U.K.).

### *Definition of under-, acceptable-, and over-reporters of energy intake*

Since there is random day-to-day variation in EI and in TEE, exact agreement between EI and TEE over 7 days in one individual is unlikely. Therefore the accuracy of the reported EI was assessed using the confidence limits of agreement between reported EI and TEE at the individual level as

suggested by Black (Black 2000). Misreporters of EI were defined from their ratio  $EI_{rep}: TEE_{mea}$ . The 95 % confidence limits (CL) of agreement between  $EI_{rep}: TEE_{mea}$  were calculated as;  
 $95\% \text{ CL} = \pm 2 \sqrt{[(CV^2_{EI}/d) + (CV^2_{TEE}/d)]}$  where  $CV_{EI}$  was the coefficient of variation for the reported EI (baseline=23.3; Intervention=25.3),  $CV_{TEE}$  the coefficient of variation for the  $TEE_{mea}$  (baseline=13.9; Intervention=14.7) and  $d$  the number of days (7). At baseline acceptable reporters were defined as having a ratio of  $EI_{rep}:TEE_{mea}$  in the range 79% -121%. Under-reporters as  $EI_{rep}:TEE_{mea} < 79\%$  and over-reporters as  $EI_{rep}:TEE_{mea} > 121\%$ . At intervention acceptable reporters were defined as having a ratio of  $EI_{rep}:TEE_{mea}$  in the range 78% -122%. Under-reporters as  $EI_{rep}:TEE_{mea} < 78\%$  and over-reporters as  $EI_{rep}:TEE_{mea} > 122\%$ .

### *User acceptability*

During the personal interview each child was asked to complete a questionnaire with assistance from one parent, and return it after the baseline recordings to gain qualitative feedback on the user acceptability of the WebDASC. The questionnaire contained 18 questions regarding the amount of help provided from parent's, reporting time used the first day and the following days, preferred search facility by the child and by parent, relevance of the portion size pictures, usefulness of the information's given, acceptability of the reporting period, influence on dietary habits and suggestions for improvement and questions about the design and game.

### *Statistics and power*

In the present study it was decided to take a relatively large SD of 2,5 MJ into consideration when estimating sample size, since little was known about the uncertainty of accelerometer measurements used to measure energy expenditure in Danish Children. With a significance level of 0.05, 51 participants were needed to obtain a power of 80% of detecting a mean difference between TEE and EI of 1 MJ (Cole 1997).

Differences in characteristics between the participants and the random sample from the DANSDA 2003-8 were evaluated using the  $\chi^2$  statistic, and independent t-test. The validity of estimated EI from the WebDASC was tested by comparison with TEE measured with the accelerometer using paired-sample t-test. Differences in the number of UR, OR and AR between baseline and intervention were evaluated using  $\chi^2$  test.



Agreement between the EI and TEE was assessed by the modified Bland-Altman plot for repeated measurements which takes into account both a random between individual effect and a random error within the individual (Bland & Altman 2007). The limits of agreement are defined as two times the corrected standard deviations of the differences above and below the mean.

Linear mixed models were used to assess the intervention effect (the period factor baseline; intervention), the effects of background factors such as gender, education, BMI, age and illness and their mutual interactions on EI and TEE. The fixed factor effects in the model were gender, education, BMI, age, illness that affected eating and period and all their two-way interactions. To adjust for dependency in repeated measures within subjects, random effects were added for subject. Non-significant fixed effects were removed from the models (testing for the interactions before testing for main effects) leading to simplified models for summary of the significant effects.

Homogeneity of variance and normality of the residuals were examined using graphical methods.

Categorical agreement between EI and TEE was assessed using cross classification of EI and TEE divided into quartiles and applying kappa statistics. Pearson correlation coefficients were also calculated.

Repeatability between baseline and intervention was assessed for both EI and TEE using the Intra Class Correlation Coefficient (ICC).

In all statistical analyses a significance level of 5% was applied. Data were analyzed using SPSS for Windows version 19.

## **Results**

81 children (34 boys; 47 girls) with assistance from parents reported their diet in the WebDASC and wore the accelerometer for 7 consecutive days at baseline. At intervention 78 completed the food recording and 73 had acceptable accelerometer results giving 72 children (28 boys; 44 girls) at the intervention period with measures for both EI and TEE.

### *Characteristics of the study population*

The volunteer study population was representative of the randomly selected population in the DANSDA 2003-08 with regard to gender, intentions to eat healthy and parental responsibility for cooking. But compared with the DANSDA 2003-08, the study population:

- Consisted of a higher proportion of children with parents with a vocational education.

- Ate a healthier diet at baseline containing less saturated fat, and added sugars and more dietary fiber.
- Had a greater part of parents that were unsatisfied with healthiness of own dietary habits.
- Were lower and weighed less. It should be noted that height and weight in the DANSDA 2003-08 was self-reported by parents.
- Reported lower energy level compared to BMR (EI/BMR) (Table 1).

### *Energy intake vs. energy expenditure*

The differences between estimated EI and TEE were -0.02 MJ/d at baseline and -0.06 MJ/d at intervention. There was no significant difference between EI and TEE either at baseline or at intervention (Table 2). Furthermore, there was no significant difference between baseline and intervention for neither of the measures EI, EI: TEE, EI: BMR. However, TEE was significantly higher at intervention than baseline (Table 3). Furthermore, there were significantly more days reported that illness affected eating at baseline compared to intervention.

Approximately 20 percent of the study population is defined as under-reporters and 20 percent as over-reporters of EI at baseline and intervention (Table 3) reflecting the trend seen in the Bland-Altman plot (Figure 2). The diet of under-reporters was more likely to be affected by illness during the reporting periods and it contained more protein compared to plausible-, and over-reporters. Furthermore, under-reporters had significantly higher BMI (within the normal range) and were more overweight compared to plausible-, and over-reporters (Table 4). The diet of over-reporters contained more fat, saturated fat and less protein compared to plausible-, and under-reporters. Furthermore, over-reporters had significantly lower TEE and BMI compared to plausible-, and under-reporters (Table 4.)

The 95% limits of agreement was -3.48 and 3.44 MJ/d (Figure 2) for both periods.

Including both periods Pearson's correlation coefficients between EI and TEE were 0.31 ( $p < 0.001$ ), and the proportion of participants, appearing in the same quartile for both EI and TEE was 32%; 73% were classified into correct or adjacent quartiles, 20% were misclassified and 7% were grossly misclassified. The value for Kappa were 0,128 ( $p = 0,047$ ) indicating slight agreement (Viera & Garrett 2005). Correlation and cross-classification were better for baseline than intervention when analyzing the periods separately (results not shown).

### *Intervention effect and interactions with energy intake and total energy expenditure*

The results from the linear mixed models showed that main effects of age and education were insignificant for both EI and TEE and period for EI. For TEE there were two way interactions between period and parents education, and children with parents of a higher educational level (short, medium and long further education) had a higher TEE in the intervention period compared to baseline. The mixed models showed that those not reporting unusual intakes due to illness in the study period overall had a 1233 kJ (95% CI: 732 to 1734) higher mean EI, and a 343 kJ (95% CI: 169 to 518) higher mean TEE compared to those who reported eating was affected by illness. Boys had a 924 kJ (95% CI: 309 to 1540) higher mean EI compared to girls. EI fell with -145 kJ (95% CI: -255 to -11), and TEE increased on average 118 kJ (95% CI: 76 to 161) for every one unit increase in BMI. Boys had a significantly higher TEE corresponding to a mean of 1682 kJ (95% CI: 1472 to 1893) compared to girls.

### *Repeatability*

The ICC between baseline and intervention for EI were 0.45 (95% CI: 0.25 to 0.61) indicating moderate agreement. The ICC between baseline and intervention for TEE were 0.78 (95% CI: 0.67 to 0.86) indicating good agreement.

### *Qualitative feed back*

74 out of 81 who completed the dietary assessment using the WebDASC at baseline returned the user acceptability questionnaire. 90 % of the children received more or less help from parents to complete WebDASC. In 75% of cases mothers were prime assistant with the dietary assessment. The average time spend completing the WebDASC the first day was 35 min. and 15 min. the following days. 80% found the recording duration acceptable. 85-90% found the task of finding and reporting foods and portion sizes more or less easy. Children preferred the category browse search, whereas parents preferred the free text search. All liked the user interface design. 59% of the study population felt that the recording period more or less influenced their eating choices.

## **Discussion**

The study showed that in a motivated volunteer sample of Danish 9-11 year-old schoolchildren the WebDASC provided an acceptable estimation of EI at group level compared to accelerometer-estimated TEE. Bland-Altman plot demonstrated that the mean difference between EI and TEE was

20 kJ a day for both periods and the SD of the differences were 1.76 MJ/day. These findings indicated agreement between the two methods of the energy equation. However, the differences (EI-TEE) tended to be positive when EI was high and negative when EI was low. This bias is also seen in a study of 13 year-olds EI estimated from both a Food Frequency Questionnaire and 3 repeated 24-hour recalls validated against TEE assessed by accelerometers (Gigante et al. 2010), and in a study using the position and motion monitor (ActiReg®) to validate 7-8 year-old children's EI estimated from a 7-day pre-coded food diary (Rothausen et al. 2012).

Approximately 60% was classified as plausible reporters and 20% as over-reporters and 20% as under-reporters in both periods – reflecting the trends shown in the Bland-Altman plot. This is different from other studies using motion sensors to assess TEE in children showing that under-reporting is a larger problem than over-reporting (Andersen et al. 2005; Lillegaard & Andersen 2005; Noel et al. 2010), but over-reporting is not uncommon among children (Forrestal 2011).

#### *Over-reporting*

Accelerometer limitations (e.g. not worn during water activities, insensitive to cycling, load carriage and other non-ambulatory activities (NAA) restricted to upper torso movement) cannot explain over-reporting in the present study as these activities were low (14 min/day). Instead the children characterized as over-reporters have a low TEE and BMI and report higher fat intake and lower protein intake compared to acceptable-, and under-reporters. The lower BMI among over-reporters is also seen in a study among 4-11 year-old children, where over-reporters were lighter compared to under- and accurate reporters (Fisher et al. 2000). In a Norwegian study, adult over-reporters tended to have lower BMIs and were more likely to want to increase their weight compared with accurate reporters (Johansson et al. 1998). It is likely that this mechanism is the same in children with a low BMI, and therefore they tend to report portion-sizes in a larger direction, or this can be guided by parents who wish for their children to increase growth, eat more, and therefore instinctively help the child report larger portion sizes. Maternal pressure to eat has been shown to be inversely correlated to children's BMI (Matheson et al. 2006). Over-reporting in this study may be a result of general over-estimation of portion sizes and also of high fat foods as indicated by the relatively higher fat content in over-reporters diet.

### *Under-reporting*

Under-reporters were more likely to report that illness affected eating during the reporting period than both acceptable- and over-reporters, and results from the linear mixed models showed that illness significantly influenced energy intake downwards. This is also seen in a study on an adult population, where illness during the recording period had significantly impact on under-reporting (Rennie et al. 2007), and a German study including children and adolescent found that plausible reporters had a higher percentage of “no unusual recording days” (Forrestal 2011).

Under-reporters had higher BMI (within the normal range), and reported less EI compared to acceptable-, and over-reporters. Other studies also demonstrate that 7-11 year-old children that under-report their dietary intake have higher BMI's and are more weight concerned compared to plausible reporters, and over-reporters (Lanctot et al. 2008; Ventura et al. 2006). This tendency is well known, and weight consciousness have been identified as the most consistent determinant of misreporting (Livingstone et al. 2004). Reporting accuracy may also be compromised by parental obesity status and/or by the extent to which parents perceive that such information is a reflection of their child's weight (Livingstone et al. 2004). Parents in the present study were more likely to be overweight than parents for the same age group in the DANSDA (54% vs. 42% both based on self-reported weight and height). Mothers in the present study were more likely to be overweight compared to fathers (56% vs. 44%). The health and weight focus of the OPUS study may have made parents and especially mothers who also were the main food provider, comply more to a healthier diet in the reporting period. The selective under-reporting towards less fat and higher protein is well known among adults (Goris et al. 2001b; Rasmussen et al. 2007; Samuel-Hodge et al. 2004), and may be a reflection of the parents and mothers healthier dietary focus. 40% of parents were very unsatisfied with own dietary habits, and the OPUS pilot study might have provided an welcoming opportunity to change dietary habits. 59% of the study population indicated that they changed their eating habits more or less during the recording period. However, it is not clear if this change was caused by reactivity to the health focus of the study or the food reporting itself. Most likely it is a combination of both.

### *Overall reporting and repeatability*

The reported level of EI is low compared to the DANSDA and TEE is also low. This might be explained by a seasonal effect as data was collected during winter whereas DANSDA data is collected throughout the year.

Kolle and colleagues also found seasonal variations in physical activity level using accelerometers in a representative sample of 9 year-old Norwegian children, with physical activity level being lowest during winter (Kolle et al. 2009).

The ability of the WebDASC to rank individuals according to TEE was overall fair ( $r = 0.31$ ). This is slightly lower than was observed in a Norwegian study (Andersen et al. 2005) but better at baseline compared to intervention. This difference may be due to the nature of the intervention with the NND. Previous studies has shown that it is more difficult for children to record unfamiliar foods compared to familiar foods (Livingstone & Robson 2000). Therefore it is essential to make it easy to report the unfamiliar NND foods in the WebDASC, and this was improved after the validation study.

The repeatability of EI between baseline and intervention was moderate ( $r = 0.45$ ). The repeatability can be hard to assess, because the conditions of two periods will most likely be different. In this study the NND was served at the intervention period. However, if the children were in energy balance the two different conditions should not influence EI. But TEE was influenced at the intervention period. Probably the different health measures taken generally in the OPUS pilot study at intervention, the improved weather conditions and the activity registration, have influenced the higher educated families and their children to comply more to a favorably life-style and to be more physical active in the intervention period.

### *Strengths and Weaknesses*

The strength of the present study was that an objective method was used to measure TEE, which is not likely to have correlated errors with the dietary assessment method.

The results from the qualitative questionnaire showed that the WebDASC method was well accepted by participants and they provided useful feedback for improvements. This together with the lower educational level in the present study compared to the general population, implies that the web-based method does not require a high educational level.

A further strength of this study is that the evaluation of the WebDASC was performed under exactly the same circumstances as it is intended to be used in the OPUS school meal intervention study including same procedures, same setting, same age group, and a baseline and intervention period with the NND although not representing all seasons.

Comparison of EI with TEE rests on the energy balance concept, i.e. EI equals TEE in the recording period. In the present study 22 out of 81 schoolchildren reported a lower EI than their estimated BMR, half due to illness. Using TEE estimated from AEE, BMR and DIT as a comparison measure to EI under these circumstances may be a problem as BMR is a major constant component of TEE (BMR~ 70% of TEE in the present study). TEE will always be minimum the BMR, whereas EI may vary from a zero-intake during illness and upwards. This affects comparison analysis.

The comparison of EI to measurements of TEE is interesting due to different sources of errors and bias. But an estimate calculated from estimated BMR, DIT and a prediction equation converting accelerometer counts to AEE is not a “gold standard” measure of energy expenditure. Errors most likely have been introduced in estimating the different parts of TEE as choice of prediction equation, which would have affected the number of UR and OR.

There is no consensus about the most appropriate energy expenditure prediction equation from accelerometer data, including how to distinguish between periods of non-wear time and bouts of sedentary behavior (Corder et al. 2008). The prediction equation used in the present study to estimate TEE is based on a small number of participants, but it is derived from doubly labeled water measurements, and to the authors knowledge, it is the only equation based on free-living European children of the same age-group as in the present study (Nilsson et al. 2008).

It is important to note that the study sample was composed of volunteers with little ethnic, social and cultural diversity, although representative with regard to gender, parental intentions to eat healthy and parental responsibility for cooking in the age group 9-11 year-old.

## **Conclusion**

This study showed an acceptable estimation of EI with WebDASC at group level compared to accelerometer-estimated TEE in 9-11 year-old schoolchildren. The ability to rank individuals according to EI when compared to TEE was fair and better when reporting familiar foods, in comparison with unfamiliar foods. Gender, BMI, and illness had impact on the reported EI. It is likely that the weight and health focus of the OPUS study and the diet assessment influenced the diet of misreporters so their reported energy intake came to reflect the child's present weight status instead of usually intake.

### **Key messages**

- Web-based dietary assessment by 9-11 year-old children, assisted by parents, can be both feasible and acceptable by participants in intervention studies.
- Diet assessment and study focus may cause reactivity to reported energy intake so it reflects the child's (and/or parents) weight status.
- How reactivity to diet assessments and study circumstances can be minimized should be investigated.

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### **Author's contributions**

A. Biloft-Jensen were responsible for the study design, developing the background interview, diet assessment instruction materials, dietary data collection and participated in the data collection and wrote the manuscript. T. Christensen was responsible for the dietary data processing. M.F. Hjorth was responsible for the accelerometer data, the accelerometer data processing and participated in the data collection. E. Trolle, I. Tetens, L.F. Andersen participated in design discussions. M.F. Hjorth, E. Trolle, I. Tetens, L.F. Andersen, P.B. Brockhoff and J. Matthiessen participated in the critical revision of the manuscript and the statistical analyses.

### **Source of funding and conflict of interest**

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Table 1. Characteristics of the study sample compared with the population of 9-11 year old children in the Danish National Survey of Diet and Physical Activity 2003-08 (DANSDA)\*

	WebDASC <sup>§</sup> evaluation study sample (n 81)		DANSDA 2003-08 (n 250)	
<b>Subjects</b>	SD		SD	
Boys/girls (%)	42/58		48/52	
Age (years)	10.3	0.6	10.0	0.8
Parental education <sup>†</sup> (%)				
Basic school	4		9	
Vocational education	54 <sup>a</sup>		41 <sup>b</sup>	
Short further education	9		11	
Medium and long further education	33		38	
Weight (kg)	35.5 <sup>b</sup>	6.9	39.3 <sup>a</sup>	9.4
Height (cm)	144.0 <sup>b</sup>	7.2	148.1 <sup>a</sup>	9.1
BMI (kg/m <sup>2</sup> )	17.0 <sup>b</sup>	2.4	17.6 <sup>a</sup>	2.9
Overweight and obese <sup>‡</sup> (%)	10 <sup>b</sup>		21 <sup>a</sup>	
<b>Dietary composition</b>				
Energy intake kJ/d	7084 <sup>b</sup>	1651	8397 <sup>a</sup>	1908
Fat (E %)	33	4.7	33	4.6
Saturated fat (E%)	13 <sup>b</sup>	2.4	14 <sup>a</sup>	2.4
Protein (E %)	15 <sup>a</sup>	2.2	14 <sup>b</sup>	2.2
Carbohydrate (E %)	52	4.9	53	4.8
Added sugar (E %)	11 <sup>b</sup>	4.3	13 <sup>a</sup>	4.8
Dietary fibre (g 10 MJ)	25 <sup>a</sup>	5.7	21 <sup>b</sup>	5.1
EI/BMR	1.42 <sup>b</sup>	0.4	1.57 <sup>a</sup>	0.4
<b>Dietary focus</b>				
Parental intention to eat healthily (%)				
Very often or often/ once in a while and never	88/12		89/11	
Parental satisfaction with own dietary habits (%)				
Yes, very	14 <sup>b</sup>		32 <sup>a</sup>	
Yes, to some extent	48		54	
No, only partly or not at all	38 <sup>a</sup>		14 <sup>b</sup>	
Parental responsibility for cooking (%)				
Mother	62		66	
Father	16		15	
Mother/father or mother/father/children together or in turns or others	22		19	

Mean values within a row with unlike superscript letters were significant different between this study and the DANSDA 2003-08 (P<0.05)

\* (Pedersen et al. 2010)

<sup>§</sup>Web-based Dietary Assessment Software for Children

<sup>†</sup>Basic school: <12 years in school. Vocational education: 11-13 years total education, mainly practical. Short higher education: 11-13 years total education, mainly theoretical. Medium and long further education: at least 15 years total education, including academic education. Education of interviewed person.

<sup>‡</sup> Overweight is defined by Cole's standard definitions on child overweight (Cole et al. 2000).

Table 2. Difference between reported energy intake (EI) using WebDASC\* and accelerometer-estimated energy expenditure (TEE) at baseline and intervention.

	EI MJ/d		TEE MJ/d		Mean difference MJ/d	Confidence intervals MJ/d		P- value
	Mean	SD	Mean	SD		LL	UL	
Baseline (n=81)	7.08	1.65	7.10	0.99	-0.02	-0.38	0.34	0.915
Intervention (n=72)	7.29	1.85	7.35	1.08	-0.06	-0.49	0.38	0.790
Baseline and intervention (n=153)	7.18	1.74	7.22	1.04	-0.04	-0.31	0.24	0.788

Paired sample *t* test

\* Web-based Dietary Assessment Software for Children

Table 3. Reporting characteristics of the study population.

	Baseline (n=81)		Intervention (n=72)		Mean difference (n=72)	Confidence intervals		P- value
	Mean	SD	Mean	SD		LL	UL	
EI (MJ/d)	7.08	1.65	7.29	1.85	-0.25	-0.67	0.16	0.226
AEE (MJ/d)	1.34	0.69	1.62	0.77	-0.28	-0.51	-0.15	>.000
TEE (MJ/d)	7.10	0.99	7.35	1.08	-0.34	-0.49	-0.20	>.000
BMR (MJ/d)	5.05	0.47	-	-				
EI – TEE (MJ/d)	0.02	1.69	-0.06	1.84	0.08	-0.33	0.48	0.713
EI:TEE (MJ/d)	1.01	0.24	1.00	0.25	0.01	-0.05	0.07	0.770
EI:BMR	1.42	0.36	1.47	0.37	-0.05	-0.13	0.03	0.238
<b>Reporting status</b>								0.801
Acceptable-reporters* (%)	60		56					
Under-reporters <sup>§</sup> (%)	20		23					
Over-reporters <sup>†</sup> (%)	20		21					

Statistical analysis included paired sample *t* test, and  $\chi^2$  test.

\* Acceptable reporters were defined as having a ratio of EI: EE in the range: baseline: 79-121%; intervention: 78-122%.

§ Under-reporters were defined as having a ratio of EI: EE: baseline :< 79%; intervention < 78%.

† Over-reporters were defined as having a ratio of EI: EE: baseline: > 121%; intervention > 122%.

Table 4. Characteristics of under-reporters, acceptable reporters and over-reporters of energy intake in the WebDASC\* evaluation study (Baseline and intervention n=153).

	Under-reporters (n=33)		Acceptable reporters (n=89)		Over-reporters (n=31)	
		SD		SD		SD
<b>Subjects</b>						
Boys (%)	36 <sup>a</sup>		48 <sup>a</sup>		23 <sup>b</sup>	
Girls (%)	64 <sup>b</sup>		52 <sup>b</sup>		77 <sup>a</sup>	
Age (years)	10.4	0.5	10.3	0.6	10.2	0.6
Parental education <sup>§</sup> (%)						
Basic school and Vocational education	61		55		55	
Short, medium and long further education	40		45		45	
Illness affected eating (%)	56 <sup>a</sup>		27 <sup>b</sup>		31 <sup>b</sup>	
BMI (kg/m <sup>2</sup> )	18.6 <sup>a</sup>	3.3	16.9 <sup>b</sup>	1.9	15.4 <sup>c</sup>	1.4
Overweight and obese <sup>†</sup> (%)	27 <sup>a</sup>		6 <sup>b</sup>		0	
BMR MJ/d	5.2 <sup>a</sup>	0.5	5.1 <sup>a</sup>	0.4	4.8 <sup>b</sup>	0.4
Total Energy expenditure MJ/d	7.4 <sup>a</sup>	1.1	7.4 <sup>ab</sup>	1.0	6.7 <sup>c</sup>	1.0
<b>Dietary composition</b>						
Energy Intake MJ/d	5.0 <sup>c</sup>	1.0	7.4 <sup>b</sup>	1.1	9.0 <sup>a</sup>	1.3
Fat (E %)	31 <sup>c</sup>	4.2	32 <sup>bc</sup>	4.0	35 <sup>a</sup>	4.1
Saturated fat (E %)	12 <sup>c</sup>	2.0	13 <sup>bc</sup>	2.1	14 <sup>a</sup>	2.2
Protein (E %)	17 <sup>a</sup>	2.8	16 <sup>bc</sup>	2.1	15 <sup>c</sup>	2.4
Carbohydrate (E %)	52	4.7	52	4.8	50	4.2
Added sugar (E %)	10	4.1	11	4.9	11	3.6
Dietary fibre (g/10 MJ)	25	5.7	24	4.5	22	7.7
EI/BMR	1.00 <sup>c</sup>	0.17	1.46 <sup>b</sup>	0.21	1.90 <sup>a</sup>	0.21
<b>Dietary focus</b>						
Parental intention to eat healthy (%)						
Very often or often/once in a while and never	88/12		90/10		81/19	
Parental satisfaction with own dietary habits (%)						
Yes, very and to some extent/only partly or not at all	69/31		57/42		69/31	
Parental responsibility for cooking (%)						
Mother	69		59		68	
Father	25		15		13	
Mother/father or mother/father/children together or in turns or others	6		27		20	

Statistical analysis included independent *t* test, and  $\chi^2$  test.

Mean values within a row with unlike superscript uppercase letters were significant different between under-, acceptable-, and under-reporters (P<0.05).

\* Web-based Dietary Assessment Software for Children.

§ Basic school: <12 years in school. Vocational education: 11-13 years total education, mainly practical. Short higher education: 11-13 years total education, mainly theoretical. Medium and long further education: at least 15 years total education, including academic education. Education of interviewed person.

† Overweight is defined by Cole's standard definitions on child overweight (Cole et al. 2000).

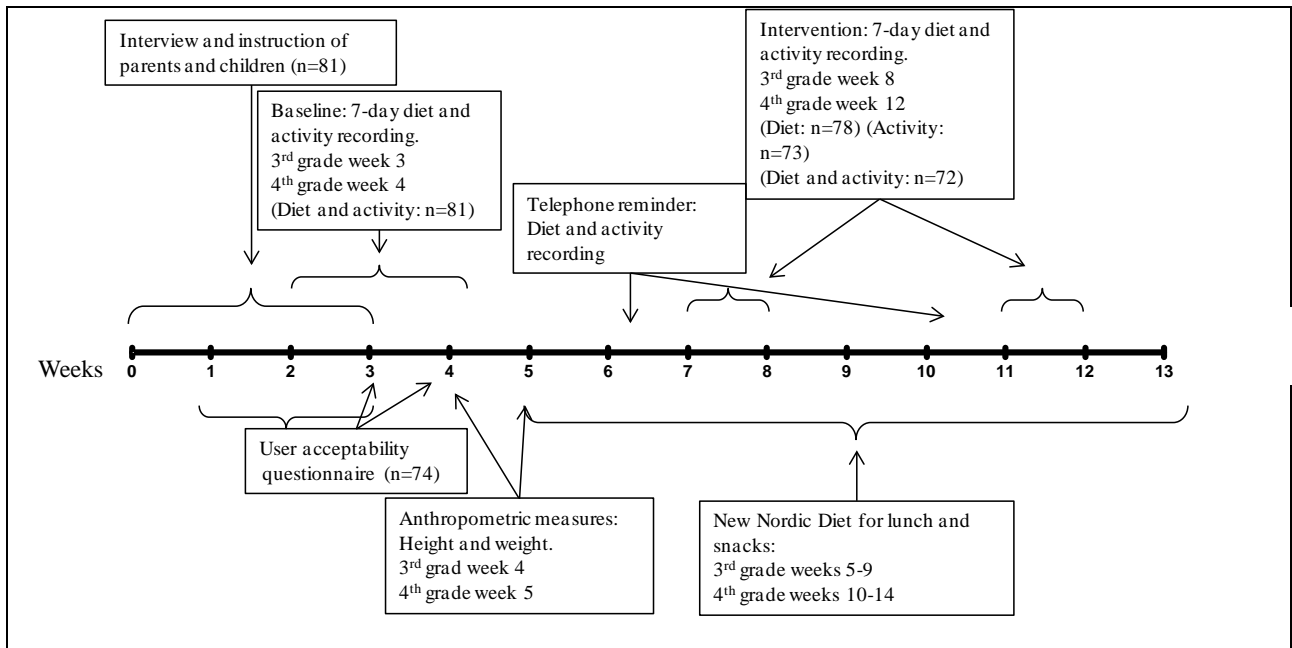


Figure 1. Design of the Web-based Dietary Assessment Software for Children evaluation study.



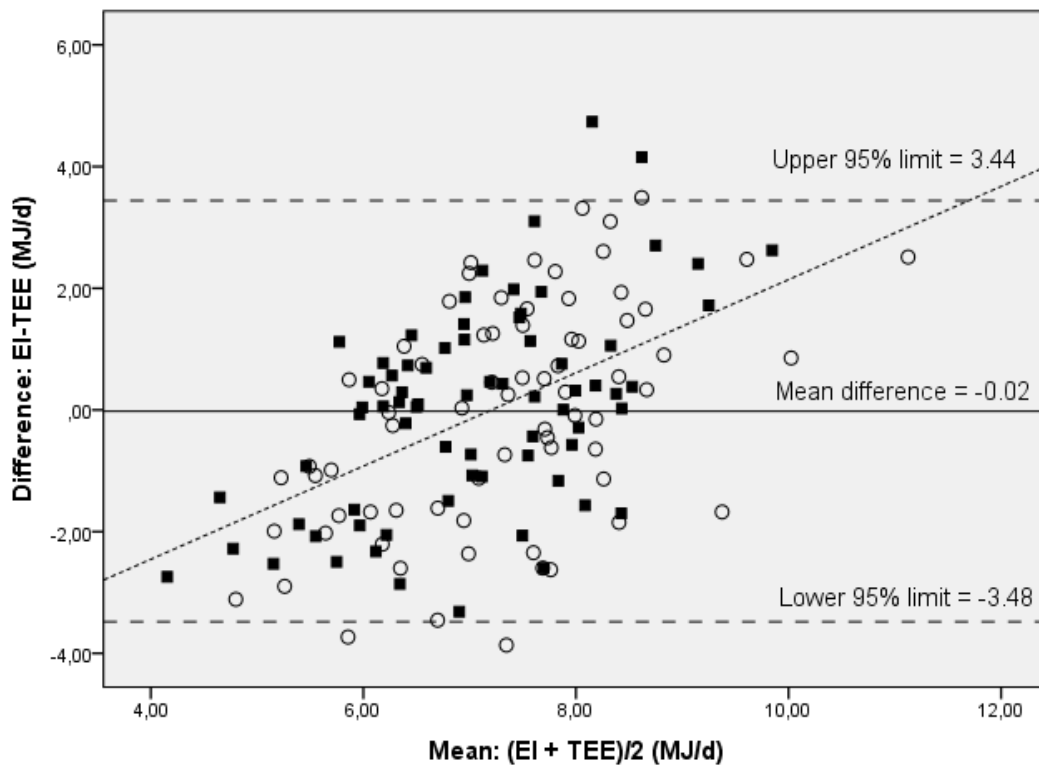


Figure 2. Bland-Altman plot of the differences between energy intake (EI) calculated from the WebDASC<sup>a</sup> and accelerometer-estimated energy expenditure (TEE) plotted against the mean of EI and TEE (n=72). ■ = Baseline, and o= Intervention

\*Web-based Dietary Assessment Software for Children

## Paper 3

### **Evaluation of a Web-based Dietary Assessment Software for children: comparing reported fruit, juice and vegetable intake to plasma carotenoid concentration and school lunch observations.**

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## **Abstract**

The potential health effects of a New Nordic Diet are tested in a school meal study among 8-11 year Old Danish children. A Web-based dietary Assessment Software for Children (WebDASC) was developed to estimate dietary intake. The present study validate self-reported fruit, juice and vegetable (FJV) intake in 8-11 year old children by comparing intake to plasma carotenoids concentration, and by comparing the reported FJV intake to actually eaten FJV, as observed by a photographic method.

81 children, assisted by parents, reported their diet for 7 consecutive days. The same 5 schooldays as they reported their diet, the children's school lunch was photographed and weighed before and after eating. After the diet reporting, fasting blood samples were taken. Estimated intake of FJV and carotenoids were compared to plasma carotenoid concentration. Accuracy of reported food and FJV consumption at school lunch was measured in terms of matches, intrusion, omission and faults when compared to images of lunch intake.

Estimated intake of FJV was significantly correlated with the total carotenoid concentration (0.58) ( $P<0.01$ ). Fruits and juice showed higher correlations than vegetables with plasma carotenoid concentration (0.38 and 0.42 vs. 0.33) ( $P<0.01$ ). Eighty-two% of participants fell into the same or adjacent quartiles when classified by FJV intake and carotenoids biomarkers. WebDASC attained 82% reporting matches overall and higher percent match for reporting fruits compared to beverages. The present study indicated that WebDASC can be used to rank 8-11 year Old Danish children according to their intake of FJV overall, and at school meals.

**Background:**

A diet high in fruit, juice and vegetables (FJV) is associated with a decreased risk of many chronic diseases<sup>(1)</sup>, and therefore several western countries have focus on increased fruit and vegetable consumption in their food based dietary guidelines<sup>(2-4)</sup>. This has set off initiatives and interventions to increase the intake of FJV in populations with the need for validated methods to measure intake.

The OPUS (Optimal well-being, development and health for Danish Children through a healthy New Nordic Diet) centre was established to promote health and prevent overweight in Danish children. One of the key aims of the OPUS centre was to create a New Nordic Diet (NND) based on food items native to the Nordic region<sup>(5)</sup>. A fundamental principle of NND is that the majority of the energy should be provided by plant based foods. The NND contains at least 700 g FJV per day per 10 MJ (300 g fruits; 400 g vegetables) excluding nuts, potatoes and seaweed<sup>(6)</sup>.

The OPUS centre includes a school meal study including more than 800 Danish children 8-11 years of age, with the aim of testing the health effects of the NND. In the OPUS School Meal Study children will be served lunch and snacks based on the NND.

To document and evaluate dietary intake, and intake of NND, a suitable measure of the childrens dietary intake including FJV, was needed. It was considered that a self-administered intuitive, child appealing web-based dietary data collection would be acceptable both for children and adults as well as being cost efficient<sup>(7)</sup>, and a Web-based Dietary Assessment Software for Children (WebDASC) was developed for this purpose<sup>(8)</sup>.

There are several challenges connected with self-reported dietary intake in general and especially in children e.g. memory of intake, ability to estimate portion size, and social desirable responses.

Because of the unavoidable errors dietary assessment methods should always be validated to avoid misinterpretation of the data output.

In the OPUS School Meal Study it is essential to know if participants are able to provide reasonable reports of FJV intake.

One method to evaluate this is to compare FJV consumption to biomarkers such like plasma concentrations of carotenoids. In developed countries, 80-90% of the carotenoid intake comes from FJV consumption<sup>(9)</sup>. A dose-response relationship between carotenoid intake and appearance in plasma has been shown<sup>(10)</sup>, making plasma carotenoids a reasonable biomarker of intake.

The provitamin A compounds:  $\alpha$ -carotene,  $\beta$ -carotene and  $\beta$ -cryptoxanthin, lutein, lycopene, and zeaxanthin represent more than 95% of the total blood carotenoids<sup>(9)</sup>, and these have been used before to validate FJV intake measured by various dietary assessment methods mainly among adults but also among adolescents<sup>(11-16)</sup>. Only few studies have been carried out with children<sup>(17; 18)</sup>. As biomarkers may be imprecise because they are influenced by factors unrelated to dietary intake, like individual variability in absorption (co-consumption of inhibitors and promoters), availability (different processing) and metabolism<sup>(19)</sup>, they should be regarded as a crude measure. Biomarkers in general convey no information about what is eaten at which meal and which day. Therefore a combination of carotenoid biomarkers with direct observations would also give insight into the reporting accuracy of meals, and hence, wider aspects of the validity and function of the dietary assessment method.

Direct observation of meals is considered a "gold standard" for evaluating the validity of dietary assessment tools, because eating is an observable behaviour<sup>(20)</sup>. Direct observation involves the comparison of foods reported eaten to foods actually eaten by observing what participants really eat. However, observations are resource demanding and is, because of the invasive nature, often not possible through longer periods like a whole day. Thus, observations have mostly been used to validate intake at selected meals in structured environments, and among 10 year old school children to validate reported school meal intake<sup>(21-23)</sup>. Digital photographic methods provide new possibilities for conducting observations and evaluating dietary assessment, and have been used before to document school lunch intake in children<sup>(24)</sup>.

The aim of the present study is to validate the estimated FJV and carotenoid intake using WebDASC by 8-11 year old children by comparing it to plasma concentrations of carotenoids. Further, to assess the accuracy of reporting school lunch intake of FJV by comparing the reported FJV intake to actually eaten FJV, as observed by a digital photographic method.

## **Method**

### *Study design*

The evaluation study was performed as part of the OPUS School Meal *Pilot Study* conducted in January – April 2011. Third and fourth-grade children at one school situated in the North eastern part of Denmark were recruited. One hundred and five pupils and their families were invited and 81

gave written consent to participate. Detailed instructions on how to report food intake in the WebDASC were provided individually to all participants by the research team as well as written instructions. Children, assisted by parents, reported their total diet in the WebDASC for 7 consecutive days. In this period the children brought their packed lunches from home as they usually do in most Danish schools. On the same 5 schooldays as they reported their diet in WebDASC the children's packed school lunch was photographed and weighed before and after lunch, and supplementary questions were asked.

All the participants' parents were interviewed, in person, about social background, health issues, attitudes and knowledge about food and health. Fasting blood samples were taken, and body weight and height were measured once by trained personnel during the week after food reporting. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Committee on Biomedical Research Ethics in the Capital Region of Denmark (no. H-1-2010-023).

#### *Food reporting in the WebDASC*

Participants recorded their diet in the WebDASC for 7 consecutive days every evening. For inclusion of participant's dietary reports in the analyses, at least 3 weekdays and 1 weekend day of food reporting had to be completed.

In the WebDASC special attention was given to age appropriate design issues. An animated armadillo guided respondents through six daily eating occasions (breakfast, morning snack, lunch, afternoon snack, dinner, and evening snack) and helped them report foods and beverages previously consumed. A database of 1300 food items, including 220 FJV's (90 fruit, 10 juice, and 120 vegetables, without counting mixed dishes containing FJV as casseroles, salads and soups etc.), was available either through category browse or free text search, aided by a spell check application. A type-in format was available for foods not otherwise found through category browse or text search. Amount consumed was estimated by selecting the closest portion size among four different digital images in 320 photo series. The WebDASC included internal checks for frequently forgotten foods (spreads, sugar, sauces, dressings, snacks, candy and beverages) and the following features to create motivation: a food-meter displaying total amount of foods reported so far, a most popular food ranking, and a computer game with a high score list. The rank list and game was accessible after completing a day's recordings. Furthermore, participants reported the intake of nutritional supplements and whether a day represented usual or unusual intake, including reasons for unusual

intakes such as illness. If a participant failed to report a day, parents were reminded the next day by an e-mail. Failing to report a day within 48 hours automatically closed the day and opened a new day instead.

FJV intake was calculated for each individual using the software system GIES (Version 1.000 d - 2010-02-26) developed at the National Food Institute, Technical University of Denmark).

Vegetables did not include potatoes which in Denmark are classified as a starchy staple. Fruit also included fruit products such as jam, nuts and concentrated fruit syrups.

#### *Estimation of carotenoid intake*

Carotenoid intake was estimated for each individual by coupling all foods reported (on databank level) to their carotenoid content. Thereafter GIES was used to estimate intake of individual carotenoids. Because a comprehensive database of the carotenoid content in Danish and Nordic foods does not exist, we chose to use the United States Department of Agriculture USDA database for US foods (USDA National Nutrient Database for Standard Reference, Release 24, 2011)<sup>(25)</sup>.

#### *Blood samples and determination of plasma carotenoids*

Overnight fasting blood samples were collected in a mobile laboratory placed outside the school, during the week after the dietary reporting. Venous blood was drawn from the forearm in EDTA tubes, centrifuged at 2500×g for 10 min at 4°C within 30 min of collection and the plasma was stored at ÷80 °C until analysis.  $\alpha$ -carotene,  $\beta$ -carotene,  $\beta$ -cryptoxanthin, lutein, lycopene and zeaxanthin in plasma were determined by high-performance liquid chromatography (HPLC) according to Søltoft et. al<sup>(26)</sup> and Toft et al<sup>(16)</sup>. In short, plasma was treated with ethanol to precipitate proteins, and the carotenoids were extracted with petroleum ether and analyzed by HPLC. Separation of carotenoids was achieved using a C<sub>30</sub> carotenoid column, and a photodiode array detector was applied for identification of the carotenoids by scanning between 200 and 600 nm. An UV detector was used for quantification at 450nm for lutein, zeaxanthin,  $\beta$ -cryptoxanthin,  $\alpha$ -carotene and  $\beta$ -carotene, and at 470 nm for lycopene. The concentrations of the carotenoids were calculated using external standard curves. Standards were obtained from Sigma-Aldrich Denmark A/S and CaroteNature GmbH Switzerland.

### *Observations of school lunch made by food photography*

White solid polystyrene plates (Model LINPAC; Size 26 cm) marked with class, date, and ID numbers were distributed to all children in the two school classes just before school lunch. The children were asked to unpack their packed lunches from home and place their food on the plate. They were further told to separate items and open up the sandwiches, so all food items would be observable. The children were asked to bring their food and drinks to one of two weighing stations where a researcher weighed the plate with the food on, and the drinks on an electronic scale (Soehnle; Vera 67002, with a precision of  $\pm 1$  g). The children were also asked if they had eaten food items from their packed lunch earlier that day. Afterwards the children proceeded to one of the two photo stations, where food and beverages were photographed. Images were taken of the plates and beverages using a Nikon COOLPIX S700 digital camera (12.1-Megapixel) based on the following standard procedure: A cubelite (Lastolite Cubelite 58 cm) was used to ensure suitable lighting and a squared plate mat was used as background and as an internal reference of size (squares = 2 x 2 cm) and to mark the placement of the plate, the camera tripod and fix points to adjust the camera angle. Images were taken from the camera tripod (43 cm tall) at an app. 45 degree angle looking down at the plates making it possible to see depth of foods. When the children had finished eating the procedure was repeated. Any package or wrapping that was weighed the first time (yoghurt and noodle cups, muesli bar wrappings etc.) was left on the plate and also weighed the second time. The second time the children were asked if they had received any foods or drinks or given away any, and if they wanted to save leftovers for later. The questions should help qualifying the food reporting in the WebDASC and the comparison with the images. An experienced dietician assessed the accuracy of the children's diet records at lunch, by hand, for each individual by scoring the items reported against the two images (before and after eating). Each item was classified either as a match (item recorded eaten and observed eaten), an intrusion (items reported eaten but not observed eaten), an omission (item observed eaten but not reported eaten) or a fault (item reported eaten does not describe the item observed eaten). Matches, omissions and intrusions also included assessment of the recorded serving size e.g. if there were two carrots eaten as seen from the school lunch image and there was only one carrot reported in the WebDASC (judged by WebDASC image weight), this was recorded as an omission, and e.g. if a raisin portion seen from the school lunch images were smaller than the reported raisin portion in the WebDASC (judged by WebDASC image weight) this was recorded as an intrusion.



### *Anthropometric measurements*

Participants were weighed, fasting overnight, without shoes in light indoor clothing to the nearest 0.1 kg on an electronic digital scale (Tanita BWB-800S, Tokyo, Japan). Height was measured without shoes to the nearest 0.1 cm with a portable stadiometer (CMS Weighing Equipment LTD, London, U.K.).

### *Statistics*

The participants of this study were compared to a random sample from the Danish National Survey of Diet and Physical Activity (DANSDA) 2003-8, and differences in characteristics were evaluated using the  $\chi^2$  statistic, z test and independent t-test.

Total plasma carotenoids concentration and total FJV intake were normally distributed; however this was not the case for carotenoid intake and for fruit, juice or vegetable intake independently. Therefore medians and inter quartile range were reported for the estimated carotenoid intake, and Spearman correlations were calculated between the individual plasma carotenoids and fruit, juice and vegetable intake.

Partial correlation coefficients adjusted for gender, BMI, total energy expenditure (TEE), age, education, fat intake and illness were calculated for the association between reported total FJV intake and total plasma concentrations of carotenoids. Only significant factors were retained in the final correlations.

Comparison of carotenoids concentrations between users and non-users of dietary supplements were performed by the independent t-test.

Categorical agreement between reported FJV intake and plasma carotenoids was assessed using cross classification of FJV intake and plasma carotenoids divided into quartiles and applying kappa statistics.

Linear mixed models were used to assess a weekday and meal effect to qualify school lunch observations of FJV intake, and to assess the influence of background factors such as gender, education, BMI, age and illness and their mutual interactions on FJV intake.

The fixed factor effects in the model were gender, education, BMI, age, illness that affected eating and all their two-way interactions. To adjust for dependency in repeated measures within subjects, random effects were added for subject. Non-significant fixed effects were removed from the models leading to simplified models for summary of the significant effects. Homogeneity of variance and normality of the residuals were examined using graphical methods.

In all statistical analyses a significance level of 5% was applied. Data were analyzed using SPSS for Windows version 19.

## **Results**

### *Characteristics of the study population*

Eighty one children (34 boys; 47 girls), with assistance from parents, reported their diet in the WebDASC for 7 consecutive days. Seventy three of these had a blood sample taken. Seventy seven children had their lunch weighed and photographed during the diet assessment period, not all on all 5 days due to illness and vacation.

The volunteer study population was representative of the randomly selected population in the DANSDA 2003-8 with regard to gender, and use of supplements. But the study population consisted of a higher proportion of children with parents with a vocational education; Had a higher intake of vegetables; Had lower BMI's, but it should be noted that height and weight in the DANSDA 2003-08 was self-reported by parents; Reported lower energy intake relative to BMR (EI/BMR) (Table 1). Furthermore, the parents answered to a higher degree, that vegetables characterized a healthy diet, when asked "What does in your opinion characterize a healthy diet".

### *Fruit and vegetable intake based on the WebDASC*

The study population reported eating significantly more FJV during school days (403 g/day) than on weekend days (321 g/day) (Figure 1), corresponding to a mean difference of 82 g ( $P < 0.001$ ). The FJV intake at main meals was highest for lunch (101 g/day), thereafter dinner (88 g/day) and lowest for breakfast, especially when not including juice (18 g/day; 60 g/day including juice). The FJV intake at snack meals was highest in the afternoon (74 g/d), and lowest in the evening snack meal (46 g/d) (Figure 1). Results from the linear mixed models showed that illness had significant influence on the intake of FJV on different days and to different meals. Reporting that illness affected dietary intake was associated with a lower FJV intake corresponding to 19 g less per meal per day ( $p = 0.002$ ).

### *Plasma carotenoid concentrations and estimated intake of carotenoid.*

No differences in plasma concentrations of carotenoids between supplement users and non-users were found which reflects that standard Danish vitamin supplements do not contain carotenoids. Therefore both users and non-users of supplements were analyzed together.

The estimated average (plus SD) intake of carotenoids was 8.0 (7.4) mg/day and the plasma average concentrations was 0.77 (0.32)  $\mu\text{g/mL}$  (Table 2). The relative contributions of the individual plasma carotenoids to total plasma concentration reflected the relative contribution of the individual carotenoid intake to total carotenoid intake ( $\chi^2$ :  $p=0.220$ ) (Figure 2).

89 % of the estimated carotenoid intake came from FJV. As seen in Table 3, vegetables mainly contributed with  $\beta$ -carotene (reflecting intake of carrot, sweet red pepper, broccoli and dark green and orange coloured vegetables) and with lycopene (reflecting intake of tomato and tomato products). Fruits mainly contributed with lutein & zeaxanthin (reflecting intake of orange juice, mandarin orange, orange, grape, pear, apple, melon and banana) and  $\beta$ -carotene (reflecting intakes of mandarin orange, orange, grape and melon), and juice mainly contributed with  $\beta$ -cryptoxanthin (reflecting intake of orange juice) and lutein & zeaxanthin (reflecting intake of orange juice and apple juice)<sup>(25)</sup>.

As illustrated in Table 4, the Spearman correlation between total plasma concentration of carotenoids and FJV intake were 0.58 ( $P<0.01$ ). The highest Spearman correlation coefficient observed for fruit intake was to plasma  $\beta$ -cryptoxanthin ( $r=0.59$ ;  $P<0.01$ ), and for juice intake to  $\beta$ -carotene ( $r=0.32$ ;  $P<0.01$ ). The highest Spearman correlation observed for vegetable intake was to  $\alpha$ -carotene ( $r=0.43$ ;  $P<0.01$ ).

Partial correlation coefficients, adjusted for gender, BMI, and energy expenditure, between total plasma concentrations of carotenoids and FJV intake were 0.49 ( $P<0.01$ ) (result not shown).

Cross classification between FJV intake and total plasma carotenoids concentration showed that 55% was classified in the correct quartiles, 82 % was classified in correct or adjacent quartile, 17% was misclassified and 1 % was grossly misclassified. The Kappa value was 0.4, indicating fair agreement (results not shown).

### *Photographic observations of school lunch vs. recorded intake of FJV*

For school lunch reporting's WebDASC obtained 82% matches, 14% intrusions, 3% omissions and 1% faults for total foods and beverages (results not shown).

As illustrated in Table 5 overall reporting accuracy for fruit, juice, vegetables and other foods were not significantly different. However, a higher percent match and a lower percent intrusion for fruit compared to beverages and lower percent omission compared to foods was observed.

Most (90% in total) recording errors for FJV were intrusions e.g. reporting a portion size images illustrating a larger portion than the eaten portion size (35%) or reporting fruits and vegetables not eaten (65%).

That intrusions were the most common reporting error was also reflected in the total amount of foods reported, which were higher than the total amount of food actually eaten at lunch (Mean reported: 243g vs. Mean weight: 209g,  $P < 0.001$ ). The same was true for beverages (Mean reported: 184g vs. Mean weight: 147g,  $P < 0.001$ ).

## **Discussion**

### *Comparing estimated FJV and carotenoid intake to plasma carotenoid concentration*

The present study demonstrated significant correlations between estimated FJV intake using the WebDASC and plasma carotenoid concentration. The Spearman correlations between plasma concentrations of the individual carotenoids and respective dietary intakes were higher in the present study compared to a study by Neuhauser of adolescents aged 12-17 years<sup>(27)</sup>. In the study of Neuhauser, however, the dietary assessment used was a Food Frequency Questionnaire (FFQ), which is known to be less precise than a 7-day Food Diary as used in the present study<sup>(28)</sup>.

The partial correlation between FJV intake and plasma carotenoid concentrations in the present study (0.49) was also better than found in other studies validating FFQ, Food Diaries (FD) and 24-hour Recall (24hR). In a study of adolescents (5<sup>th</sup> and 8<sup>th</sup> grade) the correlations found were FFQ= 0.24 and 24hR= 0.14<sup>(13)</sup>; and FFQ=0.13; and FD= 0.20<sup>(15)</sup>; and FFQ= 0.32 to 0.42<sup>(16)</sup> in two studies of adults. The higher partial correlation in the present study might be explained by Danish children in that age group prefer eating visible fruits and vegetables<sup>(29)</sup>, and the more visible foods are, the easier it is to remember and to report accurately. On the contrary, the content of FJV in mixed dishes could be difficult for the individual to estimate correctly in the WebDASC, because the FJV in mixed dishes are predetermined in a recipe, which is not likely to accurately reflect the FJV content of individual recipes and eaten mixed dishes. Furthermore, there is a limited ability to differentiate between cooked and raw vegetables in the WebDASC, which affects carotenoid bioavailability and thereby plasma concentrations. The predominant vegetable in mixed dishes eaten by children is canned tomatoes and tomato puree (in bolognaise and casseroles, pizzas,

lasagna etc.), which is especially hard to estimate. This might explain some of the missing correlation between reported vegetable intake and lycopene plasma concentration. However, the relative contribution of individual plasma carotenoids to total plasma carotenoids reflected the relative contribution of individual carotenoid intake to total estimated carotenoid intake. This illustrates that the proportion of single carotenoids eaten corresponds to the proportion of single carotenoids in the blood.

The carotenoid intake in Denmark has earlier been estimated to 10 mg/day based on food balance sheets<sup>(9)</sup> which is in good agreement with the estimated intake of 8 mg/day in 8-11 year olds in the present study. It should be noted that a database over content in US foods was used for estimating intake and therefore not accurately reflected the content in Danish/Nordic foods. Margarine and fruit drinks are often fortified with beta-carotene in the US<sup>(30)</sup>, and  $\beta$ -carotene is used by the food industry as a colorant of various foods like cheese, and egg yolks which may also contribute to different contents in American and Danish foods. This might explain some of the high contribution of fruits (which included fruit drinks) to  $\beta$ -carotene intake. In addition, it has been found that although  $\beta$ -carotene predominantly occurs in vegetables, the same quantity of intake from fruits and vegetables resulted in a four-fold greater increase in serum levels with  $\beta$ -carotene from fruits compared to vegetables<sup>(31)</sup>. The bioaccessibility of carotenoids in vegetables is known to be low because their chemical structure deeply interacts with macromolecules within the plant food matrix<sup>(9)</sup>.

#### *Comparing reported intake of FJV to observed intake of FJV at school lunch*

School meals seem to provide a good opportunity to evaluate the reporting accuracy of FJV intake in the present study, since school meals contributed with the highest intake of FJV during the week. In the present study a modified observation technique was used, including a digital photographic method, weighing and questioning. In a number of previous studies investigating accuracy of reported school meals researchers or dieticians have been observing 1-3 children at a time and recording items and amounts eaten for each child<sup>(21; 22; 32-34)</sup>. Photographing the children's school lunches gave, in addition, the opportunity to capture more details e.g. inside sandwiches, and time to evaluate the reported serving sizes more thoroughly by comparing them to food images and known weights of these. This method is also less sensitive to observer variability, because the same dietician is able to evaluate all the images. However, the method used might have underestimated

accuracy. The children had their packed lunches with them all morning, and some children did eat food items before school lunch time. They still recorded these food items as lunch (and not morning snack) and therefore the food items appeared as recorded in WebDASC, but not on the images. The questions about “eating from the packed lunch earlier in the day” verified this, but it was still registered as a reporting error, because it was not reported at the correct meal. It would, however, not influence estimations of daily food or nutrient intake.

The reporting accuracy for fruit, juice and vegetables was comparable to the accuracy for other foods. But it was found that the children were better at reporting fruit intake than beverages at school lunch. This might be explained by the fact that fruit is very visible foods easy to count and the size is well known, opposed to beverages which are often brought to school in opaque water bottles of various sizes and refilled during the day. In the WebDASC this should be compared to different fillings of a standard glass, which would be difficult. The estimation of beverages should be improved in future versions of WebDASC. Other American studies, by Baxter et al., of the same age group have found less accuracy when reporting school meals<sup>(33-35)</sup> than the present study. It should be noted that in these studies a statistical weight was assigned to each item according to importance by meal component so that errors regarding reporting main components counted more than errors for condiments. The results from these studies are therefore not directly comparable to the present study, where only the FJV part of the meal is evaluated. But a higher accuracy in the present study might be explained by the parent assistance. Parents probably had prepared or assisted preparing the packed lunches, and therefore were able to assist their children in reporting their lunch intake. In contrast, in the studies of Baxter et al. no parent assistance were provided, and in addition the children had school meals prepared by a school cater which may contain unfamiliar foods compared to packed lunches from home as in the present study. Previous studies have shown that it is more difficult for children to record unfamiliar foods compared to familiar foods<sup>(36; 37)</sup>.

The percent obtained matches of FJV recordings in the WebDASC can be viewed as a form of ranking, showing that children, assisted by parents, are able to report the correct food item and choose the correct portionsize among 4 images in the WebDASC, and there by ranking them self according to quantity of intake.

### *Strengths and limitations*

The strength of the present study was that two objective methods were used to evaluate reported FJV intake, which complimented each other, and which were not likely to have correlated errors with the dietary assessment method.

A further strength of this study was that the evaluation of the WebDASC and reported FJV intake was performed under exactly the same circumstances as intended to be used in the OPUS School Meal Study including same procedures, same setting, and same age group. Furthermore, the lower educational level of parents in the present study compared to the general population implies that the web-based method does not require a high educational level.

Plasma concentrations of circulating nutrients and carotenoids reflect both short and long term intake<sup>(31)</sup>. In contrast, a dietary assessment method usually reflects either long term intake (FFQ) or short term intake (24 hR and FD) as used in the present study. Therefore it is difficult to evaluate a correlation coefficient; however, in the present study it was higher when compared to similar studies.

A weakness of the present study is that the study sample is composed of volunteers with little ethnic, social and cultural diversity, although representative with regard to gender and parental focus on fruits.

Furthermore, the introduction to the NND before giving consent to participate, the health focus of the study, the parental focus on vegetables and the diet reporting may have caused the participants to be more thorough when reporting vegetables compared to reporting other foods or less healthier foods. Furthermore, 33% reported that illness affected their eating in the reporting period, and this was also true for FJV and energy intake which were low in the reporting period. The short term change in FJV intake due to illness hardly influenced the ranking of participants according to intake, since illness was of varying duration and hit participants at random. The low energy intake was also reflected in low total energy expenditure (Table 1), which besides illness, also was due to the weather conditions in January 2011 with snow, ice, and low temperatures.

### *Conclusion*

The present study demonstrated statistically significant correlations between FJV intake estimated by WebDASC and plasma carotenoid concentrations. Furthermore, the accuracy of reported FJV

intake in WebDASC was fairly good when compared to observed intake at school lunch by a digital photographic method. The present study indicated that the WebDASC can be used to rank 8-11 year Old Danish children according to their intake of FJV overall, and on school meal level.

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A. Biloft-Jensen was responsible for the study design, developing the background interview, diet assessment instruction materials, dietary data collection, the assigning of carotenoid content to reported foods and participated in the data collection and wrote the manuscript. C.T. Damsgaard was responsible for recruiting the participants and collecting the blood samples. A. Bysted was responsible for the plasma analysis of carotenoids. T. Christensen was responsible for the dietary data processing. E. Trolle, I. Tetens, L.F. Andersen A. Bysted and P. Knuthsen participated in design discussions. All authors contributed to the critical revision of the manuscript and the statistical analyses.



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Table 1. Characteristics of the study sample compared with the population of 9-11 year old children in the Danish National Survey of Dietary Habits and Physical Activity 2003-08 (DANSDA)

	<i>WebDASC* evaluation study sample (n 81)</i>		<i>DANSDA 2003-08 (n 250)</i>	
	Mean	SD	Mean	SD
<b>Participant data</b>				
Boys/girls (%)	42/58		48/52	
Age (years)	10.3	0.6	10.0	0.8
Parental education <sup>†</sup> (%)				
Basic school	4		9	
Vocational education	54 <sup>a</sup>		41 <sup>b</sup>	
Short further education	9		11	
Medium and long further education	33		38	
BMI	17.0 <sup>b</sup>	2.4	17.6 <sup>a</sup>	2.9
Overweight and obese <sup>‡</sup> (%)	10 <sup>b</sup>		21 <sup>a</sup>	
Supplement users (%)	58		62	
Illness affected eating (%)	33		-	
Total energy expenditure (TEE) (MJ/d) <sup>§</sup>	7.1	1.0	-	
Total energy intake (MJ/d)	7.1 <sup>b</sup>	1.7	8.4 <sup>a</sup>	1.9
<b>Fruit and vegetable intake (g/10MJ per day)</b>				
Fruit and vegetable intake with juice	541	270	499	263
Fruit and vegetable intake without juice	429 <sup>a</sup>	231	375 <sup>b</sup>	206
Vegetable intake	212 <sup>a</sup>	124	159 <sup>b</sup>	87
Fruit intake	217	157	217	157
Juice intake	112	112	123	140
<b>Parental focus on fruit and vegetable (%)</b>				
A healthy diet contains lots of fruit <sup>  </sup>	19		18	
A healthy diet contains lots of vegetables <sup>  </sup>	84 <sup>a</sup>		74 <sup>b</sup>	

<sup>a,b</sup> Mean values within a row with unlike superscript letters were significant different between this study and the DANSDA 2003-08 (P<0.05)

\*Web-based Dietary Assessment Software for Children

<sup>†</sup> Educational level of interviewed parent. Basic school: <12 years in school. Vocational education: 11-13 years total education, mainly practical. Short higher education: 11-13 years total education, mainly theoretical. Medium and long further education: at least 15 years total education, including academic education.

<sup>‡</sup> Overweight and obese: Based on age- and sex-specific cut offs defined to pass through BMI of 25 and 30 kg/m<sup>2</sup> at age 18 according to Cole et al. 2000<sup>(38)</sup>

<sup>§</sup> Total energy expenditure estimated from accelerometer counts using the prediction equation from Nilsson et al 2008<sup>(39)</sup>, calculated basal metabolic rate and diet induced thermogenesis.

<sup>||</sup> Coded answer to the question “What characterizes in your opinion, healthy food”.

Table 2. Plasma carotenoid concentration and estimated intake of carotenoids in 9-11 year-old schoolchildren indicated as mean, standard deviations (SD), medians and inter quartile range (IQR).

	Mean	SD	Median	IQR
<b>Plasma concentration of carotenoids (<math>\mu\text{g/mL}</math>) (n=73)</b>				
<i>Total carotenoids</i>	0.77	0.32	0.74	0.54; 0.91
Lutein & zeaxanthin	0.10	0.04	0.09	0.07; 0.12
$\beta$ -cryptoxanthin	0.12	0.10	0.10	0.05; 0.16
$\alpha$ -caroten	0.10	0.07	0.08	0.06; 0.12
$\beta$ -caroten	0.28	0.17	0.24	0.18; 0.34
Lycopene	0.17	0.08	0.16	0.11; 0.21
<b>Estimated intake of carotenoids (mg/d) (n=81)</b>				
<i>Total carotenoids</i>	8.00	7.40	5.90	4.01; 10.12
Lutein & zeaxanthin	0.85	0.45	0.74	0.55; 0.99
$\beta$ -cryptoxanthin	0.18	0.17	0.13	0.06; 0.26
$\alpha$ -carotene	1.21	1.84	0.76	0.25; 1.44
$\beta$ -carotene	3.57	4.53	2.47	1.26; 4.39
Lycopene	2.20	2.47	1.77	0.89; 2.59

Table 3. Relative contribution of vegetable, fruit and juice to intake of individual carotenoids, indicated as mean (%) and standard deviation (%).

<i>Carotenoids</i>	Vegetables (n=81)		Fruit (n=81)		Juice (n=65)	
	Mean percent	SD	Mean percent	SD	Mean percent	SD
Lutein & zeaxanthin intake mg/d	7	5	36	21	51	22
$\beta$ -cryptoxanthin intake mg/d	1	1	15	14	40	18
$\alpha$ -carotene intake mg/d	14	8	5	5	1	1
$\beta$ -carotene intake mg/d	42	15	33	13	8	4
Lycopene intake mg/d	36	21	10	20	-	-

Table 4. Spearman correlations between plasma carotenoids and the estimated intake of fruit, juice and vegetable

Plasma concentrations of carotenoids	$\alpha$ -carotene plasma	$\beta$ -carotene plasma	$\beta$ -cryptoxanthin plasma	Lycopene plasma	Lutein + zeaxanthin plasma	Total carotenoids plasma
Estimated intake per day:						
Fruit	.31**	.32**	.59**	-.04	.09	.38**
Vegetable	.43**	.38**	.21	-.02	-.04	.33**
Juice	.24*	.32**	.31*	.27*	.19	.42**
Fruit, juice and vegetable (FJV)	.46**	.47**	.52**	.19	.19	.58**

\*Correlation is significant at the 0.05 level

\*\*Correlation is significant at the 0.01 level

Table 5. Relative reporting matches, intrusions, omissions and faults (%) of fruit, juice, vegetables, foods and beverages when comparing school lunch intake to school lunch reportings in the WebDASC among 77 children.

	Fruit (n=158)	Juice (n=27)	Vegetables (n=411)	Beverages ex. juice (n=255)	Foods ex. fruit and vegetables (n=1208)
Match (%) <sup>*</sup>	89 <sup>a</sup>	89	82	77 <sup>b</sup>	81
Intrusion (%) <sup>†</sup>	10 <sup>b</sup>	11	16	22 <sup>a</sup>	13 <sup>b</sup>
Omission (%) <sup>‡</sup>	1 <sup>b</sup>	0	2 <sup>b</sup>	0	5 <sup>a</sup>
Fault (%) <sup>§</sup>	0	0	0	1	1

Tested by  $\chi^2$  statistic

<sup>a,b</sup> Mean values within a row with unlike superscript letters were significant different ( $P < 0.05$ ).

\* Item recorded eaten and observed eaten, does also include match of portion sizes.

<sup>†</sup> Items reported eaten but not observed eaten, does also include reporting of too large portion size.

<sup>‡</sup> Item observed eaten but not reported eaten, does also include missing portions.

<sup>§</sup> Item reported eaten does not describe the item observed eaten



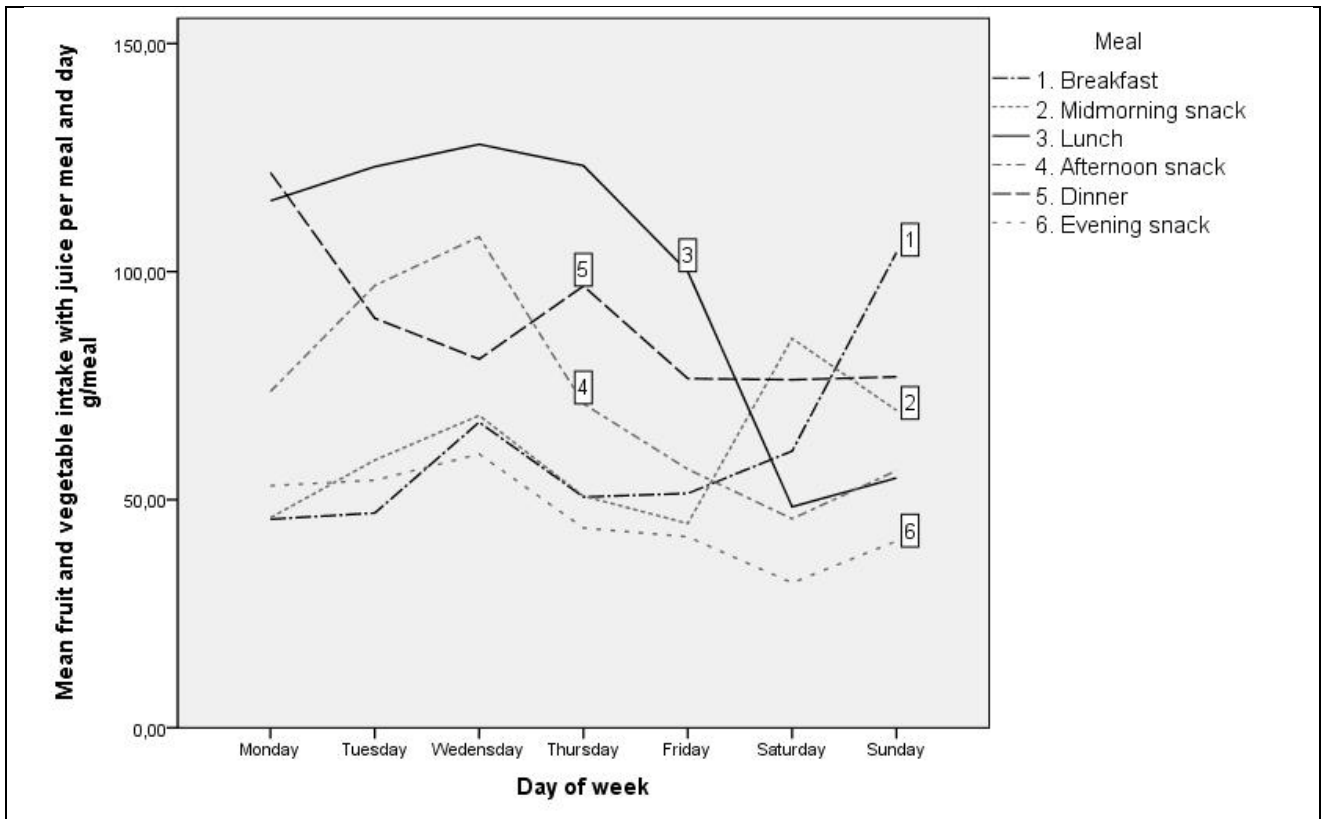


Figure 1. Intake of fruits and vegetables at different meals during the week (n=81).

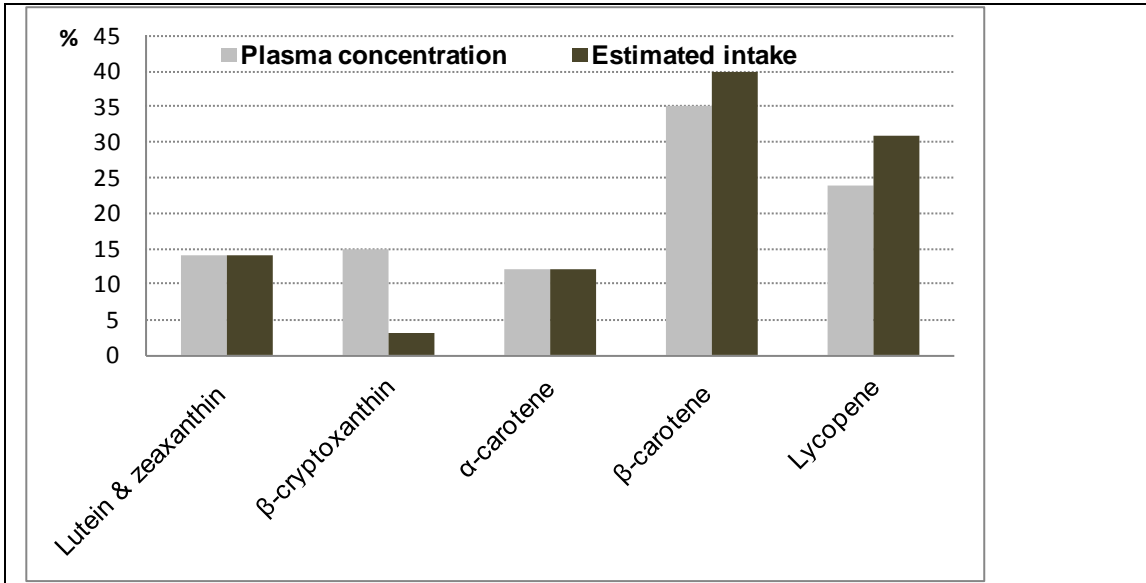


Figure 2. Relative contribution (%) of individual carotenoids to total carotenoid plasma concentration and total estimated carotenoid intake (n=81).

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