Aspects of energy intake assessment, dietary intake patterns and sleep duration in children

Berit Worm Rothausen
PhD Thesis
2012

DTU Food
National Food Institute

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Supervisors
Professor, Inge Tetens
Division of Nutrition
National Food Institute
Technical University of Denmark

Senior Advisor, Jeppe Matthiessen
Division of Nutrition
National Food Institute
Technical University of Denmark

Professor, Lene Frost Andersen
Department of Nutrition
Institute of Basic Medical Sciences
University of Oslo, Norway

Professor, Per Bruun Brockhoff
Department of Informatics and Mathematical Modeling
Technical University of Denmark

Evaluation Committee
Senior Scientist, Lone Banke Rasmussen
Division of Nutrition
National Food Institute
Technical University of Denmark

Researcher, Anne Lise Brantsæter
Department of food safety and nutrition
Division of Environmental Medicine
Norwegian Institute of Public Health

Associate Professor, Christine Dalgaard
Environmental Medicine
Institute of Public Health
University of Southern Denmark

Photo: Colourbox
ISBN: 978-87-92763-30-3

Division of Nutrition
National Food Institute
Technical University of Denmark
Mørkhøj Bygade 19
DK - 2860 Søborg

Table of contents

Preface and acknowledgements

The present PhD thesis is based on work carried out during my employment at the Department of Nutrition, National Food Institute, Technical University of Denmark, between 2008 and 2012. The data included in this thesis arise from two nutritional research studies: the Danish National Survey of Dietary Habits and Physical Activity 2003-2008 and the EFCOVAL (European Food Consumption Validation) study. The work was financially supported by the National Food Institute, Division of Nutrition and the Danish Veterinary and Food Administration.

Several people and in particular my supervisors Professor Inge Tetens, Senior Advisor Jeppe Matthiessen, Professor Lene Frost Andersen and Professor Per Bruun Brockhoff have contributed to this thesis in different ways with valuable advices and guidance. I especially wish to thank Inge Tetens, my main supervisor during the last period of my PhD study and Jeppe Matthiessen for their great encouragement, their dedication and always positive and constructive supervision, which have been invaluable to me. Furthermore, I wish to thank Lene Frost Andersen for her thoughtful input and experienced overview, Per Bruun Brockhoff for his helpfulness and expertise in statistical matters, and Senior Advisor Margit Velsing Groth for her support and care as my main supervisor during the first period of my PhD study.

Moreover, I am very grateful to Assistant Professor Camilla Hoppe for all her kindness and support and for our collaborations and far-reaching personal talks, which I have enjoyed very much, and to Deputy head of division Ellen Trolle for her commitment and always helpful assistance in the work with the EFCOVAL study. I also wish to thank Data Manager Karsten Kørup for his effort in relation to data clean up and data management, not least regarding all my work with these matters beyond what is included in this thesis. Furthermore, I would like to give my thanks to all my colleagues at Division of Nutrition for always being so welcoming and helpful and for making it such a pleasant place to work. Especially thanks to my great office mates (on/off during periods) PhD Ulla Holmboe Gondolf, PhD Sevil Alinia, Trine Holmgaard Nielsen, Mia Hjort Frandsen and Maj-Britt Gille for their friendship and room for sharing knowledge, laughs and big and small stuff in life.

Finally, a very special appreciation to my closest friends and particularly my dearly loved family for being my greatest support throughout all, and for all the wonderful love and joy they bring into my life every day.

Berit Worm Rothausen, April 2012

Abbreviations

24-HDR	24-Hour Dietary Recall
7-dFR	7-day pre-coded Food Record
ActiReg®	A position and motion sensor
AR	Acceptable Reporters
BMI	Body Mass Index (kg/m^2)
BMR	Basal Metabolic Rate
E%	Percentage of total energy
EE	Energy Expenditure
EI	Energy Intake
EFCOVAL	European Food Consumption Validation study
EFSA	European Food Safety Authority
FFQ	Food Frequency Questionnaire
FPQ	Food Propensity Questionnaire
g	Gram
HCP	Health Conscious Pattern
kJ	Kilojoule
MET	Metabolic Equivalent, expressing the energy cost of physical activities as multiples of BMR
MJ	Megajoule
n	Number of subjects
OR	Over-Reporters
P	P-value
PAL	Physical Activity Level
PCA	Principal Component Analysis
PP	Processed Pattern
r	Pearson correlation coefficient
SD	Standard Deviation
SFI	The Danish National Centre for Social Research (Det Nationale Forskningscenter for Velfærd, tidl. Socialforskningsinstituttet)
SSBs	Sugar sweetened beverages
UR	Under-Reporters
Z-score	A standard score indicating how many standard deviations an observation is above or below the mean

List of papers

This thesis is based on the work presented in the following four papers:

Paper I Rothausen BW, Matthiessen J, Groth MV, Brockhoff PB, Andersen LF, Trolle E. Comparison of estimated energy intake from 2x24-hour recalls and a 7-day food record with objective measurements of energy expenditure in children. *Food Nutr Res. 2012;56. doi: 10.3402/fnr.v56i0.12221*

Paper II Rothausen BW, Matthiessen J, Hoppe C, Andersen LF, Brockhoff PB, Tetens I. Differences in Danish children's diet quality on weekdays vs. weekend days. *Public Health Nutr. 2012 May 25:1-8*

Paper III Rothausen BW, Matthiessen J, Brockhoff PB, Andersen LF, Tetens I. Dietary patterns on weekdays and weekend days in 4-14 year-old Danish children. *Resubmitted 2012*

Paper IV Hoppe C, Rothausen BW, Biltoft-Jensen AP, Matthiessen J, Groth MV, Chaput J-P, Tetens I. Relationship between sleep duration, dietary intake and BMI in 4-14-year-old Danish children. *Submitted 2012*

The papers are referred to in the text as Paper I-IV and are reproduced in full as appendices.

Summary

Background

A healthy balanced diet throughout childhood is an important determinant for health and wellbeing and is a key factor in prevention of overweight and several chronic diseases. Knowledge about children's dietary habits is therefore an important public health issue, and valid and reliable dietary assessment methods for children are needed. Children's dietary intake on weekdays and weekend days and the relationship between sleep duration and diet have only been sparsely investigated and further insight into these aspects may be valuable for further research and public health initiatives.

Objectives

The specific objectives of the present thesis were: (i) to evaluate energy intake (EI) estimated with a 2x24-hour recall method (2x24-HDRs) and the 7 day pre-coded food record (7-dFR) used in the Danish National Survey of Dietary Habits and Physical Activity 2003-2008 in children (Paper I); (ii) to compare children's diet quality on weekdays (Monday-Thursday), Fridays and weekend days (Saturday-Sunday) (Paper II); (iii) to investigate their dietary intake patterns on weekdays and weekend days (Paper III); and (iv) to examine the relationship between sleep duration, BMI and food and nutrient intake in children (Paper IV).

Methods

EI estimated with 2x24-HDRs and the 7-dFR was evaluated by comparison with energy expenditure (EE) assessed using ActiReg® (PreMed AS, Oslo, Norway), a combined position and motion recording instrument. The study was conducted as part of the EFCOVAL (European Food Consumption Validation) study and included children in the age of 7-8 years (n=67) and 12-13 years (n=64). The analyses for Paper II-IV were based on data from the Danish National Survey of Dietary Habits and Physical Activity 2003-2008 and were conducted for the three age groups 4-6, 7-10 and 11-14 years. Diet quality was assessed by use of indicator variables and the unit g/10MJ, while dietary intake patterns were identified by use of Principal Component Analysis (n=784). The relationship between sleep duration, BMI and food and nutrient intake was assessed by Spearman's correlation coefficient and multiple linear regression analysis (n=802).

Results

Compared to EE, EI was overestimated by 3% with the 2x24-HDRs (P=0.126) and underestimated by 7% with the 7-dFR (P=0.001) in the 7-8 year-old children. In the 12-13 year-old children, EI was underestimated by 10% with the 2x24-HDRs (P<0.001) and by 20% with the 7-dFR (P<0.001). The Pearson correlation coefficients between EI and EE were 0.48 for $EI_{2x24\text{-}HDR}$ and 0.32 for $EI_{7\text{-}dFR}$ in the 7-8 year-olds, and 0.48 for $EI_{2x24\text{-}HDR}$ and 0.37 for $EI_{7\text{-}dFR}$ in the 12-13 year-olds. The proportion of children classified in the same or adjacent quartiles was 76% for $EI_{2x24\text{-}HDR}$ and 73% for $EI_{7\text{-}dFR}$ in the 7-8 year-olds, and 83% for $EI_{2x24\text{-}HDR}$ and 70% for $EI_{7\text{-}dFR}$ in the 12-13 year-olds.

For both genders in all three age groups, EI was consistently higher on weekend days than on weekdays. Moreover, intake of sugar-sweetened beverages and white bread was higher, whereas intake of rye bread was lower. This is in accordance with the findings of a higher percentage of energy from added sugars, a lower fibre content and a higher energy density of the diet on weekend days than on weekdays. In children aged 4-6 and 7-10 years, the diet on weekend days was also characterised by higher intakes of sweets and chocolate and lower intakes of fruit and vegetables (P<0.05). Overall, the diet on Fridays appeared as a mix of the diets on weekdays and weekend days. Two dietary patterns

labelled “processed” and “health conscious” emerged consistently on both weekdays and weekend days. Factor scores from corresponding dietary patterns were significantly correlated between weekdays and weekend days with exception of the “health conscious” pattern in the 7-10 year-olds. Children with high agreement for the “processed” pattern had a higher intake of sugar sweetened beverages, lower intakes of fruit and vegetables and a higher dietary energy density compared to children with high agreement for the “health conscious“ pattern ($P<0.05$). Moreover, these variables indicated that the actual dietary intake on weekend days was less healthy compared to week days for both patterns.

Sleep duration and BMI was negatively correlated ($P<0.001$). In multiple linear regression analyses, sleep duration was not associated with energy intake (beta=-0.044, P=0.097), but solely with intake of vegetables (beta=0.057, P=0.027), dietary fibre (beta=0.054, P=0.041) and liquid “empty calories” (beta=-0.055, P=0.035).

Conclusions

Misreporting of EI seemed modest at group level both with the 2x24-HDRs and the 7-dFR in the 7-8 year-old children, whereas under-reporting appeared to be more evident in the 12-13 year-olds, especially with the 7-dFR. Overall, the 2x24-HDRs performed slightly better than the 7-dFR in terms of ranking of individuals according to EI. However, there are other aspects than EI that should be taken into consideration in the overall evaluation of the two methods, for example that the higher EI with the 2x24-HDRs mainly comprised higher intakes of healthy foods compared to the 7-dFR. Further developments and refinements of dietary assessment methods are especially needed for older children and adolescents.

For both genders in the three age groups, average EI and energy density of the diet were consistently higher on weekend days than on weekdays. The diet quality appeared to be lower on weekend days compared to weekdays and to be at an intermediate level on Fridays. The dietary pattern analyses suggest that children tend to maintain the same overall dietary patterns in weekdays and weekends, although the actual dietary intake is generally less healthy during weekends. These findings indicate that more focus on the differences between weekdays and weekend days regarding EI and key variables, such as fruit and vegetables and foods high in added sugars, could prove useful for enhancing public health initiatives, especially regarding children with less healthy dietary patterns.

Sleep duration was negatively correlated with BMI. However, sleep duration was not associated with energy intake and the conception that children with short sleep duration have less healthy eating habits than children with longer sleep duration was only weakly supported by the present findings. More research is required to understand better the implications of chronic short sleep duration on appetite and energy balance, and whether strategies to improve sleep can influence appetite control and risk for weight gain.

Sammenfatning (Danish summary)

Baggrund

En sund og varieret kost gennem barndommen er en vigtig determinant for sundhed og trivsel og er en betydningsfuld faktor i forebyggelsen af overvægt og en række kostrelaterede sygdomme. Viden om børns kostvaner er derfor et vigtigt folkesundhedsmæssigt aspekt, og der er behov for at have valide og pålidelige kostregistreringsmetoder. Børns kostindtag på hverdage og weekenddage samt sammenhængen mellem søvnlængde og kost er kun undersøgt i begrænset omfang, og bedre indsigt i disse aspekter kan være værdifuld i videre forskningsøjemed og for sundhedsfremme.

Formål

De specifikke formål med nærværende afhandling var: (i) at evaluere energiindtag (EI) estimeret med en 2x24-timers recall metode (2x24-HDRs) og den 7-dages præ-kodede kostdagbog, der er anvendt til børn i Den nationale undersøgelse af danskernes kostvaner og fysiske aktivitet 2003-2008 (Paper I), (ii) at sammenligne børns kostkvalitet mellem hverdage (mandag-torsdag), fredage og weekenddage (lørdag-søndag) (Paper II), (iii) at undersøge deres kostmønstre på hverdage og weekenddage (Paper III), samt (iv) at undersøge sammenhængen mellem søvnlængde, BMI og kostindtag blandt børn (Paper IV).

Metoder

EI estimeret med 2x24-HDRs og med kostdagbogen blev evalueret ved sammenligning med energiforbrug (EE) målt ved hjælp af ActiReg® (PreMed AS, Oslo, Norway), en kombineret positions- og bevægelsessensor. Undersøgelsen blev udført som en del af EFCOVAL (European Food Consumption Validation) studiet og inkluderede børn i alderen 7-8 år (n=67) og 12-13 år (n=64). Analyserne til Paper II-IV blev baseret på data fra Den nationale undersøgelse af danskernes kostvaner og fysiske aktivitet 2003-2008 og blev udført for de tre aldersgrupper 4-6, 7-10 og 11-14 år. Kostkvaliteten blev undersøgt ved hjælp af indikatorvariable og enheden g/10MJ, mens kostmønstre blev identificeret ved hjælp af Principal Komponent Analyse (n=784). Sammenhængen mellem søvnlængde, BMI og kostindtag blev analyseret ved hjælp af Spearmans korrelationskoefficient og multiple lineære regressionsanalyser (n=802).

Resultater

I forhold til EE blev EI overestimeret med 3% med 2x24-HDRs (P=0.126) og underestimeret med 7% med kostdagbogen (P<0.001) blandt de 7-8 årige børn. Blandt de 12-13 årige børn blev EI underestimeret med 10% med 2x24-HDRs (P<0.001) og med 20% med kostdagbogen (P<0.001). Pearson korrelationskoefficienterne mellem EI and EE var 0.48 for $EI_{2x24\text{-}HDR}$ og 0.32 for $EI_{kostdagbog}$ blandt de 7-8 årige, og 0.48 for $EI_{2x24\text{-}HDR}$ og 0.37 for $EI_{kostdagbog}$ blandt de 12-13 årige. Andelen af børn, der blev klassificeret i de samme eller tilstødende kvartiler, var 76% for $EI_{2x24\text{-}HDR}$ og 73% for $EI_{7\text{-}dFR}$ blandt de 7-8 årige, og 83% for $EI_{2x24\text{-}HDR}$ og 70% for $EI_{kostdagbog}$ blandt de 12-13 årige.

For begge køn i alle tre aldersgrupper var EI højere på weekenddage end på hverdage. Indtag af sukkersøde drikke og hvidt brød var ligeledes højere, hvorimod indtag af rugbrød var lavere. Dette er i overensstemmelse med, at der var en højere energiprocent fra tilsat sukker, et lavere fiberindhold og en højere energitæthed i kosten på weekenddage i forhold til hverdage. Blandt børn i alderen 4-6 og 7-10 år var kosten også karakteriseret af højere indtag af slik og chokolade og lavere indtag af frugt og grønt (P<0.05). Overordnet set fremstod kosten på fredage som en blanding af kosten på hverdage og weekenddage.

To kostmønstre kaldet "processed" og "health conscious" blev konsekvent fundet på både hverdage og weekenddage. Factor scores fra enslydende kostmønstre var signifikant korreleret mellem hverdage og weekend dage med undtagelse af "health conscious"-mønstret blandt de 7-10 årige. Børn med højt tilhørsforhold til "processed"-mønstret havde et højere indtag af sukkersøde drikke, lavere indtag af frugt og grønt og en kost med højere energitæthed i forhold til børn med højt tilhørsforhold til "health conscious"-mønstret ($P<0.05$). Derudover indikerede disse variable, at det absolutte kostindtag var mindre sundt på weekenddage end på hverdage for begge kostmønstre.

Søvnlængde og BMI var negativt korrelerede ($P<0.001$). I multiple lineære regressionsanalyser var søvnlængde ikke associeret med energiindtag (beta=-0.044, P=0.097), men udelukkende med indtag af grøntsager (beta=0.057, P=0.027), kostfibre (beta=0.054, P=0.041) og sukkersøde drikke.

Konklusioner

Fejlrapportering af EI syntes at være begrænset både med 2x24-HDRs og kostdagbogen blandt de 7-8 årige børn, hvorimod under-rapportering var mere fremtrædende blandt de 12-13 årige, særligt med kostdagbogen. Generelt var 2x24-HDR metoden en anelse bedre end kostdagbogen til at rangordne individer efter EI. Der er imidlertid andre aspekter end EI, der bør tages i betragtning i en overordnet evaluering af de to metoder, bl.a. at det højere EI med 2x24-HDRs hovedsageligt dækkede over højere indtag af sunde fødevarer i forhold til kostdagbogen. Der er endvidere særligt behov for videreudvikling og forbedring af kostregistreringsmetoder til større børn og unge.

For begge køn i de tre aldersgrupper var det gennemsnitlige EI og kostens energitæthed højere på weekenddage end på hverdage. Kostkvaliteten blev fundet at være lavere i weekenden end på hverdage, og på et mellemliggende niveau på fredage. Kostmønsteranalyserne peger på, at overordnede kostmønstre fastholdes mellem hverdage og weekenddage, til trods for at det absolutte kostindtag generelt er mindre sundt i weekenden. Disse resultater indikerer, at mere fokus på forskellene mellem hverdage og weekenddage vedrørende EI og nøglevariable, som frugt og grønt og fødevarer med højt indhold af tilsat sukker, kan vise sig gavnlig i ernæringsoplysning, især i forhold til børn med mindre sunde kostmønstre.

Søvnlængde var negativt korreleret med BMI, men søvnlængde var ikke associeret med energiindtag, og de foreliggende resultater støtter kun til dels opfattelsen af, at kort søvnlængde er associeret med mindre sunde kostvaner. Der er brug for yderligere forskning for at opnå bedre forståelse af implikationerne af kort søvnlængde over lange perioder for appetit og energibalance, og for i hvilket omfang strategier til at forbedre søvn kan påvirke appetitkontrol og risiko for vægtøgning.

1. Introduction

A healthy balanced diet throughout childhood is an important determinant for health and wellbeing and is a key factor in prevention of overweight, obesity and several chronic diseases (WCRF/AICR 2007; WHO 2003). Childhood is a stage of life where multiple physiological and psychological changes take place, and children represent a special population group with regard to nutrition. Because they are growing, children have relatively high nutritional requirements, and younger children especially are reliant on parents and care givers for many of their choices of food. Moreover, childhood is considered as a formative period of life where habits and preferences are established, and the development and maintenance of healthy dietary behaviours is therefore of great importance (Ovesen et al. 2004).

Overall, the dietary intake of children in Denmark and other Western countries gives reason for concern. Compared to food based dietary guidelines and nutritional recommendations, the diet of many children are generally characterised by too low an intake of fruit, vegetables and fish, whereas intake of foods high in added sugars and fat is too high (Pedersen et al. 2010; Elmadfa et al. 2009). Moreover, the increasing prevalence of childhood overweight and obesity has become a significant public health challenge (Matthiessen et al. 2008a; Lytle 2012; Reilly 2006). Not only do overweight and obesity tend to track from childhood into adulthood and thereby increase the risk of subsequent morbidity and mortality (Singh et al. 2008), childhood obesity is also associated with early markers of adult disease such as raised cholesterol and triglycerides levels, hypertension and impaired glucose tolerance (Lobstein et al. 2006). Independently of the weight status of the children, improved nutrition is a vital factor in promoting health and development in children, thus, there is an obvious need to address this issue.

Sleep duration in childhood is another aspect related to diet and health because the adequacy of sleep duration may have an impact on weight regulation, possibly through an effect on appetite regulation and eating patterns (Knutson et al. 2012; Kim et al. 2011). In several studies, an association between short sleep duration and increased adiposity has been observed in children and adolescents (Patel et al. 2008; Cappuccio et al. 2008). However, the relationship between sleep and diet is a rather new area in nutritional science and has not been fully explored.

1.1 Dietary assessment in children

Population-wide information on food and nutrient intake in children is essential for several purposes including monitoring of nutritional status, evaluating the effectiveness of public health interventions and research on associations between diet and health. It is therefore important to obtain valid and reliable data on dietary intake and determinants for dietary behaviour. It is well acknowledged that no method is suitable for all research purposes. Each method has notable strengths and limitations to be considered, and the most appropriate method will depend on several factors such as the objectives of the study, the type of data required, the available resources and the population of interest (Andersen et al. 2011).

Overall, the assessment of dietary intake is complex and presents special methodological challenges in children (Livingstone et al. 2004). Depending on their age and cognitive developmental stage, children may lack sufficient knowledge of food, have memory constraints and limited abilities to accurately describe their dietary intake (Thompson & Subar 2008). Furthermore, it is generally difficult to estimate portion sizes properly for children (Frobisher & Maxell 2003). Depending on the age of the child, parents need to assist with supplementary information, and it is generally suggested that children up to at least 8-10 years of age need support from their parents to complete a dietary assessment (Livingstone 2004; McPherson et al. 2008). Children often spend many hours away from home, and although parents may provide accurate records of what their children consume at home, recording of out-of-home consumption can be difficult. Therefore, information about what has been consumed may sometimes be needed from caregivers or teachers as well (EFSA 2009).

The commonly used methods in national surveys in European countries are food records and dietary recalls, some supplemented by food frequency questionnaires (FFQs) or food propensity questionnaires (FPQs) (Merten et al. 2011). Although most European countries conduct national food consumption surveys, the availability of high quality and comparable food consumption data is limited by the differing methods and design of the existing surveys (de Boer et al. 2011a; Elmadfa et al. 2009). However, efforts to obtain more comparable methods for national surveys have been made, for example the EFCOVAL (European Food Consumption Validation) study (Andersen et al. 2011; de Boer et al. 2011a) that aimed to develop and evaluate a trans-European dietary assessment methodology, and the Nordic Monitoring of Diet and Physical Activity project to establish a common, Nordic monitoring system on diet, physical activity and overweight (Fagt et al. 2009).

1.1.1 Food records

In Denmark, the national cross-sectional survey called the Danish National Survey of Dietary Habits and Physical Activity has used a 7-day pre-coded food record since 1995. Food records, also known as food diaries, provide a prospective description of foods and beverages consumed. Each day during a specified number of days, often 3-7 days, respondents record detailed information about their dietary intake in a structured food record, which is filled out concurrently with actual intake or at the end of each day. Food records may include pre-coded response categories combined with open answer options to facilitate a detailed and precise recording including brand names and food preparation methods. For weighed food records, the amounts consumed are weighed using a scale, whereas for estimated food records, like the one used in the Danish National Survey of Dietary Habits and Physical Activity, portion sizes are estimated in household measures or by use of pictures (Thompson & Subar 2008).

By recording dietary intake close to the time of consumption, recall bias may be reduced. Furthermore, food records over several days, preferably including both weekdays and weekend days, can potentially be used to provide estimates of actual or usual intake at the individual level. Among the limitations are that the method imposes a large participation burden, and the respondents therefore must be literate and motivated. This may introduce selection bias and an over-representation of more highly educated and health conscious individuals. Moreover, the dietary intake may be influenced during the recording period by the demands of providing detailed dietary records during several days, which may increase the risk of underreporting (EFSA 2009). Additionally, some of the respondents may be motivated by the participation and awareness of their diet to lower their dietary intake in order to lose weight.

1.1.2 24-hour dietary recalls

The 24-hour dietary recall (24-HDR) approach is a retrospective method in which the respondents are asked to report, describe and estimate the quantities of all foods and beverages consumed during the preceding 24 hours or the preceding day. The recall is often a computer assisted interview conducted by a trained interviewer in person or by telephone. The interviewer records descriptions of the dietary intake through a structured approach with specific probing questions to help the respondent remember and describe all foods consumed throughout the day (Thompson & Subar, 2008). Like food records, portion sizes are estimated in household measures or by use of pictures.

The major advantages of using 24-HDRs are that the method is relatively quick, does not require literacy and is less burdensome for the respondents than completing a food record. The recordings are open-ended, and a personal interview with probing questions may help to keep the children´s attention and allows for recording of rich details on recipes, brand names and food preparation methods. Limitations of the 24-HDR method include that it relies on memory, and especially for children, it can be difficult to distinguish between what they usually consume and what they consumed yesterday. This may lead to omissions and intrusions (foods reported, but not actually eaten) (Baxter et al. 2009). Furthermore, the interview situation may influence the reporting of children as well as assisting parents towards giving more socially desirable answers. In addition, it is critical to have well-trained interviewers with thorough knowledge about foods and nutrition in order to obtain the most optimal information during the interview (Thompson & Subar 2008).

A single 24-HDR per individual can be used to characterize the average dietary intake at group level, however, it has limited ability to capture usual consumption at the individual level. It is therefore recommended to conduct at least two non-consecutive 24-HDRs and to supplement the 24-HDR data with additional information from a food frequency questionnaire (FFQ) or a food propensity questionnaire (FPQ) (Subar et al. 2006; EFSA 2009). When two or more non-consecutive 24-HDRs are available, the within-subject variability can be reduced by statistical methods, and the intake frequencies from the FFQ or FPQ can be used to estimate individual usual intake of episodically consumed foods and their distributions (Souverein et al. 2011; Harttig et al. 2011; Haubrock et al. 2011).

Collection of dietary intake data on non-consecutive days is generally preferred, because their independence allow the capture of a better estimate of the existing intra-individual variability than consecutive records. (Thompson & Subar 2008; EFSA 2009). This is especially relevant when using statistical methods to reduce intra-individual variance of intake, as these rely on a hypothesis of independence between the different days. Whereas it is relatively easy to collect data on non-consecutive days when using a 24-HDR method, the inclusion of independent days in a food record method is often more complicated and expensive (EFSA 2009).

1.1.3 Food frequency questionnaires

FFQs are questionnaires used in order to assess the frequency with which food groups are consumed during a specified time period, typically the past month or year. The FFQ method is often used in nutritional studies because it is relatively inexpensive and easy to administer and process. However, the appropriateness of the food list is crucial in the food frequency method, and it can be challenging to develop a FFQ that includes enough but not too many food items so all respondents may provide the right answers without being encouraged to overestimate. Moreover, since respondents are required to report their average frequencies and portion sizes over a long period of time, FFQs are generally cognitively difficult to complete, especially for children (Thompson & Subar 2008). FPQ is a recently developed dietary assessment tool for use in combination with data from multiple 24-HDRs. Much of the same information is collected with FPQs as with FFQs, but without information about portion sizes (Subar et al. 2006).

1.2 Evaluation of dietary assessment methods

Dietary assessment methods used in nutritional epidemiology typically rely on self-reported information, and although there are several approaches to the assessment of dietary intake, the validity and reliability of dietary intake data are inherently challenged by methodological issues. Misreporting of dietary intake is a well-recognised and pervasive problem in studies of children as well as adults (Forrestal et al. 2011; Poslusna 2009). This is of concern for the evaluation of food and nutrient intake as well as for the assessment of associations between dietary intake and health. Validation of new dietary assessment methods is therefore required. Validity of a dietary method describes the degree to which the method measures the true intake of what it was intended to measure during the study period (Livingstone & Black 2003). The average long-term intake is the key objective of many dietary assessments, but usual intakes of individuals may be one of the most challenging aspects to validate, because the "true" usual intake is never known with absolute certainty.

Dietary assessment methods have often been evaluated at group level by relative validation, whereby a dietary assessment method is compared against another similar method (Livingstone 2004). However, most dietary assessment methods are subject to some of the same errors, such as recall bias, and high agreement between two methods may be due to a high level of agreement in the errors (McPherson et al. 2008). It is therefore important to evaluate dietary assessment methods against objective measures, which do not suffer from errors in self-reporting. While some biomarkers of intake are available for energy intake (EI) and food groups, the use of biomarkers is generally expensive, invasive and limited in terms of the reflection of wider aspects of dietary intake (Thompson et al. 2010).

EI is a single measure that covers the whole dietary intake and evaluation of EI by comparison with estimates or measures of total energy expenditure (EE) has been widely used in order to assess the overall validity of dietary reporting (Livingstone & Black 2003). This approach is based on the assumption that EI and EE are equivalent under conditions of energy balance. The doubly labelled water (DLW) method is considered to be the gold standard reference method for validation of estimates of EI because it provides the most accurate measure of EE in free-living subjects (Ainslie et al. 2003). However, the cost of and requirements for highly specialised analytical laboratory equipment with the DLW method precludes its use in many studies. Furthermore, urine collection is required from the respondents, which is burdensome especially in children.

Estimates of total EE can also be determined by more feasible and cost-effective ways, for example by applying an estimate of physical activity level (PAL) to the basal metabolic rate (BMR) estimated from equations. Preferably, physical activity is assessed by the use of physical activity monitors, such as ActiReg®, Sensewear Armband or other instruments (Arvidsson 2009). Although motion sensors do not provide perfect measures for physical activity or energy expenditure, they eliminate the subjectivity of self-reported physical activity and are not likely to have correlated errors with the dietary assessment methods.

1.2.1 Identification of misreporters

Another approach in the assessment of misreporting is to determine the prevalence of misreporters. Exact agreement between EI and EE at the individual level is unlikely during a short recording period due to random day-to-day variation in both EI and in EE. Therefore, when evaluating EI against EE, a range of values must be considered, above or below which the reported intake is unlikely to represent either habitual intake or random high or low intake. When objective measurements of EE are available, the proportion of misreporters is usually assessed using the 95% confidence limits of agreement between EI and EE at the individual level (Livingstone et al. 2003). This approach classifies respondents as acceptable reporters, under-reporters, or over-reporters according to whether the individual's EI:EE ratio lies within, below or above the 95% confidence limits of agreement.

If no objective measurements of EE are available, EI must be evaluated against presumed energy requirements. Most often a hypothesis of a sedentary or light activity level has been set for the overall sample. This procedure, known as the Goldberg cut-off criterion is the most widely used method to identify misreporters (Goldberg et al. 1991; Black 2000). It was originally developed for use in adults, but has been applied to children due to the lack of other standardised methods for children (Lioret et al. 2011). Although the Goldberg cut-off has been further adapted for use in children by taking age- and gender-specific values for physical activity into account, cut-offs based on assumed PAL values for groups of children should be applied with caution in the evaluation of EI (Livingstone et al. 2003).

1.3 Danish children's dietary intake on weekdays and weekend days

It has been suggested that family factors and the nature of foods available at home, in schools and in fast-food establishments are some of the most significant determinants of the eating habits of children (Taylor et al. 2005). In this context, weekdays and weekend days differ in many ways, both structurally and culturally, which may influence the dietary intake patterns, for example through more access to foods and snacks, combined with likely expectations of fewer restrictions on weekend days than during weekdays (Iversen et al. 2011). Periods of holidays and summer vacations have been associated with increases in weight status in children (von Hippel et al. 2007) and similar differences may apply on a smaller scale to weekends.

Previous research from other countries has suggested that children's snacking and other daily dietary habits differ on weekdays compared to weekend days (Andersen et al. 2003; Hart et al. 2011; Cullen et al. 2002). Moreover, Friday stands out as a weekday, on which the diet may resemble both weekdays and weekend days in terms of diet quality, since breakfast and lunch might follow a "weekday pattern" whereas the rest of the day might be characterised by "weekend habits" with more focus on the palatability and pleasure of eating than nutritional concerns. These differences may have an impact on overall diet quality and may be of importance for total energy balance. Although it is a general notion in daily life that dietary intake differs between weekdays and weekend days, few studies have specifically investigated this.

1.3.1 Dietary intake patterns

There are no simple, well-accepted criteria to classify diets as either "healthy" or "unhealthy". Different approaches and methods can however be used to describe and evaluate dietary intake depending on the aspects of interest and the quality of available data. Dietary patterns can be derived through a hypothesis-driven *a priori* approach or an empirical, data-driven *a posteriori* approach. *A priori* defined dietary patterns are based on previous knowledge regarding diet–disease relationships and how well individuals comply with nutritional recommendations and/or dietary guidelines. By contrast, the *a posteriori* approach refers to the use of multivariate statistical methods in order to identify "sets" of dietary habits, in which way the available data determine the patterns (Bountziouka et al. 2011; Michels & Schulze 2005).

A range of dietary indices has been developed to evaluate overall diet quality, for example the Healthy Eating Index-2005 (Guenther et al. 2008) and the Diet Quality Index (Newby et al. 2003). Since dietary indices reflect rather specific aspects of the diet they may offer valuable information that is simple and comprehensible (Lazarou et al. 2011; Michels & Schulze 2005). While dietary indices have been widely used in adult populations, the use of indices in children has been more limited (Lazarou et al. 2011). The development of indices is a demanding process which includes a large degree of subjectivity in terms of defining the scoring system with differentiated weighting of different food items. Moreover, an index developed for one study will depend on that type of data and may not be applicable for other studies.

A more simple approach to obtain an indication of the diet quality is to focus on indicator variables, and a set of indicator variables has been developed and validated in the Nordic Monitoring Project (Fagt et al. 2009). Analyses have shown that certain food groups in particular explain a considerable proportion of the variation in the relative content of total fat, saturated fat, added sugars and dietary fibre in the diet, and thus the overall nutritional quality of the diet (Sepp et al. 2004). Consideration of the intake of these food groups is therefore especially valuable.

Another indicator of diet quality is the energy density, which is a measure of the amount of energy provided per unit weight of a food item or a diet, i.e. kJ/100g. In general, foods higher in fat, added sugars or starch, for example fats and fastfood, typically have a high energy density, whereas foods high in water, for example fruits and vegetables, typically have a lower energy density (WHO 2003). In line with this, a diet with low energy density is likely to be characterised by a relatively high content of dietary fibre and a relatively low content of total fat and added sugars. Previous studies have shown an inverse association between energy density and overall dietary quality in children (Patterson et al. 2010) as well as in adults (Ledikwe et al. 2006a). The World Health Organization has stated that there is convincing evidence that a high intake of energy-dense foods promotes weight gain and overweight (WHO 2003). Energy density therefore seems useful as a simple indicator of overall diet quality and of relevance in relation to energy balance and prevention of overweight. Currently, the World Cancer Research Foundation and the American Institute for Cancer Research recommend that the average energy density of diets should be lowered towards approximately 525 kJ/100g excluding beverages at population level (WCRF/AICR 2007).

The use of statistical methods to define dietary patterns in a population has facilitated more extensive analyses of dietary intake, and among the data-driven methods, principal component analysis (PCA) is one of the most commonly used methods (Slattery et al. 2010; Tucker et al. 2010). PCA allows inclusion of many food items and uses the correlations between a large number of variables to identify underlying dimensions in the data. On the basis of the included food groups, PCA creates principal components, i.e. dietary patterns, according to the combination of foods that are consumed together. The dimensionality of the data is thus reduced while as much as possible of the relevant information is retained (Eriksson et al. 2006). Other commonly used methods include cluster analysis, which aggregates individuals into mutually exclusive clusters with similar characteristics in dietary intake, and reduced rank regression, which identifies dietary patterns associated with selected response variables, i.e. nutrients or biomarkers that have known relations with a disease outcome of interest (Tucker et al. 2010).

Although the use of PCA has been applied most widely in studies of adult populations, several dietary studies have investigated PCA derived dietary patterns in children and the associations of these patterns with various outcomes such as weight status and socio-economic indicators (Oellingrath et al. 2010; Lioret et al. 2008; Craig et al. 2010). Furthermore, PCA has been used to assess the stability of dietary patterns over time during childhood as well as in adulthood (Oellingrath et al. 2011; Northstone et al. 2008; Crozier et al. 2009; Borland et al. 2008).

1.4 Sleep duration and dietary intake

It is well recognised that adequate sleep duration is crucial for wellbeing and cognitive performance (Hart et al. 2005; Wolfson & Carskadon 2003), and in recent years, the potential metabolic implications of inadequate sleep duration have received increasing attention. Evidence from experimental and observational studies suggests that inadequate sleep may play a role in the risk of development of overweight and obesity as well as in vulnerability to associated diseases, such as diabetes and cardiovascular disease (Knutson et al. 2012).

Several observational studies have demonstrated an increased risk of overweight or obesity associated with short sleep durations in infants (Taveras et al. 2008), children and adolescents (Danielsen et al. 2010; Patel et al. 2008; Garaulet et al. 2011) and adults (Cappuccio et al. 2008; Chaput et al. 2008). In two meta-analyses it was concluded that short sleep duration is associated with an increased risk of obesity in children (Chen et al. 2008; Cappuccio et al. 2008). Furthermore, a few studies have demonstrated a longitudinal association between short sleep duration in childhood and higher body weight (Silva et al. 2011; Carter et al. 2011; Magee & Hale 2011).

Increased energy intake appears to be the most plausible explanation as to why short sleepers have a higher risk of becoming overweight or obese. However, the relationship between sleep duration and dietary intake has been sparsely investigated (Westerlund et al. 2009; Landis et al. 2009) and little is known about the relationship between sleep duration, BMI and dietary intake in Danish children.

2. Aim and objectives

The overall aim of the work presented in this thesis was to examine various aspects of dietary intake in Danish children, and to contribute with new knowledge concerning diet and health related issues in children.

The specific objectives of the four papers included in the present thesis were:

- to evaluate energy intake estimated with the 2x24-hour recall method from the EFCOVAL study, and the 7 day pre-coded food record used in the Danish National Survey of Dietary Habits and Physical Activity 2003-2008 against energy expenditure estimated using ActiReg® measurements in children aged 7-8 years and 12-13 years (Paper I)

- to compare differences in diet quality on weekdays (Monday-Thursday), Fridays and weekend days (Saturday-Sunday) in 4-14 year-old children by use of indicator variables (Paper II)

- to investigate dietary patterns on weekdays (Monday-Thursday) and weekend days (Saturday-Sunday) in 4-14 year-old children by use of Principal Component Analysis (Paper III)

- to examine the relationship between sleep duration, BMI and food and nutrient intake in children aged 4-14-years (Paper IV)

3. Methods

This section contains a summary of the design and methods of the four papers included in this thesis. Further details of the methods can be obtained from the individual papers in the appendix.

3.1 Evaluation of estimated energy intake (Paper I)

Paper I is based on a method comparison study conducted as part of the EFCOVAL (European Food Consumption Validation) study. One of the main objectives of the EFCOVAL study was to develop and evaluate a trans-European methodology to be used for estimating the intake of foods, nutrients and potentially hazardous chemicals in representative dietary surveys in children (de Boer et al. 2011a). The method suggested for children 7-14 years of age was two non-consecutive 24-hour recalls (2x24-HDRs) using the EPIC-Soft computer program combined with a food recording booklet (Andersen et al. 2011; Slimani et al. 2011). A relative validation of the suggested 2x24-HDR method was performed against the 7-day pre-coded food record (7-dFR) used in the Danish National Survey of Dietary Habits and Physical Activity 2003-2008. Results from this study regarding food and nutrient intake are presented elsewhere (Trolle et al. 2011).

In Paper I, EI estimated with the 2x24-HDRs and the 7-dFR was evaluated by comparison with EE assessed by use of ActiReg® (PreMed AS, Oslo, Norway) (Hustvedt et al. 2004), a combined position and motion recording instrument, in Danish children aged 7-8 years and 12-13 years. Participants were recruited through the Central Office of Civil Registration, using a random sample, stratified by age, from the Capital region of Denmark.

3.1.1 Study design

Participation included completion of two non-consecutive 2x24-HDRs, a pre-coded 7-dFR, and objective assessment of EE by use of ActiReg® during the same 7 days as the 7-dFR was filled in. A flow chart of the measurements of dietary intake and energy expenditure is presented in Figure 1. Trained interviewers visited the participants at their homes and conducted the recalls on two scheduled visits. Height and weight measurements of the children were made after the recall at the first visit. The recalls were aimed to be separated by 4 to 6 weeks. All days of the week were randomly assigned for both recalls in order to obtain an equal representation of weekdays at group level. For each participant, completion of both recalls and a minimum of 4 valid days with concurrent measurements from the 7-dFR and ActiReg® were required for inclusion in the analyses.

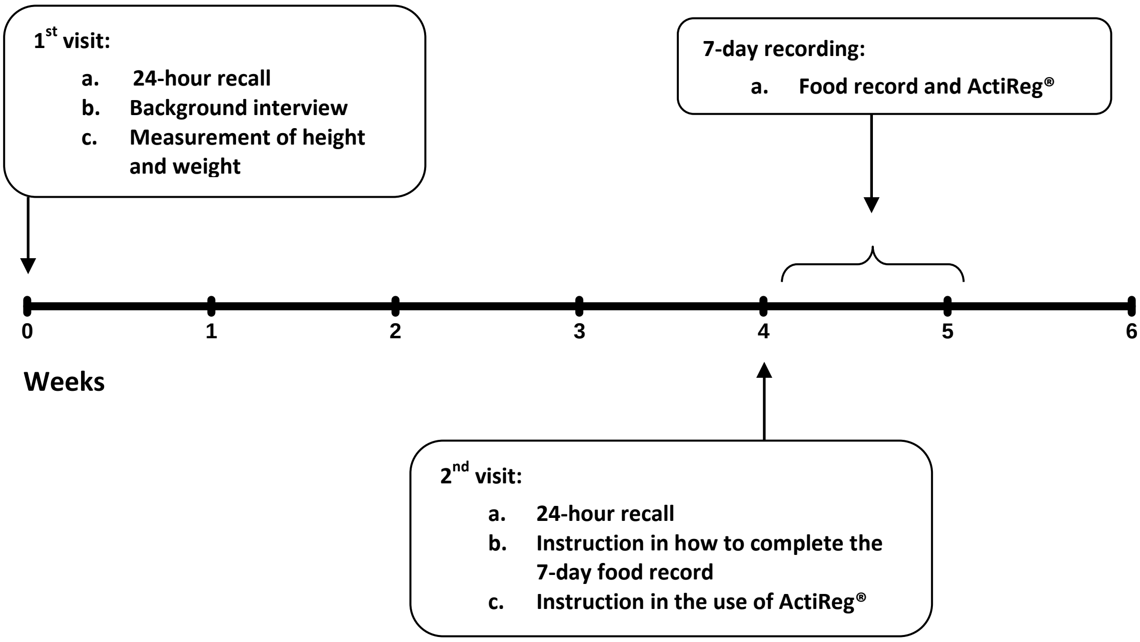

Figure 1. Flow chart of the measurements of dietary intake, energy expenditure and anthropometry

3.1.2 Dietary assessment

The 2x24-HDRs were based on face-to-face computer-assisted interviews using the standardised recall interview program EPIC-Soft (Slimani et al. 2011), which comprised four main steps: 1) General information (non-dietary), 2) Quick list (chronological list of consumed foods without quantification), 3) Description and quantification of foods and recipes, and 4) Quality controls at nutrient level. One of the parents was present during the interviews and assisted with supplementary information when necessary (description of food intake, information about recipes, cooking methods etc.). The responding parent was the mother in 92% of the recalls. The EPIC-Soft version employed was a country-specific version, updated prior to the study in order to cover new food items and to meet the specific requirements of this study.

Participants received a food recording booklet for the children to take to school or to other places outside their home on the days of assessment, i.e. the day before each recall. If relevant, proxy persons (school staff, day care staff, or others) were contacted in advance and asked to help the children with the booklet. The quantities of consumed foods were estimated from predefined household measures (cups, spoons, slices, etc.) or photos from the EPIC-Soft picture book containing 125 sets of pictures with different portion sizes. In addition, some country specific pictures series on candy, rye- and wheat bread, and fat and filling on bread was used. The mean EI/day from the 2x24-HDRs ($EI_{2x24\text{-}HDR}$) was calculated for each individual using the EPIC-Soft software and the Danish Food Composition Databank (version 7; Søborg; Denmark; December 2008 (http://www.foodcomp.dk)).

The 7-dFR was identical to the food record used in the Danish National Survey of Dietary Habits and Physical Activity (Pedersen et al. 2010). For further details see section **3.2.1 Study design** and **3.2.2 Dietary intake assessment**

3.1.3 Assessment of energy expenditure

Energy expenditure was assessed by use of the ActiReg® system (PreMed AS, Norway) (Hustvedt et al. 2004). ActiReg® is a validated position and motion recording instrument that uses the combined recording of body position and movement to estimate energy expenditure. Participants were instructed to carry ActiReg® for 7 consecutive days during all waking hours except during activities in water, such as swimming, showering etc. and during high contact sports. During the night when the children were sleeping, the ActiReg® equipment was taken off and placed in a horizontal position as this mimics the recording of lying still. If the monitor was taken off for a period of 15 minutes or more during daytime, the participants were instructed to record the duration and type of activity performed.

Mean EE/day was calculated for each individual by the ActiCalc® program using estimated basal metabolic rate (BMR). Estimates of BMR were calculated from equations based on age, gender, height and weight (WHO 1985). Non-wear time was mainly due to sports activities, showering and changing clothes. EE during non-wear time was therefore estimated as corresponding to an average activity level of moderate intensity (MET[1]=3) for the ActiReg® system. To ensure that the majority of the waking hours was recorded, limits on total wear time and non-wear time were applied. Thus, if ActiReg® was not carried for 3 hours or more during daytime, and/or total wear time was less than 10 hours per day, the day was omitted from analysis (Matthiessen et al. 2008b; Tudor-Locke et al. 2011).

3.2 The Danish National Survey of Dietary habits and Physical Activity (Paper II-IV)

Paper II-IV are based on data from the Danish National Survey of Dietary Habits and Physical Activity, which is a nation-wide, representative, cross-sectional survey. Since 2000 the survey has provided an on-going national monitoring of dietary intake in the population group between 4-75 years. The overall aim of the survey is to monitor status, trends and variations in dietary intake and physical activity in Denmark as well as attitudes towards and determinants of dietary habits.

In the present thesis we used data from children aged 4-14 years who participated in the Danish National Survey of Dietary Habits and Physical Activity in the period 2003-2008. The study population comprised a simple random sample of children retrieved from the Central Office of Civil Registration. In comparison with census data from Statistics Denmark, the distribution of gender and age of the participants could be characterised as representative for the Danish population of children aged 4-14 years.

3.2.1 Study design

Participation in the Danish National Survey of Dietary habits and Physical Activity included a face-to-face interview with one of the parents (the mother in 87% of the cases) and the completion of a 7-day pre-coded food record and a physical activity questionnaire. Trained interviewers visited the participants at their homes where they conducted the interviews and instructed the participants in how to complete the recordings. The interviews included socio-economic variables and information about height and weight of the children. For each participant, completion of a minimum of 4 valid days is the standard criteria chosen for the use of data from the Danish National Survey of Dietary habits and Physical Activity. However, in the specific analysis of dietary intake on weekdays and weekend

[1] MET = Metabolic Equivalent, expressing the energy cost of physical activities as multiples of BMR

days, only children with 7 consecutive days of dietary recording were included. A flow-chart of the sample is given in Figure 2.

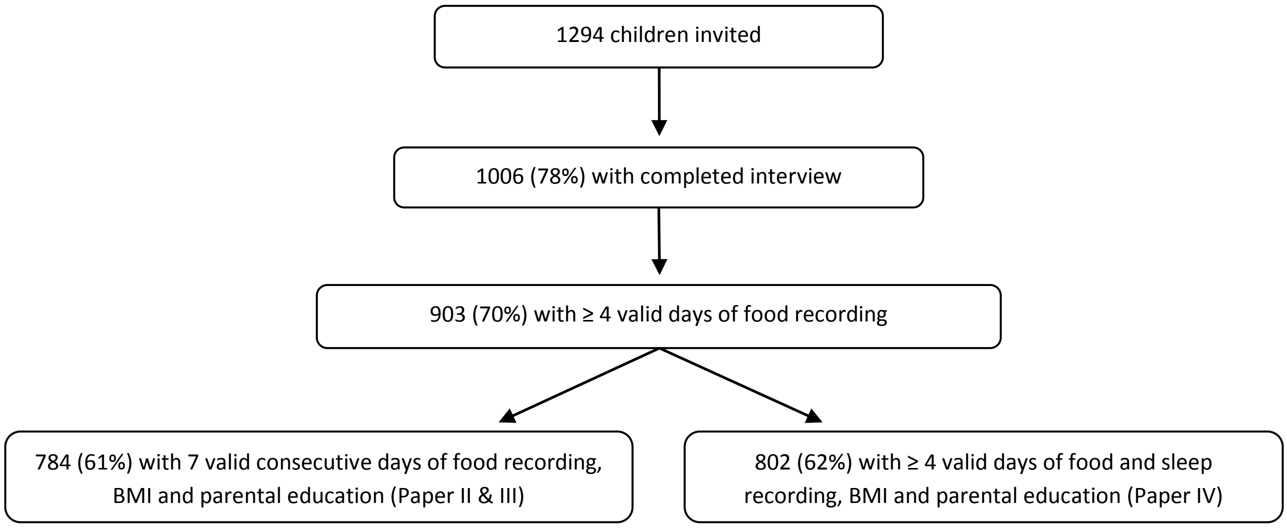

Figure 2. Flow chart of the sample of children invited to participate in the Danish National Survey of Dietary Habits and Physical Activity 2003-2008

3.2.2 Dietary intake assessment

Dietary intake was recorded every day for 7 consecutive days in food records (7-dFR) with pre-coded response categories, which included open answer options. Children and their parents were instructed in person by trained interviewers from SFI-Survey[2] on how to complete the food record. The parents were responsible for completing the 7-dFR and deciding to what extent their children were capable of assisting. Thus, parents reported the majority of the dietary intake for the children, but to a less degree for older children.

The 7-dFR was organised according to the typical Danish meal pattern (breakfast, lunch, dinner and in-between meals). Each meal was divided into sections with headings, such as beverages, bread, spreadable fats, meat and vegetables, to make it easier to find and record the relevant foods and dishes. For food items not included in the 7-dFR, participants wrote type of food and portion size in open-answer categories. The quantities of foods consumed was given in predefined household measures (cups, spoons, slices, etc.) or estimated from photos in a picture book containing 14 food sets of pictures, each containing 4 to 6 different portion sizes. As a supplement to the food record, participants also received a food recording booklet for the children to take to school or to other places outside their home on the days of assessment.

Data were scanned using The Eyes & Hands program (version 5.2, 2005; Readsoft Ltd, Milton Keynes, Buckinghamshire, UK). The mean EI/day from the 7-dFR ($EI_{7\text{-dFR}}$) was calculated for each individual using the software system General Intake Estimation System (GIES) (version 0.995a, released 26th of June 2005), developed at the National Food Institute, Technical University of Denmark (Søborg,

[2] SFI: The Danish National Centre for Social Research (Det Nationale Forskningscenter for Velfærd, tidl. Socialforskningsinstituttet)

Denmark), and the Danish Food Composition Databank (version 7; Søborg; Denmark; December 2008 (http://www.foodcomp.dk)).

3.2.3 Sleep duration (Paper IV)

Every day, on the same 7 days as the food record was completed, sleep duration during the last night and day was reported. For each child, a minimum of 4 days with measurements of diet and sleep duration was required for inclusion in the statistical analyses.

3.3 Data treatment and statistical analysis

Data were analysed with SPSS version 19.0 for Windows (SPSS Inc., Chicago, IL, USA) and R statistical software 2.9.1 (R Development. Core Team, 2009 (http://www.r- project.org)). Statistical differences were considered significant at $P<0.05$.

3.3.1 Evaluation of estimated energy intake (Paper I)

Data of EI and EE were approximately normally distributed. Differences between EI and EE for groups of children and between the age groups and genders were analysed using paired and unpaired t-tests, respectively. Pearson correlation coefficients were calculated between EI and EE. Agreement between measurements of EI and EE was visualised using the Bland Altman method of agreement analysis, i.e. plotting the difference between the two methods against the mean of the measurements, which makes the magnitude of disagreement and any outliers or trends visual (Bland & Altman 1986). Agreement on category level between EI and EE was examined by classification of EI into quartiles.

The proportions of possible over- and under-reporters were assessed using the confidence limits of agreement between recorded EI and EE at the individual level. Participants were classified as acceptable reporters, under-reporters, or over-reporters according to whether the individual's EI:EE ratio was within, below or above the 95% confidence limits of agreement between the two measurements (Livingstone et al. 2003). The 95% confidence limits of agreement between $EI_{2x24\text{-}HDR}$ and EE and between $EI_{7\text{-}dFR}$ and EE were calculated as

$$95\%\ CL = \pm 2 \sqrt{((CV^2_{EI}/d) + (CV^2_{EE}/d))}$$

where d is the number of days of assessment, and CV_{EI} and CV_{EE} are the pooled mean coefficients of variation in EI (by 2x24-HDRs or 7-dFR) and EE, respectively.

The method of triads was used to calculate validity coefficients between the unknown true EI and EI estimated with the 7-dFR, EI estimated with the 2x24-HDRs and EE, respectively (Ocké & Kaaks 1997). This method is a triangular approach that can be used when data from a dietary assessment method, a reference method and a biomarker, or another objective method are available. The correlations between each of the three methods are used to estimate a validity coefficient, which expresses the correlation between reported intake and the unknown true intake.

If Q, R and M denote the measurements from the 2x24-HDRs, the 7-dFR and ActiReg®, respectively, and T denotes the true unknown EI, the validity coefficients can be calculated as follows:

$$VC_{QT} = \sqrt{(r_{QR} \times r_{QM} / r_{RM})}$$

$$VC_{RT} = \sqrt{(r_{QR} \times r_{RM} / r_{QM})}$$

and $$VC_{MT} = \sqrt{(r_{QM} \times r_{RM} / r_{QR})}$$

where r_{QR} is the correlation between the 2x24-HDRs and the 7-dFR, r_{QM} the correlation between the 2x24-HDRs and the ActiReg®, and r_{RM} is the correlation between the 7-dFR and ActiReg®. The low number of subjects in each age group precluded the analysis being undertaken separately for each age group. Differences between the two dietary assessment methods in the proportion of children classified as acceptable reporters, under- or over-reporters, respectively, were tested with the Stuart-Maxwell test. Multiple linear regression analyses were performed for each dietary assessment method with EI:EE as the dependent variable and age, gender, BMI and parental educational level as independent variables.

3.3.2 Weekdays and weekend days (Paper II-III)

Weekdays and weekend days were defined as Monday to Thursday and as Saturday to Sunday, respectively. Friday was kept as a period of its own, instead of making a dichotomous weekday-weekend day variable, since preliminary analysis showed that intakes on Fridays differed from both Monday to Thursday and from Saturday to Sunday.

The main analyses were performed separately for the three age groups 4-6, 7-10 and 11-14 years due to the wide age range of children in the study population and the associated different degree of parental influence on the diet and dietary recording. Differences between gender regarding height, weight and BMI were analysed using paired *t*-test, whereas differences between age groups regarding height, weight and BMI were analysed using one-way ANOVA and Tukey´s post hoc test. Differences regarding parental education and weight status were assessed between gender and between age groups using the χ^2 test and Fisher's exact test. The prevalence of under-reporters was assessed using the Goldberg cut-off criterion, taking age and gender specific values for physical activity into account (Goldberg 1991; Lioret et al. 2011). PAL values corresponding to light physical activity were used to define cut-off values for under-reporters (Torun et al. 1996). Estimates of BMR were calculated from equations based on age, gender, height and weight (FAO/WHO/UNU 1985).

Paper II

In Paper II, EI and macronutrients were assessed on weekdays, Fridays and weekend days, as well as a number of food items selected to give an indication of the diet quality. The selection of variables was based on the work of Sepp et al. (2004) and the Nordic Monitoring project (Fagt et al. 2009), which has shown that certain food groups explain a considerable part of the variation in the relative content of total fat, saturated fat, added sugars and dietary fibre in the diet, and thus the overall nutritional quality of the diet. Energy density of the diet was calculated separately for a) solid foods and liquids consumed as food (for example, soups and yoghurt) and b) beverages, including both energy-containing and non-energy-containing beverages (for example milk/juice and water/tea, respectively) and presented as kJ/100g.

Differences in EI, macronutrient intake and energy density between weekdays, Fridays and weekend days were analysed using paired t-tests. For some of the food items, especially sausages, full-fat cheese, fries and fried potatoes, a high percentage of the children (up to 79% within the three age groups) had zero-intakes during the week. To account for zero-intakes the indicator variables were compared between weekdays, Fridays and weekend days using Tobit regression analysis. The Tobit regression analysis includes the zero-observations in the analysis by combining the binary information of intake versus zero-intake with the quantitative intake values for the non-zero cases. Data were analysed separately for boys and girls due to significant gender differences in dietary intake in the preliminary analyses. Since the dietary intake analyses included multiple tests, Bonferroni corrections with k=3 were performed. The unit g/10MJ was used to take into account differences in the total EI and to assess the quality of the diet rather than absolute intakes.

Paper III

In Paper III dietary patterns were identified on weekdays and weekend days for each age group by use of PCA (Eriksson et al. 2006). Separate analyses for each gender were not conducted due to the limited sample sizes in each age group. Specific gender differences were therefore not part of the scope of this paper. Before conduction of the principal components analyses, dietary intake data were aggregated into a total of 32 food items based on relevant similarities in type of food and macronutrient composition. Energy density (kJ/100g) of the diet calculated for solid food and liquids consumed as food, were included in the PCA together with the other dietary variables.

PCA sequentially creates linear combinations (components) of the input variables that exhibit maximal possible variance. Used on a correlation matrix it is a way to explain the overall correlation structure by a few key components. With dietary data, the components can be perceived as dietary patterns. The correlations of each food item with a dietary pattern are called factor loadings. Food variables with factor loadings >0.2 or <-0.2 were considered to have a strong association with the corresponding pattern, and were used to identify and label the specific dietary patterns (Slattery 2010). The chosen number of patterns on weekdays and weekend days was primarily based on examination of the scree-plots and the interpretability of the components. The effect of adding or removing one or more components was also assessed, however, for all three age groups a solution with two patterns was considered as best representing the data. The patterns were labelled "processed" and "health conscious" based on the general characteristics of the foods with the highest factor loadings within each pattern.

For each child, a factor score for each of the patterns was calculated. The factor score indicates how closely the child's individual dietary pattern is in agreement with the overall dietary pattern. The derived factor scores were all approximately normally distributed. Pearson correlation coefficients between these factor scores were calculated to assess the associations between dietary patterns on weekdays and weekend days. The 95% confidence intervals were calculated for each of the correlations.

To clarify further the possible differences between the patterns, groups of children with high agreement for a pattern and also low or intermediate agreement for the other pattern were defined. Thus, within each age group, the group of children with factor scores in the highest tertile for the "processed" pattern and factor scores in the lowest or intermediate tertiles for the "health conscious" pattern was named "High PP". The group of children with factor scores in the highest tertile for the “health conscious” pattern and in the lowest or intermediate tertiles for the “processed” pattern was named “High HCP”.

Daily intakes on weekdays and weekend days of selected variables (fruit & vegetables, sugar sweetened beverages (SSBs), sweets & chocolate and energy density for solid foods and liquids consumed as food), were compared between the “High PP” group and the “High HCP” group in each age group using unpaired t-tests.

3.3.3 Sleep duration and dietary intake (Paper IV)

Associations between sleep duration and BMI Z-scores and between sleep duration and age were analysed using Spearman’s rho correlation coefficients. Differences between parental educational level, sleep duration, weight status and gender were assessed using the χ^2 test and Fisher’s exact test. Differences in BMI between parental educational levels were analysed using the Kruskal-Wallis test. Multiple linear regression analyses were performed separately for each dietary variable with sleep duration as the dependent variable and age and BMI as forced covariates in the models. In order to further elucidate the dietary patterns in relation sleep duration, the median sleep duration within each of the three age groups 4-6, 7-10 and 11-14 years, was used as a cut-off to define groups of children with short and long sleep duration. Dietary intake, in terms of EI, macronutrients, major food groups and food groups of selected high energy-dense foods with nutritional or dietary similarities, were compared between groups of children with short and long sleep duration using the Mann-Whitney U-test.

4. Results

This section contains a summary of the main results of the four papers included in this thesis. Further details of the results can be obtained from the individual papers in the appendix.

4.1 Evaluation of estimated energy intake (Paper I)

In the study of evaluation of estimated EI, described in Paper I, we found that in the group of 7-8 year-old children, there was a significant difference between mean EI from the 7-dFR ($EI_{7\text{-dFR}}$) and EE, but not between EI from the 2x24-HDRs ($EI_{2x24\text{-HDR}}$) and EE (Table 1). In the group of 12-13 year-old children, both $EI_{2x24\text{-HDR}}$ and $EI_{7\text{-dFR}}$ differed significantly from EE. In the 7-8 year-olds, $EI_{2x24\text{-HDR}}$ was overestimated by 3%, whereas $EI_{7\text{-dFR}}$ was underestimated by 7% compared to EE. In the 12-13 year-olds, $EI_{2x24\text{-HDR}}$ was underestimated by 10% and $EI_{7\text{-dFR}}$ by 20% compared to EE.

Table 1. Energy intake estimated with 2x24-HDRs ($EI_{2x24\text{-HDR}}$) and the 7-day food record ($EI_{7\text{-dFR}}$), energy expenditure estimated with ActiReg® (EE), and the relationship between estimates of EI and EE in each age group (mean (SD))

	7-8 years			12-13 years		
	Boys (n=32)	Girls (n=35)	All (n=67)	Boys (n=32)	Girls (n=32)	All (n=64)
$EI_{2x24\text{-HDR}}$ (MJ/d)*	9.2[a] (1.6)	8.7[a] (1.4)	9.0 (1.5)	10.6[a] (2.6)	9.1[b] (2.0)	9.9 (2.4)
$EI_{7\text{-dFR}}$ (MJ/d)†	8.5[a] (1.7)	7.7[b] (1.2)	8.1 (1.5)	9.4[a] (2.1)	7.9[b] (1.6)	8.6 (2.0)
EE (MJ/d)	9.0[a] (0.9)	8.4[b] (0.9)	8.7 (0.9)	12.1[a] (2.1)	10.0[b] (1.0)	11.0 (2.0)
$EI_{2x24\text{-HDR}}$ - EE (MJ/d)	0.2[a] (1.3)	0.3[a] (1.4)	0.3 (1.3)	-1.5[a] (2.5)	-0.8[a] (2.0)	-1.2 (2.3)
$EI_{7\text{-dFR}}$ - EE (MJ/d)	-0.6[a] (1.5)	-0.7[a] (1.4)	-0.6 (1.5)	-2.7[a] (3.0)	-2.1[a] (1.9)	-2.4 (2.5)
$EI_{2x24\text{-HDR}}$ / EE (MJ/d)	1.02[a] (0.14)	1.04[a] (0.16)	1.03 (0.15)	0.89[a] (0.21)	0.92[a] (0.19)	0.90 (0.20)
$EI_{7\text{-dFR}}$ / EE (MJ/d)	0.94[a] (0.17)	0.93[a] (0.17)	0.93 (0.16)	0.80[a] (0.20)	0.80[a] (0.18)	0.80 (0.19)

[a,b]For each age group, mean values within a row with unlike superscript letters were significantly different (P<0.05)
*Mean values for $EI_{2x24\text{-HDR}}$ were significantly different from EE in the group of 12-13 year-olds (P<0.001)
†Mean values for $EI_{7\text{-dFR}}$ were significantly different from EE in the group of 7-8 year-olds (P=0.001) and 12-13 year-olds (P<0.001)

The Bland-Altman plots illustrate large variation in the degree of misreporting at individual level, and under-reporting as well as over-reporting with both methods. The 95% limits of agreement were -2.42 and 2.93 MJ/d for the 2x24-HDRs and -3.56 and 2.32 for the 7-dFR in the 7-8 year-olds, and -5.69 and 3.39 MJ/d for the 2x24-HDRs and -7.36 and 2.59 MJ/d for the 7-dFR in the 12-13 year-olds.

The 95% confidence limits of agreement between $EI_{2x24\text{-HDR}}$ and EE and between $EI_{7\text{-dFR}}$ and EE, defined acceptable reporters by having an EI:EE ratio within the range of 0.75-1.25 for the 2x24-HDRs and 0.77-1.23 for the 7-dFR. In the 7-8 year-olds, the prevalence of under-reporters was 1.5 % with the 2x24-HDRs and 16% with the 7-dFR. The corresponding figures were 23.4% and 42.2% in the 12-3 year-olds. The proportions of under-reporters did not differ between genders.

In the 7-8 year-old children, the proportion of individuals correctly classified in the same quartile for both EI and EE was 46% for $EI_{2x24\text{-HDR}}$ and 30% for $EI_{7\text{-dFR}}$. The proportion classified in the same or adjacent quartiles was 76% and 73% for $EI_{2x24\text{-HDR}}$ and $EI_{7\text{-dFR}}$, respectively. Gross misclassification ranged from 3% for $EI_{2x24\text{-HDR}}$ to 7% for $EI_{7\text{-dFR}}$.

In the 12-13 year-old children, the proportion correctly classified in the same quartile was 36% for $EI_{2x24\text{-}HDR}$ and 34% for $EI_{7\text{-}dFR}$, whereas the proportion classified in the same or adjacent quartiles was 83% for $EI_{2x24\text{-}HDR}$ and 70% for $EI_{7\text{-}dFR}$. The percentage grossly misclassified was 3% for $EI_{2x24\text{-}HDR}$ and 11% for $EI_{7\text{-}dFR}$.

The Pearson correlation coefficients between EI and EE were 0.48 for $EI_{2x24\text{-}HDR}$ and 0.32 for $EI_{7\text{-}dFR}$ in the 7-8 year-olds, and 0.48 for $EI_{2x24\text{-}HDR}$ and 0.37 for $EI_{7\text{-}dFR}$ in the 12-13 year-olds. For both age groups combined, the coefficients were 0.51 for $EI_{2x24\text{-}HDR}$ and 0.29 for $EI_{7\text{-}dFR}$. Using the method of triads, the validity coefficient was 0.81 (95% CI: 0.59-1.00) for $EI_{2x24\text{-}HDR}$ and 0.46 (95% CI: 0.18-0.66) for $EI_{7\text{-}dFR}$.

In multiple linear regression models with EI:EE as the dependent variable, and age, gender, BMI and parental educational level as independent variables, age remained significantly associated with $EI_{2x24\text{-}HDR}$:EE (P=0.006), whereas BMI remained significantly associated with $EI_{7\text{-}dFR}$:EE (P<0.001). When entered one-by-one in the multiple linear regression model, BMI and age were significantly negatively associated with EI:EE for both dietary assessment methods (P<0.001).

4.2 The Danish National Survey of Dietary habits and Physical Activity

The analyses for paper II and III were based on the same sample of 4-14 year-old children (n=784, 50% boys). The prevalence of under-reporters identified using the Goldberg cut-off criterion, taking age- and gender specific values for physical activity into account, was 1.0% in the 4-6 year-olds, 3.8% in the 7-10 year olds and 16.6 % in the 11-14 year olds. The proportions of under-reporters did not differ between genders.

4.2.1 Diet quality on weekdays, Fridays and weekend days (Paper II)

In the study of children's diet quality on weekdays, Fridays and weekend days, described in Paper II, we found that for both genders in all age groups, EI was consistently higher on weekend days than on weekdays (P<0.05). Moreover, intake of sugar-sweetened beverages and white bread was higher, whereas intake of rye bread was lower. In accordance with this, we found a higher percentage of energy from added sugars, lower fibre content and higher energy density on weekend days vs. weekdays (P<0.05). In children aged 4-6 and 7-10 years, the diet on weekend days was also characterised by higher intakes of sweets and chocolate and lower intakes of fruit and vegetables (P<0.05). Overall, the diet on Fridays appeared as a mix of the diets on weekdays and weekend days, and levels of EI and energy density seemed in general to resemble the level on weekend days more than on weekdays.

For each gender in the three age groups 4-6 years, 7-10 years and 11-14 years, respectively, mean intake (g/10MJ) of selected food groups on weekdays, Fridays and weekend days are presented in Figure 2a-b, while mean EI, nutrient intakes and energy density for solid foods and liquids consumed as food are presented in Table 2.

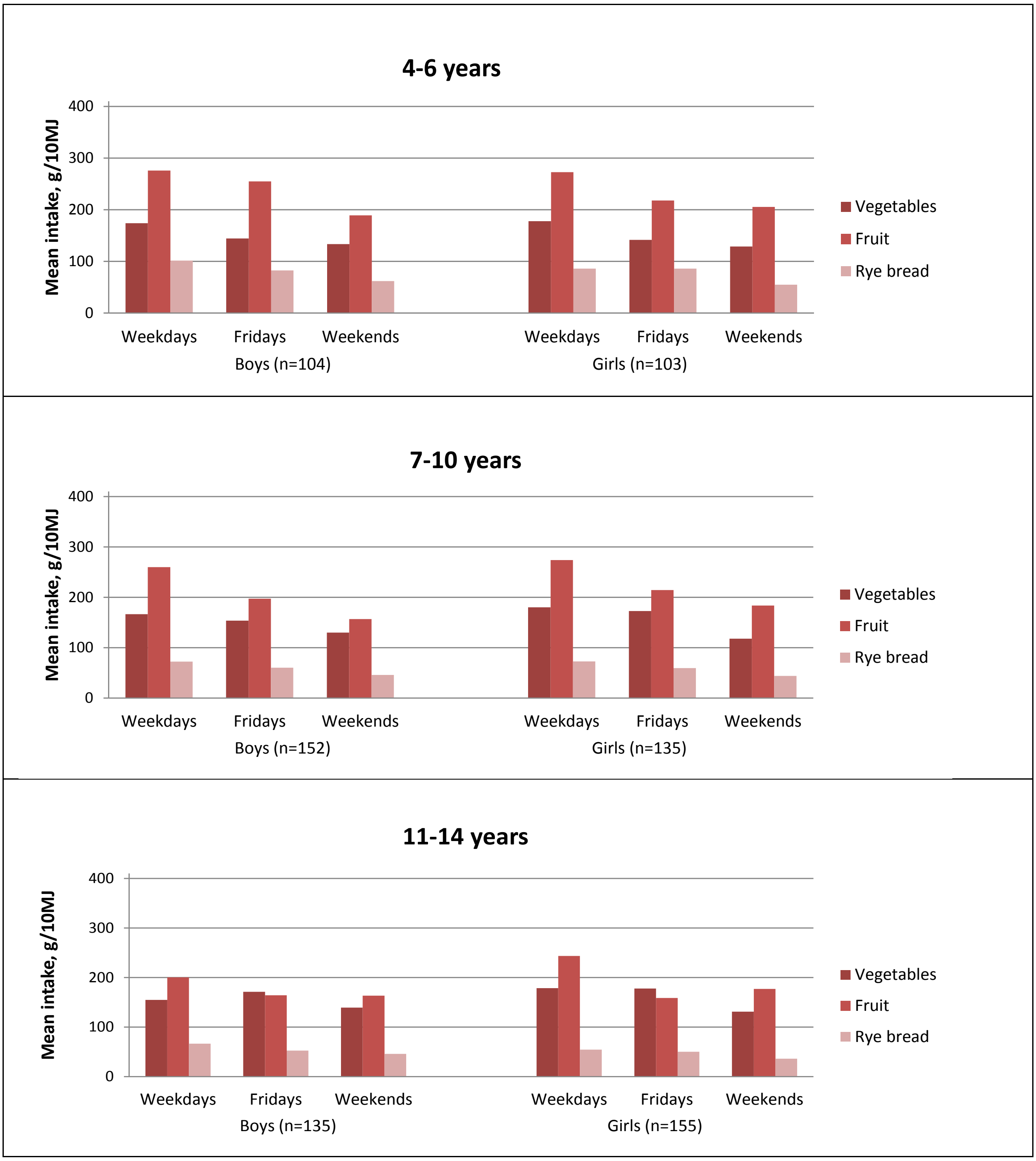

Figure 2a. Mean intake (g/10MJ) of selected food groups on weekdays, Fridays and weekend days presented for the three age groups 4-6 years, 7-10 years and 11-14 years (exact values and standard deviations are provided in Table 2-4 in Paper II).

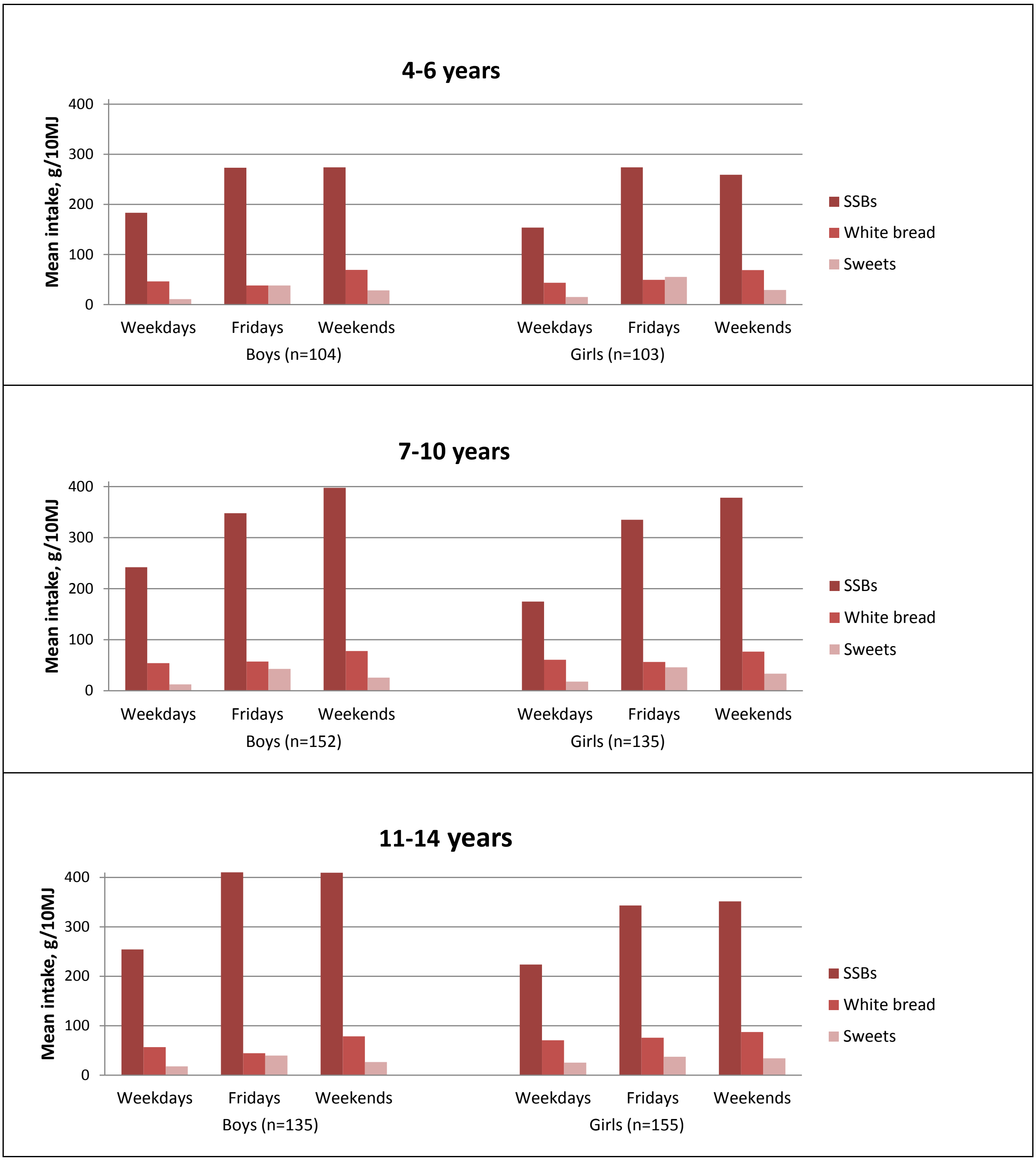

Figure 2b. Mean intake (g/10MJ) of selected food groups on weekdays, Fridays and weekend days presented for the three age groups 4-6 years, 7-10 years and 11-14 years (exact values and standard deviations are provided in Table 2-4 in Paper II). SSBs, Sugar sweetened beverages.

Table 2. Energy, nutrient intakes and energy density* of the diet on weekdays (Monday-Thursday), Fridays and weekend days (mean (SD))

	Boys			Girls		
	Weekdays	Friday	Weekend	Weekdays	Friday	Weekend
4-6 years		**n=104**			**n=103**	
Energy, MJ/d	7.5 (1.8)[b]	8.3 (2.6)[a]	8.4 (2.7)[a]	6.6 (1.4)[b]	7.2 (2.1)[a]	7.4 (1.7)[a]
Total fat, E%	33 (5)[b]	34 (7)[a,b]	35 (6)[a]	34 (5)[a]	32 (7)[b]	35 (6)[a]
Carbohydrates, E%	52 (5)	52 (7)	51 (6)	51 (5)[b]	54 (7)[a]	52 (6)[b]
- Added sugars, E%	9 (5)[b]	14 (8)[a]	13 (6)[a]	10 (4)[b]	15 (8)[a]	14 (5)[a]
Fibre, g/10 MJ	25 (6)[a]	22 (8)[b]	20 (6)[c]	25 (6)[a]	21 (7)[b]	19 (5)[c]
Protein, E%	15 (2)[a]	14 (3)[b]	14 (3)[b]	15 (2)[a]	14 (3)[b]	13 (2)[c]
Energy density, kJ/100g	704 (127)[b]	794 (220)[a]	844 (197)[a]	712 (140)[b]	826 (229)[a]	864 (204)[a]
7-10 years		**n=152**			**n=135**	
Energy, MJ/d	8.4 (1.9)[c]	9.8 (3.3)[a]	9.0 (2.7)[b]	7.8 (2.4)[b]	9.0 (2.9)[a]	8.6 (2.3)[a]
Total fat, E%	33 (5)[b]	32 (7)[b]	34 (6)[a]	33 (5)	32 (6)	33 (6)
Carbohydrates, E%	52 (6)[b]	55 (7)[a]	52 (7)[b]	52 (5)[b]	55 (7)[a]	53 (6)[a,b]
- Added sugars, E%	11 (5)[b]	15 (8)[a]	15 (7)[a]	10 (4)[b]	16 (8)[a]	16 (7)[a]
Fibre, g/10 MJ	23 (7)[a]	21 (8)[b]	18 (6)[c]	24 (6)[a]	21 (7)[b]	18 (5)[c]
Protein, E%	15 (2)[a]	14 (3)[b]	14 (3)[b]	15 (2)[a]	13 (3)[b]	13 (3)[b]
Energy density, kJ/100g	727 (149)[b]	841 (223)[a]	879 (191)[a]	713 (152)[c]	804 (215)[b]	859 (182)[a]
11-14 years		**n=135**			**n=155**	
Energy, MJ/d	9.0 (2.8)[b]	10.5 (4.6)[a]	10.3 (3.8)[a]	7.4 (2.0)[b]	8.1 (3.4)[a]	8.2 (2.5)[a]
Total fat, E%	33 (6)	32 (8)	34 (7)	31 (5)	31 (9)	32 (6)
Carbohydrates, E%	52 (6)[b]	54 (9)[a]	52 (7)[a,b]	54 (6)	55 (9)	54 (7)
- Added sugars, E%	11 (6)[b]	15 (10)[a]	14 (8)[a]	11 (5)[b]	14 (9)[a]	15 (7)[a]
Fibre, g/10 MJ	23 (7)[a]	20 (9)[b]	19 (6)[b]	23 (7)[a]	21 (8)[b]	18 (6)[c]
Protein, E%	15 (3)[a]	14 (3)[b]	14 (3)[b]	15 (2)[a]	14 (4)[b]	14 (3)[b]
Energy density, kJ/100g	775 (167)[b]	854 (244)[a]	868 (217)[a]	734 (165)[b]	840 (236)[a]	864 (236)[a]

*Energy density for solid foods and liquids consumed as food
[abc]For each gender group, mean values within a row with unlike superscript letters were significantly different (P<0.05)

As presented in Table 3, large proportions of the children did not meet a range of specified nutritional recommendations and dietary guidelines.

Table 3. Proportions of children aged 4-14 years meeting or not meeting specific nutritional recommendations

Recommendation	% meeting the recommendation	% not meeting the recommendation
Added sugars < 10 E%[1]	34	66
Saturated fatty acids < 10E%[1]	4	96
Fish ≥ 200 g/week[2]	11	89
Fruit and vegetables ≥ 400 g/day[2] (only 4-10 year-old children)	23	77
Fruit and vegetables ≥ 600 g/day[2] (only 11-14 year-old children)	6	94

[1]According to the Nordic Nutrition Recommendations 2004 (NNR 2004).
[2]According to "Kostrådene 2005" (Astrup et al. 2005). More specifically the recommended intake of fruits and vegetables for children aged 4-10 years is 300-500 g/day.

4.2.2 Dietary intake patterns identified by Principal Component Analysis (Paper III)

In the study of PCA derived dietary patterns, described in Paper III, we found that two dietary patterns, labelled “processed” and “health conscious”, emerged on both weekdays and weekend days in all three age groups. The factor loadings for these patterns are presented in Tables 4-6.

The patterns differed slightly between age groups and between weekdays and weekend days. However, in all age groups the principal component labelled “processed” was characterised by high positive loadings on energy density, white bread, fat on bread, and jam, honey and chocolate spreads on both weekdays and weekend days. SSBs, cakes & biscuits and sweets & chocolate also had high loadings in the “processed” pattern on both weekdays and weekend days for all age groups, except for weekend days in the 4-6 year-olds. The other principal component labelled “health conscious” was consistently characterised by high loadings of fruit, vegetables and water on both weekdays and weekend days for all age groups, whereas the other variables with high factor loadings in the “health conscious” pattern varied to some extent between age groups.

Table 4. Factor loadings for food groups (g/day) and energy density (kJ/100g) for the two dietary patterns in children aged 4-6y (n=207)[1]

	Processed		Health conscious	
Food item	Weekdays	Weekend days	Weekdays	Weekend days
White bread	**0.61**	**0.45**	-0.07	**-0.34**
Energy density	**0.60**	**0.37**	**-0.58**	**-0.80**
Fats on bread	**0.55**	**0.76**	0.17	0.02
Jam, honey and chocolate spreads	**0.55**	**0.47**	0.02	-0.14
Cold cuts	**0.48**	**0.64**	**0.43**	**0.24**
Beverages, sugar sweetened	**0.41**	0.03	**-0.30**	**-0.25**
Rye bread	**0.36**	**0.55**	**0.53**	**0.31**
Sweets and chocolate	**0.34**	0.02	**-0.22**	**-0.34**
Sauce and gravy	**0.31**	**0.39**	**0.21**	-0.09
Cakes and biscuits	**0.29**	0.09	**-0.27**	**-0.32**
Juice	**0.27**	-0.09	0.16	-0.04
Dairy products, fat[2]	**0.22**	**0.23**	-0.02	-0.06
Potatoes	**0.21**	**0.31**	**0.37**	0.16
Oatmeal	**-0.24**	0.05	0.16	**0.26**
Water	0.03	**0.25**	**0.56**	**0.43**
Vegetables	-0.19	0.01	**0.51**	**0.48**
Fruit	-0.05	-0.14	**0.50**	**0.61**
Dairy products, low fat[3]	-0.15	0.01	**0.23**	**0.34**
Red meat, fat	0.20	0.19	**0.23**	**0.21**
Nuts and dried fruit	0.02	0.01	**0.32**	-0.10
Salty snacks	-0.03	0.04	**-0.23**	**-0.22**
Fast foods	-0.06	-0.17	**-0.32**	**-0.23**
Coarse bread & crisp bread	-0.07	0.09	0.12	**0.30**
Ice-cream and desserts	0.11	-0.18	-0.02	0.05
Fish and seafood	-0.11	0.03	0.00	0.16
French fries	0.09	-0.19	-0.20	-0.19
Rice, pasta and polenta	-0.09	-0.05	0.03	-0.15
Poultry	0.07	-0.08	0.20	-0.18
Red meat, lean	0.06	-0.11	0.01	0.07
Beverages, light	-0.06	0.00	0.08	-0.18
Pies and egg dishes	-0.05	-0.19	0.15	-0.08
Other breakfast cereals[4]	-0.02	-0.17	0.13	0.19
Soup	-0.01	0.14	0.08	0.17
Variation explained, %	7.8	7.5	7.9	8.1

[1]Food groups with loadings >|0.2| were considered to have a strong association with the corresponding pattern
[2]Dairy products with ≥1.5% fat
[3]Dairy products with <1.5% fat
[4]Other breakfast cereals than oatmeal

Table 5. Factor loadings for food groups (g/day) and energy density (kJ/100g) for the two dietary patterns in children aged 7-10y (n=287)[1]

	Processed		Health conscious	
Food item	Weekdays	Weekend days	Weekdays	Weekend days
White bread	**0.65**	**0.40**	0.00	0.15
Energy density	**0.47**	**0.84**	**-0.76**	-0.19
Sweets and chocolate	**0.44**	**0.22**	0.16	0.19
Jam, honey and chocolate spreads	**0.43**	**0.33**	-0.13	0.10
Beverages, sugar sweetened	**0.37**	**0.28**	-0.09	0.06
Salty snacks	**0.37**	0.11	0.06	0.03
Cakes and biscuits	**0.34**	**0.23**	-0.08	0.03
Red meat, fat	**0.29**	0.09	**0.28**	**0.53**
Fast foods	**0.29**	0.01	-0.15	**-0.41**
Juice	**0.28**	-0.03	**0.30**	-0.09
Fats on bread	**0.23**	**0.47**	**-0.35**	**0.28**
Cold cuts	**-0.27**	0.11	**-0.34**	**0.49**
Oatmeal	**-0.31**	**-0.26**	-0.06	**-0.06**
Dairy products, low fat[2]	**-0.36**	**-0.27**	0.02	**0.25**
Other breakfast cereals[3]	**-0.37**	**-0.25**	0.01	0.03
Rye bread	**-0.39**	-0.06	**-0.26**	**0.51**
French fries	0.19	**0.28**	-0.17	0.15
Soup	-0.03	**-0.22**	0.17	0.03
Water	0.05	**-0.23**	**0.37**	**0.30**
Nuts and dried fruit	0.04	**-0.27**	**0.33**	**0.22**
Vegetables	-0.10	**-0.49**	**0.62**	**0.39**
Fruit	0.01	**-0.62**	**0.72**	**0.31**
Potatoes	-0.09	-0.17	0.18	**0.57**
Sauce and gravy	0.20	0.13	0.07	**0.46**
Fish and seafood	-0.02	-0.12	0.17	**0.33**
Ice-cream and desserts	0.16	0.05	**0.21**	-0.04
Beverages, light	0.05	-0.18	**-0.32**	0.08
Red meat, lean	-0.16	-0.01	0.06	0.15
Pies and egg dishes	-0.13	-0.01	0.09	-0.04
Dairy products, high fat[4]	0.11	0.02	-0.03	-0.04
Coarse bread and crisp bread	-0.06	-0.14	0.08	0.04
Poultry	0.03	0.01	0.14	0.18
Rice, pasta and polenta	0.01	-0.02	0.19	-0.15
Variation explained, %	7.5	7.9	8.0	7.1

[1]Food groups with loadings >|0.2| were considered to have a strong association with the corresponding pattern
[2]Dairy products with <1.5% fat
[3]Other breakfast cereals than oatmeal
[4]Dairy products with ≥1.5% fat

Table 6. Factor loadings for food groups (g/day) and energy density (kJ/100g) for the two dietary patterns in children aged 11-14y (n=290)[1]

	Processed		Health conscious	
Food item	Weekdays	Weekend days	Weekdays	Weekend days
Energy density	**0.74**	**0.81**	**-0.40**	**-0.17**
Fats on bread	**0.66**	**0.48**	**0.31**	**0.52**
Jam, honey and chocolate spreads	**0.60**	**0.45**	0.11	0.00
White bread	**0.41**	**0.55**	**-0.20**	0.04
Cold cuts	**0.34**	0.18	**0.54**	**0.56**
Beverages, sugar sweetened	**0.29**	**0.21**	0.00	-0.17
Rye bread	**0.28**	0.19	**0.60**	**0.59**
Cakes and biscuits	**0.26**	**0.26**	-0.02	0.04
Sweets and chocolate	**0.25**	**0.24**	-0.12	-0.02
Juice	**0.24**	0.08	-0.20	**0.39**
French fries	**0.23**	0.18	-0.06	0.03
Poultry	**0.23**	-0.19	-0.04	-0.16
Vegetables	**-0.25**	**-0.37**	**0.59**	**0.32**
Fruit	**-0.29**	**-0.44**	**0.23**	**0.42**
Soup	**-0.32**	-0.10	-0.12	0.03
Other breakfast cereals[2]	**-0.40**	**-0.27**	0.06	0.08
Red meat, fat	0.01	**0.23**	**0.32**	0.07
Potatoes	-0.03	0.08	**0.57**	0.04
Sauce and gravy	0.02	0.17	**0.38**	-0.14
Water	-0.20	-0.10	**0.32**	**0.47**
Dairy products, fat[3]	-0.03	-0.11	**0.29**	**0.31**
Nuts and dried fruit	-0.02	-0.05	**0.29**	0.09
Fish and seafood	-0.01	0.07	**0.25**	0.18
Fast foods	-0.15	-0.13	**-0.32**	-0.17
Salty snacks	0.04	0.09	**-0.24**	0.01
Coarse bread & crisp bread	0.17	-0.04	0.08	**0.46**
Rice, pasta and polenta	-0.19	0.06	0.00	0.17
Pies and egg dishes	-0.13	-0.13	-0.04	-0.17
Oatmeal	-0.11	-0.17	0.18	-0.09
Red meat, lean	0.07	0.16	0.00	-0.02
Beverages, light	0.04	0.07	-0.20	-0.13
Dairy products, low fat[4]	0.02	-0.01	0.12	0.08
Ice-cream and desserts	0.01	0.04	-0.14	-0.10
Variation explained, %	8.0	7.1	7.9	6.5

[1]Food groups with loadings >|0.2| were considered to have a strong association with the corresponding pattern
[2]Other breakfast cereals than oatmeal
[3]Dairy products with ≥1.5% fat
[4]Dairy products with <1.5% fat

Pearson correlation coefficients between the factor scores from each dietary pattern showed significant positive correlations between corresponding patterns on weekdays and weekends ($P<0.05$), with exception of the “health conscious” pattern in the 7-10 year-olds (Table 7).

Table 7. Pearson correlation coefficients (r) and 95% confidence intervals between the factor scores obtained on weekdays and weekend days in 4-6, 7-10 and 11-14 year-old children

	"Processed" pattern		"Health conscious" pattern	
	Weekdays vs. weekend days		Weekdays vs. weekend days	
	r	95% CI	r	95% CI
4-6y (n=207)	0.34	0.21-0.45	0.32	0.19-0.43
7-10y (n=287)	0.17	0.05-0.28	0.09	-0.02-0.21
11-14y (n=290)	0.48	0.39-0.56	0.35	0.28-0.45

Comparisons of "High PP" groups with "High HCP" groups (i.e. groups of children with high agreement for the "processed" pattern and high agreement for the "health conscious" pattern, respectively), showed that energy density of the diet as well as intake of sweets & chocolate and SSBs were significantly higher, whereas intake of fruit & vegetables was significantly lower, in the "High PP" groups than in the "High HCP" groups ($P<0.05$) (Table 8). These differences were evident on both weekdays and weekend days for all age groups, except for intake of sweets and chocolate on weekend days in the 7-10 year-olds. Moreover, the absolute intake data indicated less healthy dietary intakes on weekend days for both the "High PP" and the "High HCP" groups. No significant differences regarding BMI, weight status, gender and parental educational level were found between the "High PP" and the "High HCP" groups within each age group.

Table 8. Mean energy density (kJ/100g) and mean intake of fruit & vegetables, sweets & chocolate and sugar sweetened beverages (SSBs) (g/d) on weekdays and weekend days for the "High PP" and the "High HCP" groups within each age group

	Weekdays					Weekend days				
	"High PP"		"High HCP"		P-value*	"High PP"		"High HCP"		P-value*
	Median	(P_5; P_{95})	Median	(P_5; P_{95})		Median	(P_5; P_{95})	Median	(P_5; P_{95})	
4-6y	**n 46**					**n 44**				
Energy density[a]	848	(668; 1148)	570	(501; 768)	<0.001	999	(767; 1445)	617	(473; 839)	<0.001
Fruit & vegetables	147	(19; 387)	382	(184; 735)	<0.001	85	(0; 401)	331	(93; 685)	<0.001
Sweets & chocolate[a]	7	(0; 42)	2	(0; 20)	0.001	25	(0; 108)	10	(0; 41)	0.002
SSBs[b]	113	(0; 744)	0	(0; 244)	<0.001	272	(0; 750)	100	(0; 513)	0.001
7-10y	**n 67**					**n 58**				
Energy density[a]	832	(684; 1121)	571	(402; 701)	<0.001	1056	(913;1301)	740	(447; 935)	<0.001
Fruit & vegetables[c]	155	(31; 327)	427	(194; 1051)	<0.001	55	(0;216)	313	(102; 1196)	<0.001
Sweets & chocolate[a]	13	(0; 53)	6	(0; 34)	0.003	15	(0;81)	15	(0; 81)	0.454
SSBs[a]	163	(0; 1100)	100	(0; 323)	<0.001	350	(0;1300)	263	(0; 805)	0.047
11-14y	**n 64**					**n 66**				
Energy density[a]	894	(748; 1152)	638	(437; 823)	<0.001	1053	(788;1382)	720	(453; 981)	<0.001
Fruit & vegetables[c]	100	(0; 371)	348	(84; 753)	<0.001	64	(0;203)	383	(86; 947)	<0.001
Sweets & chocolate[b]	22	(0; 135)	5	(0; 47)	<0.001	31	(0;159)	13	(0; 91)	0.003
SSBs[a]	213	(0; 738)	50	(0; 919)	0.011	400	(0;1100)	125	(0; 1278)	0.013

"High PP", children with factor scores in the highest tertile for the "processed" pattern and in the lowest or intermediate tertiles for the "health conscious" pattern;
"High HCP", children with factor scores in the highest tertile for the "health conscious" pattern and in the lowest or intermediate tertiles for the "processed" pattern;
P_5, 5th percentile; P_{95}, 95th percentile;
*Comparing "High PP" groups with "High HCP" groups within each age group
[a]Significant differences between weekdays and weekend days for both the "High PP" and the "High HCP" group: P<0.05
[b]Significant differences between weekdays and weekend days for the "High HCP" group: P<0.05
[c]Significant differences between weekdays and weekend days for the "High PP" group: P<0.05

4.2.3 Sleep duration and dietary intake (Paper IV)

In the study of the relationship between sleep duration and dietary intake, described in Paper IV, we found that sleep duration was negatively correlated to age (P<0.001) and to BMI Z-scores (P<0.001).

In multiple linear regression models, sleep duration was positively associated with vegetables (beta=0.057, P=0.027) and dietary fibre (beta=0.054, P=0.041), and negatively associated with liquid "empty calories" (beta=-0.055, P=0.035), but not with energy intake (beta=-0.044, P=0.097) nor with any of other the dietary variables (shown in Table II in Paper IV) (P>0.05).

The median sleep duration used as cut-off values for short sleep duration were 10.15 h/day for the 4-6 year-old children (n=212), 9.63 h/day for the 7-10 year-old children (n=289) and 8.99 h/day for the 11-14 year-old children (n=301). There were no differences between children with sleep duration above and below the median for age group regarding energy intake or macronutrient (protein, fat, carbohydrate) contribution to energy in all three age groups.

In the 4-6 year-old children, short sleepers had a higher intake of liquid "empty calories", i.e. SSBs, (237±212 vs. 182±133 g/10MJ, P=0.002), a higher energy percentage from added sugars (12±4.5 vs. 11±3.8 E%, P=0.04) and lower intake of vegetables (144±80 vs. 170±84 g/10MJ, P=0.03) compared to long sleepers. In the group of 7-10 year-old children, short sleepers had significantly higher intakes of sweets & chocolates (28±20 vs. 22±16 g/10MJ, P=0.01) and poultry (25±23 vs. 18±18 g/10MJ, P=0.004) than long sleepers. In the 11-14 year-old children, intake of rye bread was significantly lower in short sleepers (48±46 vs. 56±43 g/10MJ, P=0.03) compared to long sleepers.

5. Discussion

The findings presented in this thesis are discussed in each of the four papers in the appendix. This section provides some further comments or descriptions to supplement or expand the discussions in the individual papers.

5.1 Evaluation of estimated energy intake

From the comparisons of reported EI with EE assessed with ActiReg® we found a modest misreporting with both dietary assessment methods in the 7-8 year-old children. EI was 3% higher than EE with the 2x24-HDRs and 7% lower than EE with the 7-dFR, suggesting that both methods are suitable to provide an appropriate estimate of EI at group level in this age group. In line with the well-known tendency towards increasing under-reporting with increasing age from childhood to adolescence (Livingstone et al. 2004; Forrestal et al. 2011), under-reporting was more pronounced with the 12-13 year-old children, and especially with the 7-dFR, as EI was 10% lower than EE with the 2x24-HDRs and 20% lower than EE with the 7-dFR in this age group. The observed degree of misreporting of EI is in accordance with findings from several validation studies of multiple 24-HDRs and pre-coded food records validated against DLW in children (Montgomery et al. 2005; Bandini et al. 2003; Burrows et al. 2010).

Based on the correlations and cross-classifications, the 2x24-HDRs performed slightly better than the 7-dFR in terms of ranking, but the results indicate that both methods can be used to rank children according to EI. Furthermore, the higher validity coefficients (VCs) obtained by the method of triads, indicated that EI was closer to the unknown "true" value when estimated with the 2x24HR than by the 7-dFR. VCs were calculated only for both age groups combined due to the limited sample size. The method of triads is based on the assumption that the errors associated with each of the three methods are independent, and that estimates from each of the three methods are linearly related to the true intake (Ocké & Kaaks 1997). However, some degree of correlation between the two dietary assessment methods cannot be ruled out, and because the VCs could have been overestimated, they should be regarded as upper limits of the true VCs.

Evaluation of reported EI against EE only identifies bias in the total dietary intake, and the assessment of whether there is selective misreporting of certain food groups is essential. The relative validation of food and nutrient intake with the 2x24-HDRs and the 7-dFR, performed by Trolle et al. (2011), showed for both age groups that the higher EI with the 2x24-HDRs was mainly due to a significantly higher carbohydrate intake. More importantly, the dietary fibre intake was found to be significantly higher with the 2x24-HDRs, which corresponded to higher intakes of cereals, fruit and vegetables. Thus, the higher EI with the 2x24-HDR method comprised higher amounts of some healthy foods compared to the 7-dFR, but not higher amounts of snacks and other less healthy foods, which in general tend to be under-reported (Andersen et al. 2004). This finding is important to consider, especially if it is assumed that the higher EI with the 2x24-HDRs specify that the dietary reporting with the 2x24-HDRs is more valid than with the 7-dFR.

It is a general finding that under-reporting appears to be more pronounced with food records than with 24-HDRs, whereas over-reporting are found to be more often associated with 24-HDRs than with food records in children (Forrestal et al. 2011; Burrows et al. 2010). In the present study, the comprehensive 24-HDR interview incorporated a major effort to collect every detail of the dietary intake, including a thorough questioning technique using systematic probing questions. Moreover, personal contact with the interviewer during the recalls most probably helped the children as well as their parents in reporting all relevant information and in maintaining high motivation. Although these aspects of the recall method may have several advantages, the interview situation may also enhance the tendency towards social desirable behaviour and may have affected the reporting more in the 2x24-HDRs than in the 7-dFR (Maurer et al. 2006; Klesges et al. 2004). With both methods, participants knew in advance which days the dietary intake was going to be reported. Since it may be easier to keep to a more socially desirable diet on two non-consecutive days than during 7 consecutive days, modification of the children's dietary intake might also have been more likely with the 2x24-HDRs. Although the 7-dFR is less prone to bias due to the interviewer-effect, concerns have been raised about the use of this method because of the potential for study fatigue to develop, which may result in increasing under-reporting during the end of the recording period (Lillegaard et al. 2007; Biltoft-Jensen et al. 2009). However, this seemed not to have occurred in the present study (data not shown).

We observed that the magnitude of underreporting was higher in the 12-13 year-old than in the 7-8 year-old children. Even though older children have more developed cognitive skills compared to younger children, the assessment of dietary intake in older children and adolescents is recognised as particularly challenging. It has been suggested that for example less structured eating patterns, more frequent snacking outside the home, sensitivity to social desirability and possibly decreased interest in dietary recording may increase the susceptibility to underreporting among older children (Livingstone et al. 2004). We found the highest underreporting with the 7-dFR in the 12-13 year-olds, which might well be related to the fact that older children were more likely to fill in the food record with less parental assistance. By contrast, the 24-HDRs were conducted in the same way for both age groups.

quantified by use of the pictures. To what extent this has contributed to the higher EI reported with the 2x24-HDRs is difficult to determine because the results did not give clear indications about the direction of differences in portion size estimation (Trolle et al. 2011). Further detailed analyses are required to gain more insight into this issue.

Actireg®

The ActiReg® system uses the combined recording of body position and movement to assess physical activity and energy expenditure (Hustvedt et al. 2004). However, like other objective instruments used to measure physical activity in free-living subjects, ActiReg® shows considerable variation at the individual level. The use of ActiReg® has a number of limitations, including the ability to detect high intensity physical activity, arm work, carrying loads and water activities, whereas certain moderate intense physical activities such as walking and running slowly may tend to be overestimated (Hustvedt et al. 2004; Arvidsson 2009). Compared to DLW, mean EE assessed by use of ActiReg® was found to be 7% lower than DLW measurements in 14-15 year-old children (Arvidsson 2009), whereas in a study of adults (aged 23.3±2.1 years), mean EE was 4% lower than DLW measurements (Hustvedt et al. 2004). Based on the results from the DLW studies, it cannot be ruled out that the EE measurements presented in Paper I are slightly underestimated at group level. If so, this may have resulted in a small underestimation of the magnitude of under-reporting and likewise overestimation of the magnitude of over-reporting, however this is speculative.

The algorithm used in the study presented in Paper I has been modified since then in order to obtain better thresholds for moderate and high intensity physical activity for children (Arvidsson 2009). This was shown to improve the relationship with DLW, resulting in only 1% underestimation at group level in 14-15 year-old children (Arvidsson 2009). Unfortunately, this algorithm was not available for use in Paper I, but may be applied in future studies. Although the DLW method is the gold standard for measurements of EE in free-living subjects, the technique still has measurement errors, and objective measurements of EE through the use of a physical activity monitor like ActiReg® is an acceptable and cost-effective reference method when feasibility and precision is taken into consideration. Accordingly, ActiReg® has been used to assess EE in other validation studies in children (Andersen et al. 2005a; Lillegaard et al. 2005).

Strengths and limitations

One of the limitations of the present study is that although the reference method and the test method should preferably be conducted over the same time period, this was only possible with the 7-dFR and not the 24-HDRs. Thus, EE measurements were obtained only on the same days as the food record was filled in due to the logistical difficulties of getting the ActiReg® to the participants before each recall and the high participation burden. The study included a heavy workload for the participants and it must be recognised that the sample are volunteers, with a higher parental education than the general Danish population and most probably more motivated and health conscious than usual. Therefore results are probably a better case scenario, which is a common limitation in studies like this that have a high participation burden.

A major strength of the present study is that EE was measured with an objective method that is likely to have a minimum of correlated errors with the two dietary assessment methods. Moreover, the design allowed two dietary assessment methods to be compared with objective measurements of EE, which also enabled us to use the method of triads. The method of triads has been used in other studies for validation of nutrient intake and for validation of biomarkers for intake of different nutrients (Andersen et al. 2005b; Verkleij-Hagoort et al. 2007). To our knowledge, however, use of the method of triads to compare EI from two different dietary recording methods with objective measurements of EE has not been presented before.

Choice of methods

In any evaluation of dietary assessment methods it must be considered that various types of dietary information may be needed for different purposes, and the methodological strengths and limitations may be prioritised differently depending on the research area of concern. In national monitoring surveys it is particularly important to have cost-effective methods and to accurately translate short-term measurements of dietary intake into estimates of usual consumption (EFSA 2009). The present comparisons of the 2x24-HDRs with the 7-dFR did not indicate clearly which method is the overall most suitable dietary assessment method for school-aged children. The official conclusion from the EFCOVAL study is that the use of 2x24-HDRs in combination with a FPQ and statistical modelling of usual intake is a suitable method for adults and maybe for children aged 7 years and older (de Boer et al. 2011b). However, the EFCOVAL study did not include a FPQ for children, and this needs to be considered in future studies. EFSA's Expert Group on Food Consumption Data recommends the use of 2x24-HDRs in adults and the food record method as the most appropriate method for children from 36 months to 10 years of age (EFSA 2009). A major reason for this is that the dietary record method facilitates a combination of parents and caregivers in the dietary recording (EFSA 2009).

Forthcoming results from the PANCAKE project (Pilot study for the Assessment of Nutrient Intake and Food Consumption Among Kids in Europe), which aims to develop and test the use of a 3-day consecutive food record and a 2x1-day non-consecutive food record, may elucidate the potential for use of these methods in future trans-European food consumption surveys. Another likely approach in future settings is the use of web based dietary assessment or other technological developments, which may have potential use especially in older children and adolescents in order to increase their motivation for dietary recording (Thompson et al. 2010). In the Danish National Survey of Dietary habits and Physical Activity, the 7-dFR has been used since 1995 and will be continued to be used at least until 2013. The comparability over time through use of the same method has a high priority, however, it is possible that in time the survey will switch to the use of two non-consecutive 24-HDRs.

5.2 Dietary intake patterns on weekdays and weekend days

The dietary intakes of 4-14 year-old children was analysed for weekdays and weekend days by two different approaches presented in Paper II and III, respectively. Paper II is based on analyses of the intake of predefined key food groups, while in Paper III we used statistical analyses of food groups consumed in combination to define more comprehensive patterns. Thus, the results from these analyses provide different measures of children's dietary intake patterns on weekdays and weekend days and thereby give supporting and complementary insight into this.

Results from Paper II showed that the average EI was consistently higher on weekend days than on weekdays, and that the quality of the diet consumed during the weekend days was lower than on weekdays, whereas the dietary intake on Fridays in general appeared to be at an intermediate level. These results are supported by analyses from the previously mentioned relative validation of the 2x24-HDRs and the 7-dFR, in which comparisons of energy and macronutrient intakes between the days of the week showed significantly higher intakes of energy and added sugars on Fridays and Saturdays (Trolle et al. 2011). Few studies have specifically addressed the differences in dietary intake on weekdays and weekend days. However, a similar type of study has been conducted with Norwegian children in comparable age groups (Andersen et al. 2003). Although the dietary intake variables used in that study were not identical to those analysed in Paper II, the same overall pattern emerged for the Norwegian children, which also suggests that Friday is a special weekday in terms of dietary intake.

Using PCA, we identified two major dietary intake patterns, labelled “processed” and “health conscious”, on both weekdays and weekend days as presented in Paper III. Although not completely identical, these dietary patterns were consistently found in all three age groups. The correlations between corresponding patterns were rather low in the 7-10 year-old children. However, there is no obvious explanation for this finding. The initial analyses with varying numbers of included food groups did not show a tendency for the patterns of this age group to differ from the patterns of the other age groups. The lower correlations between corresponding dietary patterns that are presented for this age group seem rather to be an exception to the general findings.

In general, factor scores from corresponding dietary patterns on weekdays and weekend days were significantly positively correlated, suggesting that the children tended to maintain the same overall dietary patterns in weekdays and weekend days. Moreover, in accordance with the results presented in Paper II, further analyses indicated that the actual dietary intake on weekend days was generally less healthy on weekend days compared to weekdays for both patterns. According to this, children with more health conscious dietary patterns consumed a more healthy diet even on weekend days, and public health initiatives therefore have especially relevance for the children with a less healthy dietary pattern.

PCA has been used for assessment of dietary intake patterns in numerous studies in both adults and children (Slattery et al. 2010; Tucker et al. 2010), and has previously been used to assess the stability of dietary patterns during periods of several months to years in childhood, adolescence and adulthood (Oellingrath et al. 2011; Northstone et al. 2008; Cutler et al. 2011; Crozier et al. 2009). Types and numbers of patterns with similarities to those presented in Paper III have been found in other studies in children and adolescents (Craig et al. 2010; Cutler et al. 2009). To our knowledge, however, the present study is the first to assess dietary patterns obtained by use of PCA specifically on weekdays and weekend days. These results are therefore not directly comparable to those of other studies.

Public health considerations

From a public health point of view it is worrying that the majority of the Danish children did not meet the official nutritional recommendations and dietary guidelines on a weekly basis, and the present results emphasise the importance of considering the unfavourable eating patterns during weekends. Overall, the results point at a lower intake of fruit and vegetables and a general tendency to choose white bread rather than rye bread during weekends, which have a lowering effect on both the fibre content and the nutrient density of the diet. Furthermore, the higher intake of sugar-rich foods and beverages on weekend days compared to weekdays is of concern because high intakes of sugar rich foods and beverages are positively associated with risk of weight gain and with multiple measures known to increase cardiovascular disease risk in adolescents (Hu et al. 2010; Welsh et al. 2011). On the other hand high intakes of fruits and vegetables and wholegrain may assist in weight management and contribute to the prevention of many chronic diseases such as cardiovascular diseases and a number of cancers and (WCRF 2007; Hallund et al. 2007; Mejborn et al. 2008).

Parents' motives for giving give their children sugar-rich foods have recently been described in a combined qualitative and quantitative Danish study (Iversen et al. 2011). The study included pairs of parents from 16 families with 4-12 year-old children with varying sugar-consumption who participated in the Danish National Survey of Dietary Habits and Physical Activity 2005-2008. The majority of the interviewed parents claimed that they felt capable of controlling their children's intake of sugar. However, the dietary intake data revealed that the children had a considerably higher intake of added sugars than recommended. It is noteworthy that even if the parents limit their children's intake of added sugars on weekdays, the recommended level on a weekly basis can easily be exceeded by the sugar intake on weekend days. Parents also expressed the view that it has become a tradition to give the children sugar-rich foods during weekends, and that a culture of snacking while having a good time is seen as a legitimised cause for this. This view and lack of knowledge about the children's high sugar intake are important factors that contribute to the high intake of sugar (Iversen et al. 2011). The promotion of healthy eating habits may benefit from more focus on changing the common attitude that having a good time is associated with snacking of foods with high energy-density and/or low nutrient-density. This applies to children as well as their parents and surroundings.

The significantly higher EI on Fridays and weekend days compared to weekdays, stresses that not only did the children have less healthy food choices on Fridays and weekend days, they also consumed more in total rather than compensating by eating smaller amounts of regular foods. These dietary habits may promote positive energy balance, thereby increasing the risk of becoming overweight and obese. Furthermore, previous research has shown that children tend to be less physically active on weekend days than on weekdays and spend more time in sedentary behaviours, including TV viewing and other screen time (Rey-Lopez et al. 2010; Rowlands et al. 2007; Soric et al. 2010) thus further increasing the risk of weight gain during weekend days. The tendency to lower physical activity on weekend days compared to weekdays was also observed in a sub-sample of 4-14 year-old Danish children participating in the Danish National Survey of Dietary habits and Physical Activity 2007-2008, where physical activity was measured by use of pedometers (Rothausen et al. 2010).

High dietary energy density has been associated with lower dietary quality in a study of Swedish children (Patterson et al. 2010) and also with increased energy intake, weight status and risk of the metabolic syndrome in adults (Ledikwe et al. 2006a; Ledikwe et al. 2006b; Mendoza et al. 2007). The results from Paper II and III are in line with these findings and emphasize that high levels of energy density are of concern from a public health perspective. The concept of energy density is a crude proxy that obviously cannot differentiate between the nutritional quality at all nutritional levels, for example between different types of high energy dense foods such as butter and vegetable oil. Therefore, the extent to which a diet is "healthy" or not cannot be determined by the simple value of its energy density. However, the inclusion of energy density supported and strengthened the present findings. Furthermore, development of ranges of energy density levels may be of relevance in future studies especially in relation to weight management issues.

A varied, healthy diet combined with an appropriate EI level is vital for optimal health regardless of weight status, and the detection of significantly unfavourable dietary patterns during weekends, points at a considerable potential for dietary improvement. The present findings suggest that focusing attention on the differences between weekdays and weekend days regarding EI and key variables, such as fruit and vegetables and foods and beverages high in added sugars, could prove useful for enhancing public health initiatives. Children's dietary intake is influenced by numerous factors including personal factors and the social, physical and cultural environment (Rasmussen et al. 2006). Children and families may have difficulty in making healthy choices without an environment that is supportive for it, and the accessibility and affordability of healthy foods are important in each place where the child spends time (Kim et al. 2011; Rasmussen et al. 2006). This underlines that promotion of healthier eating habits may include changes at both the individual level and at population levels

Methodological considerations

Representation of weekdays

The present results illustrate that there are substantial and systematic variations in dietary intake during the week, which tend to be ignored when interpreting simple means of dietary intake variables. Due to these important differences between dietary intake on the various weekdays, a fairly equal representation of all days of the week is important in surveys assessing usual intake of a study population. Depending on the study aim, it may be sufficient to obtain an even distribution of the days of the week at group level. However, if the analyses in Paper II and III were to be made from data from 2x24-HDRs, obviously a substantially larger sample size would be needed to obtain same number of assessment days. In the present analyses of dietary patterns, the dietary data are included as means over four and two days, respectively. More ideally, the analyses should have been based on 7 non-consecutive days from each participant, however, in most studies this setting is not an option.

Indicator variables

The chosen indicator variables, which have been developed and validated for use in dietary monitoring in the Nordic countries (Fagt et al. 2009) appeared as the best choice for obtaining an indication of the diet quality. However, a limitation of the use of these indicator variables was that for some of the variables there were many zero-values, which are inherently difficult to handle and interpret. For example the intake of sausages and full fat cheese was limited with a high number of non-consumers in the present sample of Danish children. Therefore, we aimed to take the zero-intakes and skewed distributions into account by analysing data with Tobit regression analysis, which includes the zero-observations in the analysis and combines the binary information of intake versus zero-intake with the quantitative intake values for the non-zero cases. Since the development of the indicator variables is primarily based on data from adults in Sweden, it should also be recognised that the most optimal indicator variables might be different for Danish children, for example regarding capturing of intake of sugar-rich foods, which is a larger problem in children than in adults. However, further studies are needed to reveal the significance of this and whether other variables may be more suitable for Danish children.

Principal Component Analysis

PCA is an empirical method that explores existing dietary patterns without preconceived "scores". Nevertheless, it involves several subjective decisions that can influence the final interpretation (Newby et al. 2004; Michels & Schulze 2005). Results may therefore vary depending on the choices made for each step in the analysis. In line with this, we experienced that the dietary patterns presented in Paper III appeared with slight differences when we explored the effect of aggregating more or fewer of the input variables (data not shown). Moreover, when interpreting a limited number of dietary patterns, as is often the case, caution should be taken as other patterns also exist in the data set

(Michels & Schulze 2005). It seems useful therefore to combine the findings from PCA with other analyses of the diet, depending on the study objectives, to support and extend the findings. Additionally, validity of the dietary patterns and results could be strengthened by using more than one method of extracting dietary patterns.

An alternative and also commonly used data-driven method is cluster analysis, which differs from PCA in that it aggregates individuals into mutually exclusive subgroups, or clusters, with similar diets rather than grouping foods that are consumed together (Tucker et al. 2010). Thus, in contrast to PCA in which all individuals receive a score for each dietary pattern, individuals can only belong to one cluster in a cluster analysis. This classification simplifies the interpretation of the results, however, it also includes a risk of misclassification (Tucker et al. 2010). Both methods have been used to define dietary patterns, and although conceptually different, similarities between the two methods have been shown (Smith et al. 2011; Hearty & Gibney 2009; Crozier et al. 2006).

Underreporting

In acknowledgement of the concern for dietary under-reporting we assessed the prevalence of under-reporters using the Goldberg criterion, taking age- and gender specific values for physical activity into account. Although the Goldberg approach has some limitations in that it only identifies the most extreme misreporters and is considered to have a low specificity at the individual level, it is the most commonly used approach when objective measurements of energy expenditure are not available (Livingstone & Black 2003). The proportion of under-reporters in Paper II and III was only slightly lower than the proportions detected for the same 7-dFR in Paper I using ActiReg®, and under-reporting seemed to be rather limited at group level with the exception of the oldest age group. While parents take the full responsibility for the dietary recording of younger children, older children often record their intakes with less parental assistance. This is reasonable from the point of view that many parents may not know the older children's dietary intake in detail. However, food items or eating occasions may be more prone to be forgotten or missed out in the group of older children. Thus, there is a higher risk of misreporting in the dietary intake data from the 11-14 year-olds compared to the youngest age groups.

There is no simple answer to whether misreporters should be maintained or excluded from further analyses (Lioret et al. 2011; Posluna et al. 2009). Excluding the subjects identified as misreporters from the analysis leads to reduced sample size and loss of power. Adjustments are likely to cause bias since the quantity and quality of the misreported foods are unknown. Moreover, under-reporting and under-eating during the recording period cannot be distinguished. On the other hand, ignoring the presence of misreporters may lead to over-interpreted conclusions. It has been suggested that when the aim of the analyses is monitoring food intake at the population level, the best choice is to maintain the identified misreporters in the sample (Lioret et al. 2011), and this approach was taken in the studies presented in Paper II-IV. A further step is to perform the analyses both with and without inclusion of misreporters in order to examine whether this affects the results.

Strengths and limitations

Under-reporting is a persistent limitation of dietary assessment, which is also recognised in Paper II and III. The analyses were not repeated with exclusion of the identified under-reporters. However, at least in the youngest age groups the proportions of under-reporters do not suggest that it would have a significant effect. Moreover, diet quality was assessed using the unit g/10MJ in order to take differences in energy intake into account. Due to the limited sample sizes in each age group, gender differences were not part of the scope of the PCA analyses.

Strengths of the papers include the comprehensive dietary intake data amassed from daily records of dietary intake on all 7 days of the week by each participant. For the present purposes data from the 7-dFR is highly suitable. These data enabled different detailed analyses of the diet quality across the week, which have not previously been conducted in a sample of Danish children and which provided complementary results. Another major strength is the separate analyses of data for the three age groups to allow for different eating patterns and different challenges in dietary assessment represented by the wide age span of 4-14 years. Further strengths include the achieved response rate of 61%, which was obtained despite the demands related to the participation for both parents and children. Finally, the nationwide character of the study and the wide age span of the sample is a strength that renders the results more generalisable to children in the general Danish population.

5.3 Sleep duration and dietary intake

In the study of the relationship between dietary intake and sleep duration in children described in Paper IV, we found a negative association between sleep duration and BMI, which is in accordance with several other studies (Cappuccio et al. 2008; Patel et al. 2008; Nielsen et al. 2011). There was no significant association between sleep duration and energy intake, and the groups of short and long sleepers did not differ with regard to energy intake. Although this is a critical issue in the perception of the potential role of sleep duration on weight regulation, this observation is in agreement with previous findings in adults (Chaput et al. 2008), implying that a small energy gap associated with short sleeping is difficult to capture with the dietary assessment methods that are normally used in epidemiological research.

When assessing the relationship between sleep duration and dietary variables with multiple linear regression analyses, with age and BMI as covariates, we only found that vegetables and dietary fibre were positively associated with sleep duration, and that liquid “empty calories” were negatively associated with sleep duration. Groups of short sleepers had significantly higher intakes of added sugar and SSBs and lower intakes of vegetables (in the group of 4-6 year-old children), higher intakes of sweets & chocolate and poultry (in the group of 7-10 year-old children) and lower intakes of rye bread (in the group of 11-14 year-old children). However, the magnitude of the differences in dietary intakes between short and long sleepers was of a relatively small size and not consistent across age groups.

Only a few other studies have focused on the relationship between sleep duration and dietary patterns in children (Westerlund et al. 2009; Weiss et al. 2010; Chen et al. 2006; Gaina et al. 2007). The results from these studies are concordant with those found in the present study, suggesting that inadequate sleep may partly be associated with less healthy food habits in children. For example short sleep duration has also been associated with a greater likelihood of consuming “energy-rich” foods and less likelihood of consuming “nutrient-dense” foods in 10-11 year-old Finnish children (Westerlund et al. 2009). In a US sample of adolescents, short sleepers were more also more likely to consume high-energy snacks, and short sleep duration was associated with a relative increase in caloric intake derived from fat (Weiss et al. 2010). Although based on differing populations and dietary intake variables, the general findings from studies of sleep duration and diet indicate more unfavourable dietary patterns in short sleepers. However, in a study of German children and adolescents no association was observed between sleep duration and a nutrition quality score reflecting consumption of healthy and unhealthy foods (Hitze et al. 2009).

The mechanisms by which short sleep duration and body weight may be linked together are not fully understood, however, one of the most plausible underlying mechanisms is that inadequate sleep impacts the hormonal regulation of appetite (Knutson et al. 2012). In experimental studies, lack of sleep has been reported to decrease leptin levels, increase ghrelin levels and alter glucose regulation, which may lead to increased appetite and food intake (Spiegel et al. 2009; Knutson et al. 2007). In line with this, studies have shown that recurrent bedtime restriction over 14 days was accompanied by increased intake of calories from snacks in adults (Nedeltcheva et al. 2009) and moreover, that increased daytime sleep, which may have reflected an increased need for nocturnal sleep, was associated with greater food-cravings in adolescents (Landis et al. 2009). Indeed, this potential interaction between sleep and snacking behaviours needs to be examined further in children under free-living conditions (Chaput 2010).

Furthermore, tiredness during daytime may reduce the motivation to be physically active and in turn promote sedentary behaviour. An association has therefore been proposed between sleep duration, BMI and physical activity, however, results from studies concerning this have not been consistent (Garaulet et al. 2011; Ortega et al. 2011). It is most likely, that the relationship between sleep duration and BMI is multifactorial and complex. Clearly, other factors should also be considered, such as family upbringing, personal values and attitudes towards healthy eating habits and sleep hygiene, daytime napping and late-night activities such as screen time.

Methodological considerations

Sleep duration in the present study was based on the average sleep duration during the week, and differences on weekdays compared to weekend days were therefore not taken into account. Only few studies have investigated the variability in sleep patterns during the week, but it has been suggested that compensating for sleep debt accumulated during weekdays by "catchup" sleep on weekends might lower the risk of overweight and obesity (Wing et al. 2009). Obese children have also been found to have more irregular sleep schedules, and the combination of shorter sleep duration and more variable sleep patterns has been associated with adverse metabolic outcomes such as altered insulin, low-density lipoprotein and high sensitivity C-reactive protein plasma levels (Spruyt et al. 2011).

Like most of the similar studies of sleep duration in children, the present analyses relied on self-reported and not measured sleep duration. Laboratory-based polysomnography is considered the gold standard for measuring sleep objectively, but is impractical for long-term and home utilization since it is resource-demanding and difficult to use (Van de Water et al. 2011). Self-reported sleep duration in studies of children has nevertheless been found to be fairly accurate (Gaina et al. 2004), however, more studies are needed to determine the accuracy with which children and their parents report sleep duration. Sleep diaries have shown better agreement with objective measurements than sleep questionnaires (Sadeh et al. 2004). Therefore the quality of the sleep data in the present study may be considered to be relatively high. There may, however, be a potential overestimation of sleep duration in our data because parental reports of sleep duration may be determined by the time of going to bed and getting up rather than on actual time spent asleep.

Strengths and limitations

Among the limitations of the study is its cross-sectional nature that cannot disentangle cause and effect. However, the causal relation between short sleep duration and overweight is obviously difficult to assess because it requires long term randomised clinical trials. BMI was calculated from parent-reported height and weight, and may be underestimated because parental reporting tends to overestimate height and underestimate weight, especially in children with a high BMI (Himes 2009; Brettschneider et al. 2012). However, several studies have found relatively good relationships between measured and self-reported estimates of children's and adolescents' height and weight (Andersen et al. 2005c; Strauss et al. 1999). As discussed in Paper II and III the possible influence of dietary underreporting must be acknowledged, especially in the oldest children, and selective under-reporting may potentially have weakened the associations found between sleep duration and dietary intake.

This is the first study with representative population data on sleep duration and its relationship with dietary intake in Danish children. A major strength of the study is that the analyses were based on comprehensive dietary intake data and sleep duration reported every day during a week instead of a measure of usual sleep duration. Similarly to Paper II and III, the strengths also include the separate analyses for the three age groups and the nationwide character of the study, which render the results more generalisable to children in the general Danish population.

6. Conclusions and perspectives

This thesis is primarily concerned with three research areas: the evaluation of EI estimated with two different dietary assessment methods in children; investigation of children's dietary intake on weekdays and weekend days; and examination of the relationship between sleep duration, BMI and dietary intake in children.

The evaluation of EI showed that misreporting seemed modest at group level both with the 2x24-HDRs and the 7-dFR in the 7-8 year-old children when comparing EI to EE assessed with ActiReg®. Under-reporting appeared to be more evident in the 12-13 year-olds, especially with the 7-dFR. Overall, the 2x24-HDRs performed slightly better than the 7-dFR in terms of ranking of individuals according to EI. However, there are other aspects than EI that should be taken into consideration in the overall evaluation of the two methods, for example that the higher EI with the 2x24-HDRs mainly comprised higher intakes of healthy foods compared to the 7-dFR. There are pros and cons with both methods and it is still a matter of debate which method and design that is the ideal approach for school-aged children in national surveys. More research concerning the inclusion of FPQs in the use of 2x24-HDRs in children, and on the interaction between parents, children and the interviewer will benefit the further developments. Improvement of portion size estimation is challenging, however, this remains as a critical issue to consider in future research. The development and refinement of dietary assessment methods that are feasible for children is an on-going task, and the findings from the present thesis confirm that there is a special need for improved methods for older children and adolescents. The potential for use of web-based dietary assessment to collect dietary intake data is especially high for this age group and is a likely forthcoming approach in future settings.

From the analyses of dietary intake on weekdays and weekend days, we found that average EI and energy density of the diet were consistently higher on weekend days than on weekdays for both genders in the age groups 4-6, 7-10 and 11-14 years. The diet quality appeared to be lower on weekend days compared to weekdays, whereas the diet on Fridays appeared as a mix of the diets on weekdays and weekend days. Furthermore, two distinct dietary patterns, labelled "processed" and "health conscious", were identified on both weekdays and weekend days for each age group. This suggests that children tend to maintain the same overall dietary patterns in weekdays and weekends, although the actual dietary intake is generally less healthy during weekends. The findings indicate that more focus on the differences between weekdays and weekend days regarding EI and key variables, such as fruit and vegetables and foods and beverages high in added sugars, could prove useful for enhancing public health initiatives. This has especially relevance for children with less healthy dietary patterns. A next step to address is the aspect of meal patterns on weekdays and weekend days in terms of quality, frequency and contribution to energy intake. More detailed analyses are needed to evaluate the potential use of energy density as a simple indicator of diet quality and the possible role of energy density at food level in weight regulation issues. Additionally, aspects of physical activity in relation to dietary intake patterns deserve further attention in future studies since knowledge on how children's dietary intake and physical activity behaviours are related will provide important information for identification and characterization of problem areas and subgroups at risk. The promotion of healthy eating habits may also benefit from more focus on changing the common attitude that having a good time is associated with snacking of foods with high energy-density and/or low nutrient-density. This applies to children as well as their parents and surroundings.

In the present sample of 4-14 year-old Danish children, there was a negative association between sleep duration and BMI. However, sleep duration was not associated with energy intake and the conception that children with short sleep duration have less healthy eating habits than children with longer sleep duration was only weakly supported by the present findings. Analysing the sleep patterns on weekdays and weekend days and combining these with information about dietary intake and physical activity could extend the present findings and contribute to the understanding of the link between sleep duration, diet and body weight in children. So far most studies have relied on parental reporting of sleep duration, however, the development and use of objective measures of sleep might improve further studies. More research, including longitudinal measurements, is required to understand better the implications of chronic short sleep duration on appetite and energy balance, and whether strategies to improve sleep can influence appetite control and risk of weight gain.

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9. Appendices (Paper I-IV)

Paper I

Comparison of estimated energy intake from 2x24-hour recalls and a 7-day food record with objective measurements of energy expenditure in children

Rothausen BW[1], Matthiessen J[1], Groth MV[1], Brockhoff PB[2], Andersen LF[3], Trolle E[1]

[1]Division of Nutrition, National Food Institute, Technical University of Denmark, Søborg, Denmark
[2]Department of Informatics and Mathematical Modeling, Technical University of Denmark, Kongens Lyngby, Denmark
[3]Department of Nutrition, Institute of Basic Medical Sciences, University of Oslo, Oslo, Norway

Food Nutr Res. 2012;56. doi: 10.3402/fnr.v56i0.12221

Original Article

Comparison of estimated energy intake from 2 × 24-hour recalls and a seven-day food record with objective measurements of energy expenditure in children

Berit W. Rothausen[1]*, Jeppe Matthiessen[1], Margit V. Groth[1], Per B. Brockhoff[2], Lene F. Andersen[3] and Ellen Trolle[1]

[1]Division of Nutrition, National Food Institute, Technical University of Denmark, Søborg, Denmark; [2]Department of Informatics and Mathematical Modeling, Technical University of Denmark, Kongens Lyngby, Denmark; [3]Department of Nutrition, Institute of Basic Medical Sciences, University of Oslo, Oslo, Norway

Abstract

Objective: The objective of the present study was to evaluate energy intake (EI) estimated from two non-consecutive 24-hour recalls (24-HDRs) and a pre-coded seven-day food record (7-dFR) against objective measurements of energy expenditure (EE) in children.
Design: A total of 67 7–8 year-olds and 64 12–13 year-olds completed the 2 × 24-HDRs, the 7-dFR, and wore ActiReg® (PreMed AS, Oslo, Norway), a combined position and motion recording instrument, during the same seven days as the 7-dFR was filled in.
Results: In the 7–8 year-olds, EI from the 2 × 24-HDRs ($EI_{2\times 24\text{-HDR}}$) was overestimated with 3% compared to EE (not significantly different), while EI from the 7-dFR ($EI_{7\text{-dFR}}$) was underestimated with 7% compared to EE ($P = 0.001$). In the 12–13 year-olds, the corresponding figures was underestimation by 10% with the 2 × 24-HDRs ($P < 0.001$) and by 20% with the 7-dFR ($P < 0.001$). For both age groups combined, the 95% limits of agreement were −4·38 and 3.52 MJ/d for the 2 × 24-HDRs, and −5.90 and 2.94 MJ/d for the 7-dFR. Pearson correlation coefficients between EI and EE were 0.51 for $EI_{2\times 24\text{-HDR}}$ and 0.29 for $EI_{7\text{-dFR}}$, respectively. The proportion classified in the same or adjacent quartiles was 76% for $EI_{2\times 24\text{-HDR}}$ and 73% for $EI_{7\text{-dFR}}$ in the 7–8 year-olds, and 83% for $EI_{2\times 24\text{-HDR}}$ and 70% for $EI_{7\text{-dFR}}$ in the 12–13 year-olds.
Conclusion: Misreporting of EI seemed modest with both the 2 × 24-HDRs and the 7-dFR in the 7–8 year-olds when compared to EE measured with ActiReg®. Under-reporting appeared to be more evident in the 12–13 year-olds, especially with the 7-dFR. Compared to measurements of EE, the 2 × 24-HDRs seemed to perform slightly better than the 7-dFR in terms of ranking of individuals according to EI.

Keywords: *dietary assessment*; *EFCOVAL*; *ActiReg®*

Received: 14 November 2011; Revised: 10 January 2012; Accepted: 12 January 2012; Published: 15 February 2012

In nutritional epidemiology it is essential to have dietary assessment methods that are valid and feasible for use in large studies. Still, there is no dietary assessment method that is widely accepted as the best choice for such surveys in children, and further development of cost-effective methods is needed (1).

Misreporting of dietary intake is a common problem with dietary assessment methods in both children and adults (2, 3). This bias is of concern for the evaluation of food and nutrient intakes as well as for the assessment of associations between dietary intake and health. Evaluation of new dietary assessment tools is therefore required to reveal the extent of potential misreporting. This is often performed by relative validation comparing the new tool against another dietary assessment method, and/or by comparing energy intake (EI) with objective measurements of energy expenditure (EE). Doubly labelled water (DLW) is considered to be the gold standard reference method for validation of measurements of EI (4). However, the cost and requirements of highly specialised equipment with the DLW method precludes its use in many studies, and more feasible and

Citation: Food & Nutrition Research 2012. 56: 12221 - DOI: 10.3402/fnr.v56i0.12221
(page number not for citation purpose)

cost-effective ways of measuring EE, such as the use of physical activity monitors, must be applied instead.

One of the main objectives of the EFCOVAL (European Food Consumption Validation) study was to develop and evaluate a trans-European methodology to be used for estimating the intake of foods, nutrients and potentially hazardous chemicals in representative dietary surveys in children (5). According to the EFCOVAL study, the method suggested for children, 7–14 years of age, was the use of two non-consecutive 24-hour recalls (24-HDRs), using the EPIC-Soft computer program, combined with a food recording booklet (6, 7). A relative validation of the suggested 2×24-HDR method was performed against the seven-day pre-coded food record (7-dFR) used in the Danish National Survey of Dietary Habits and Physical Activity 2003–2008. Results from this study are presented elsewhere (8).

The objective of the present study was to compare estimated EI from the 2×24-HDRs and the 7-dFR, by comparison with EE measured by use of ActiReg® (PreMed AS, Oslo, Norway), a combined position and motion recording instrument, in Danish children aged 7–8 years and 12–13 years.

Methods

Participants

Participants in the age of 7–8 years and 12–13 years were recruited through the Central Office of Civil Registration, using a random sample, stratified by age, from the Capital region of Denmark. An invitation letter was sent to a total of 1,900 children and their parents, of which 170 responded. Of these, 22 responded too late and nine dropped out. Additionally six children were recruited through worksites to ensure the target sample size. Children and parents, who volunteered to participate, were contacted by telephone and received further written information about the study. Written informed consent was obtained from a parent of each child prior to their participation.

Study design

The data collection took place between August 2008 and April 2009. Participation included completion of two non-consecutive 24-HDRs, a pre-coded 7-dFR and objective assessment of EE by use of ActiReg® during the same seven days as the 7-dFR was filled in. A flow chart of the measurements of dietary intake and energy expenditure is presented in Fig. 1. Trained interviewers visited the participants at their homes and conducted the 24-HDRs on two scheduled visits. The recalls were aimed to be separated by around 4 to 6 weeks. The mean number of days between the two 24-HDRs was 36 days (range 21–83) for the 7–8 year-olds and 39 days (range 28–76) for the 12–13 year-olds. All days of the week were randomly assigned for both recalls in order to obtain an equal representation of weekdays at group level. Anthropometric measurements were made after the recall at the first visit. After the recall at the second visit, participants were provided with detailed instructions on how to fill in the 7-dFR and how to use ActiReg® during the seven-day recording period. The recordings were started on the following day. Participants were instructed to report all food items consumed on the days with dietary intake assessment and to maintain their usual eating and activity patterns. For each participant, a minimum of four valid days with concurrent measurements from the 7-dFR and ActiReg® was required for inclusion in the analyses. The study was approved by the Ethical Committee of the Municipalities of Copenhagen and Frederiksberg and by the Danish Data Protection Agency.

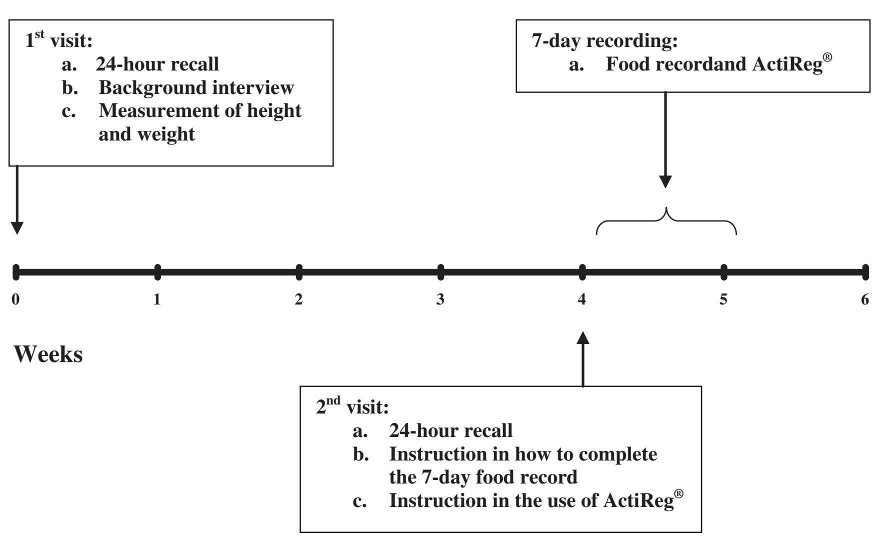

Fig. 1. Flow chart of the measurements of dietary intake, energy expenditure and anthropometry

Citation: Food & Nutrition Research 2012, **56**: 12221 - DOI: 10.3402/fnr.v56i0.12221

24-hour recalls

The 24-HDR method were based on face-to-face computer-assisted interviews using the standardised recall interview program EPIC-Soft (7), and comprised of four main steps:

(1) General information (non-dietary);
(2) Quick list (chronological list of consumed foods without quantification);
(3) Description and quantification of foods and recipes;
(4) Quality controls at the nutrient level.

One of the parents was present during the interviews and assisted with supplementary information when necessary (description of food intake, information about recipes, cooking methods etc.). The EPIC-Soft version employed was a country-specific version, updated prior to the study in order to cover new food items and to meet the specific requirements of this study. Participants received a food recording booklet for the children to take to school or to other places outside of the home on the days of assessment, i.e. the day before each 24-HDR. If relevant, proxy persons (school staff, day care staff, or others) were contacted in advance and asked to help the children with the booklet. The quantities of foods consumed were estimated from predefined household measures (cups, spoons, slices, etc.) or photos from the EPIC-Soft picture book. In addition, some country specific picture series on candy, rye- and wheat bread, and fat and filling on bread was used. The mean EI/day from the 2×24-HDRs ($EI_{2 \times 24\text{-HDR}}$) was calculated for each individual using the EPIC-Soft software and the Danish Food Composition Databank (version 7; Søborg; Denmark; December 2008, www.foodcomp.dk).

Pre-coded food record

Dietary intake was recorded every day for seven consecutive days in food records with pre-coded response categories, which included open answer options. The parents were responsible for completing the 7-dFR and deciding to what extent their children were capable of assisting. The 7-dFR, which was identical to the dietary assessment method used in the Danish National Survey of Dietary Habits and Physical Activity 2003–2008, was organised according to the typical Danish meal pattern (breakfast, lunch, dinner and in-between meals). Each meal was divided into sections with headings such as beverages, bread, spreadable fats, meat and vegetables to make it easier to find and record the relevant foods, dishes and beverages (9). For food items not included in the 7-dFR, the participants wrote type of food and portion size in open-answer categories. The quantities of foods consumed were given in predefined household measures (cups, spoons, slices, etc.) or estimated from photos of various portion sizes. Participants also received a food recording booklet for the children to take to school or to other places outside of the home on the days of assessment. Data were scanned using The Eyes & Hands program (version 5.2, 2005; Readsoft Ltd, Milton Keynes, Buckinghamshire, UK). The mean EI/day from the 7-dFR ($EI_{7\text{-dFR}}$) was calculated for each individual using the software system General Intake Estimation System (GIES) (version 0.995a, released 26 June 2005), developed at the National Food Institute, Technical University of Denmark (Søborg, Denmark), and the Danish Food Composition Databank (version 7; Søborg; Denmark; December 2008, http://www.foodcomp.dk).

ActiReg®

The ActiReg® system (PreMed AS, Norway) consists of a multisensor activity monitor (ActiReg®) and a computer program (ActiCalc32®) for processing the ActiReg® data. The monitor has two pairs of sensors – one body position sensor and one motion sensor in each pair – connected by thin cables to a battery-operated storage unit ($82 \times 45 \times 15$ mm) that was placed in an elastic belt around the waist. Each pair of sensors was attached by medical tape, one over the sternum and one at the front of the right thigh approximately midway between the hip and the knee. Stored data were transferred to a computer and processed by the ActiCalc32® program. More details about the use of the ActiReg® system and validation of the method are published elsewhere (10).

In the present study mean EE/day was calculated for each individual by the ActiCalc® program using estimated basal metabolic rate (BMR). Estimates of BMR were calculated from equations, based on age, gender, height and weight (11). Participants were instructed to carry ActiReg® for seven consecutive days during all waking hours except during activities in water, such as swimming, showering, etc., and if needed, during high contact sports. During the night when the children were sleeping, the ActiReg® equipment was taken off and placed in a horizontal position as this mimics the recording of lying still. If the monitor was taken off for a period of 15 minutes or more during daytime, the participants were instructed to record the duration and type of activity performed. A major part of the non-wear time was due to sports activities and subsequent showering and changing clothes. EE during non-wear time was therefore estimated as corresponding to an average activity level of moderate intensity (MET[1] = 3). To ensure that the majority of the waking hours was recorded, limits on total wear time and non-wear time were applied. Thus, if ActiReg® was not carried for three hours or more during daytime, and/or total wear time was less than 10 hours per day, the day was omitted from analysis (12, 13).

Anthropometric measurements

Height and body weight were measured twice in all participants and the mean values were used. Participants were weighed without shoes in light indoor clothing to the nearest 0.1 kg on a digital personal scale (Soehnle Verona 63686, Quattrotronic scale). Height was measured without shoes to the nearest cm with an ultrasonic height measuring device (Soehnle S20).

Definition of acceptable reporters and misreporters

The accuracy of the recorded EI was assessed using the confidence limits of agreement between recorded EI and EE at the individual level (14). Participants were classified as acceptable reporters, under-reporters, or over-reporters according to whether the individual's EI:EE ratio was within, below or above the 95% confidence limits of agreement between the two measurements (15). The 95% confidence limits of agreement between $EI_{2\times24\text{-HDR}}$ or $EI_{7\text{-dFR}}$ and EE were calculated as:

$$95\%\ \text{CL} = \pm 2\sqrt{(\text{CV}_{\text{EI}}^2/d) + (\text{CV}_{\text{EE}}^2/d)}$$

Here d is the number of days of assessment, and CV_{EI} and CV_{EE} are the pooled mean coefficients of variation in EI (by 2 × 24-HDRs or 7-dFR) and EE, respectively. For the 2 × 24-HDRs, the number of days was two. To account for the varying number of days (four to seven days) for the food record and the ActiReg® measurements, the mean number of days (6.2 days) was used.

Statistics

Sample size calculation was based on results from two previous studies, where ActiReg® was used to validate a pre-coded food record in children (16, 17). The SD of the mean difference between EE measured with ActiReg® and EI assessed with the food diary was 2 MJ. With a significance level of 0.05, and a power of 80%, 34 participants of each gender were needed in each age group to be certain of detecting a mean difference between EE and EI of 1 MJ.

Data of EI and EE were approximately normally distributed. Differences between EI and EE for groups of children and between the age groups and genders were analysed using paired and unpaired t-tests, respectively. Pearson's correlation coefficients were calculated between EI and EE. Agreement between measurements of EI and EE was visualised using the Bland Altman method of agreement analysis (18). Agreement on category level between EI and EE was examined by classification of EI into quartiles.

The method of triads was used to calculate validity coefficients between the unknown 'true' EI and EI estimated by the 7-dFR, EI estimated by the 2 × 24-HDRs and EE, respectively (19). If Q, R and M denote the measurements from the 2 × 24-HDRs, the 7-dFR and ActiReg® respectively, and T denotes the unknown 'true' EI, the validity coefficients can be calculated as follows:

$$\text{VC}_{QT} = \sqrt{r_{QR} \times r_{QM}/r_{RM}}$$

$$\text{VC}_{RT} = \sqrt{r_{QR} \times r_{RM}/r_{QM}}$$

$$\text{and VC}_{MT} = \sqrt{r_{QM} \times r_{RM}/r_{QR}}$$

where r_{QR} is the correlation between the 2 × 24-HDRs and the 7-dFR, r_{QM} the correlation between the 2 × 24-HDRs and the ActiReg®, and r_{RM} is the correlation between the 7-dFR and ActiReg®. This method assumes that the random measurement errors of the three methods are uncorrelated and that there is a positive linear association between each measurement and the true unknown value (19). The 95% confidence intervals for the validity coefficients were estimated using bootstrap sampling where 10,000 samples of equal size (i.e. the number of participants in the respective age group) were obtained by random sampling with replacement (19). The low number of subjects in each age group precluded the analysis being undertaken separately for each age group.

Differences between the two dietary assessment methods in the proportion of children classified as acceptable reporters, under- or over-reporters, respectively, were tested with the Stuart-Maxwell test. Multiple linear regression analyses were performed for each dietary assessment method with EI:EE as the dependent variable, and age, gender, BMI and parental educational as independent variables.

Statistical differences were considered significant at $P < 0.05$. Data were analysed with SPSS version 19.0 for Windows (SPSS Inc., Chicago, IL, USA) and R statistical software 2.9.1 (R Development Core Team, 2009 (http://www.r-project.org)).

Results

Study population

A total of 75 children aged 7–8 years and 70 children aged 12–13 years participated in the study. Data from 14 children were omitted; 12 of these due to invalid ActiReg® measurements, one due to illness during the recording period, and one with less than four completed days of the 7-dFR. Thus, complete records for 67 children aged 7–8 years and 64 children aged 12–13 years were analysed. Among these, 81% of the 7–8 year-old children and 78% of the 12–13 year-old children had six or seven days with data both from the 7-dFR and ActiReg®. For 94% of the children, at least one week-

[1]MET = Metabolic Equivalent, expressing the energy cost of physical activities as multiples of BMR

end day was included with the 7-dFR. At group level, a fairly equal representation of all days of the week was obtained with both dietary assessment methods for both age groups (data not shown). Mean wear time of the ActiReg® was 12.7 ± 0.6 hours/day for the 7–8 year-old children and 14.0 ± 0.7 hours/day for the 12–13 year-old children. Characteristics of the participants are presented in Table 1 for each age group.

Differences between EI and EE

In the group of 7–8 year-old children, there was a significant difference between $EI_{7\text{-dFR}}$ and EE ($P = 0.001$) but not between $EI_{2\times24\text{-HDR}}$ and EE (Table 2). In the 12–13 year-old children, both $EI_{2\times24\text{-HDR}}$ and $EI_{7\text{-dFR}}$ differed significantly from EE ($EI_{2\times24\text{-HDR}}$: $P < 0.001$; $EI_{7\text{-dFR}}$: $P < 0.001$). In the 7–8 year-olds, $EI_{2\times24\text{-HDR}}$ was 3% higher and $EI_{7\text{-dFR}}$ 7% lower than EE. In the 12–13 year-olds, $EI_{2\times24\text{-HDR}}$ was 10% lower and $EI_{7\text{-dFR}}$ 20% lower than EE. EE and $EI_{7\text{-dFR}}$ were significantly higher among boys than girls in both the 7–8 year-olds (EE: $P = 0.005$; $EI_{7\text{-dFR}}$: $P = 0.049$) and the 12–13 year-olds (EE: $P < 0.001$; $EI_{7\text{-dFR}}$: $P = 0.002$). $EI_{2\times24\text{-HDR}}$ was also higher among boys in the group of 12–13 year-old children ($P = 0.011$). However, the absolute differences between estimates of EI and EE, as well as the EI:EE ratios, did not differ between gender within each age group.

Agreement between EI and EE

The Pearson correlation coefficients between EI and EE were 0.29 for $EI_{7\text{-dFR}}$ and 0.51 for $EI_{2\times24\text{-HDR}}$ for both age groups combined. Bland-Altman plots showing the individual differences between values of EI and EE against the mean of EI and EE are presented for each age group and dietary assessment method in Fig. 2. The 95% limits of agreement were −2.42 and 2.93 MJ/d for the 2 × 24-HDRs and −3.56 and 2.32 for the 7-dFR in the 7–8 year-olds, and –5.69 and 3.39 MJ/d for the 2 × 24-HDRs and −7.36 and 2.59 MJ/d for the 7-dFR in the 12–13 year-olds. For both age groups combined, the 95% limits of agreement were −4.38 and 3.52 MJ/d for the 2 × 24-HDR and −5.90 and 2.94 MJ/d for the 7-dFR. The plots illustrate large variation in the degree of misreporting at individual level, and under-reporting as well as over-reporting was observed with both methods. The proportion of individuals correctly classified in the same quartile for both EI and EE are presented in Table 3. Using the method of triads for both age groups combined, the validity coefficient was of 0.81 (95% CI: 0.9 − 0.52) for $EI_{2\times24\text{-HDR}}$ and 0.46 (95% CI: 0.08–0.50) for $EI_{7\text{-dFR}}$.

Proportions of acceptable reporters, under-reporters and over-reporters

The 95% confidence limits of agreement for the ratios $EI_{2\times24\text{-HDR}}$:EE and $EI_{7\text{-dFR}}$:EE, defined acceptable reporters by having an EI:EE ratio within the range of 0.75–1.25 for the 2 × 24-HDRs and 0.77–1.23 for the 7-dFR. The proportions of acceptable reporters, under-reporters and over-reporters with each dietary assessment method are presented in Table 4. No differences between genders were observed. The proportion of children classified as acceptable reporters, under-reporters and over-reporters differed significantly between methods (7–8 year-olds: $P = 0.005$; 12–13 year-olds: $P = 0.015$).

Associations between EI:EE and background characteristics

In multiple linear regression models with EI:EE as the dependent variable, and age, gender, BMI and parental educational level as independent variables, age remained significantly associated with $EI_{2\times24\text{-HDR}}$:EE ($P = 0.006$), whereas BMI remained significantly associated with $EI_{7\text{-dFR}}$:EE ($P < 0.001$). When entered one-by-one in the multiple linear regression model, BMI and age were significantly associated with EI:EE for both dietary assessment methods ($P < 0.001$).

Discussion

In the 7–8 year-old children, a modest misreporting was observed with both methods, as EI was 3% higher than EE with the 2 × 24-HDRs and 7% lower than EE with the 7-dFR. Under-reporting seemed more pronounced in the group of 12–13 year-old children, where EI was 10% lower than EE with the 2 × 24-HDRs and 20% lower than EE with the 7-dFR. The tendency towards increasing under-reporting with increasing age from childhood to adolescence is well known, and the assessment of dietary intake in older children and adolescents is recognised as particularly challenging (2, 20).

The degree of misreporting of EI in the present study is generally in accordance with findings from several other validation studies of multiple 24-HDRs and pre-coded food records in children, using doubly labeled water as a reference method (2, 20–23). Moreover, over-reporting has been found to be more often associated with 24-HDRs than with food records (3).

In two validation studies among Norwegian 9 year-old and 13 year-old children, EI estimated from pre-coded food records was also evaluated against EE estimated with ActiReg® (16, 17). The authors observed that under-reporting of EI was somewhat higher than in the present study, i.e. 18% in the 9 year-olds and 24–34% in the 13 year-olds. Hence, the proportions of children classified as UR with the food record were larger in these Norwegian studies than in the present study. The high

Table 1. Characteristics of the participants in each age group

	7–8 years old						12–13 years old					
	Boys (*n* = 32)		Girls (*n* = 35)		All (*n* = 67)		Boys (*n* = 32)		Girls (*n* = 32)		All (*n* = 64)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	7.5	0.5	7.6	0.6	7.5	0.5	12.6	0.6	12.7	0.7	12.5	0.5
Height (cm)	131	6	132	5	131	5	161	10	160	7	161	8
Weight (kg)	27.4	3.2	28.8	4.8	28.1	4.2	52.2	12.8	49.5	8.6	50.9	10.9
BMI (kg/m^2)	16.0	1.3	16.5	2.0	16.3	1.7	19.9	3.5	19.3	2.7	19.6	3.2
Parental education (%)*												
1: Basic school	21.9		8.6		14.9		15.6		40.6		28.1	
2: Vocational education	12.5		5.7		9.0		12.5		12.5		12.5	
3: Short higher education	34.4		54.3		44.8		37.5		34.4		35.9	
4: Long higher education	31.3		31.4		31.3		34.4		12.5		23.4	

BMI, body mass index

*Parental educational level. 1: Basic school (10 years or less of total education); 2: Vocational education, upper secondary school (10–12 years); 3: Short higher education (13–15 years) (primarily theoretical); 4: Long higher education (15+ years) (primarily theoretical).

Table 2. Energy intake estimated with 2 × 24-HDRs (EI$_{2\times 24\text{-HDR}}$) and a seven-day food record (EI$_{7\text{-dFR}}$), energy expenditure estimated with ActiReg® (EE), and the relationship between estimates of EI and EE in each age group

	7–8 years old						12–13 years old					
	Boys (*n* = 32)		Girls (*n* = 35)		All (*n* = 67)		Boys (*n* = 32)		Girls (*n* = 32)		All (*n* = 64)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
EI$_{2\times 24\text{-HDR}}$ (MJ/d)*	9.2[a]	1.6	8.7[a]	1.4	9.0	1.5	10.6[a]	2.6	9.1[b]	2.0	9.9	2.4
EI$_{7\text{-dFR}}$ (MJ/d)†	8.5[a]	1.7	7.7[b]	1.2	8.1	1.5	9.4[a]	2.1	7.9[b]	1.6	8.6	2.0
EE (MJ/d)	9.0[a]	0.9	8.4[b]	0.9	8.7	0.9	12.1[a]	2.1	10.0[b]	1.0	11.0	2.0
EI$_{2\times 24\text{-HDR}}$-EE (MJ/d)	0.2[a]	1.3	0.3[a]	1.4	0.3	1.3	−1.5[a]	2.5	−0.8[a]	2.0	−1.2	2.3
EI$_{7\text{-dFR}}$-EE (MJ/d)	−0.6[a]	1.5	−0.7[a]	1.4	−0.6	1.5	−2.7[a]	3.0	−2.1[a]	1.9	−2.4	2.5
EI$_{2\times 24\text{-HDR}}$/EE (MJ/d)	1.02[a]	0.14	1.04[a]	0.16	1.03	0.15	0.89[a]	0.21	0.92[a]	0.19	0.90	0.20
EI$_{7\text{-dFR}}$/EE (MJ/d)	0.94[a]	0.17	0.93[a]	0.17	0.93	0.16	0.80[a]	0.20	0.80[a]	0.18	0.80	0.19

[a,b]Mean values within a column with unlike superscript letters were significantly different ($P < 0.05$).

*Mean values for EI$_{2\times 24\text{-HDR}}$ were significantly different from EE in the group of 12–13 year-olds ($P < 0.001$).

†Mean values for EI$_{7\text{-dFR}}$ were significantly different from EE in the group of 7–8 year-olds ($P = 0.001$) and 12–13 year-olds ($P < 0.001$).

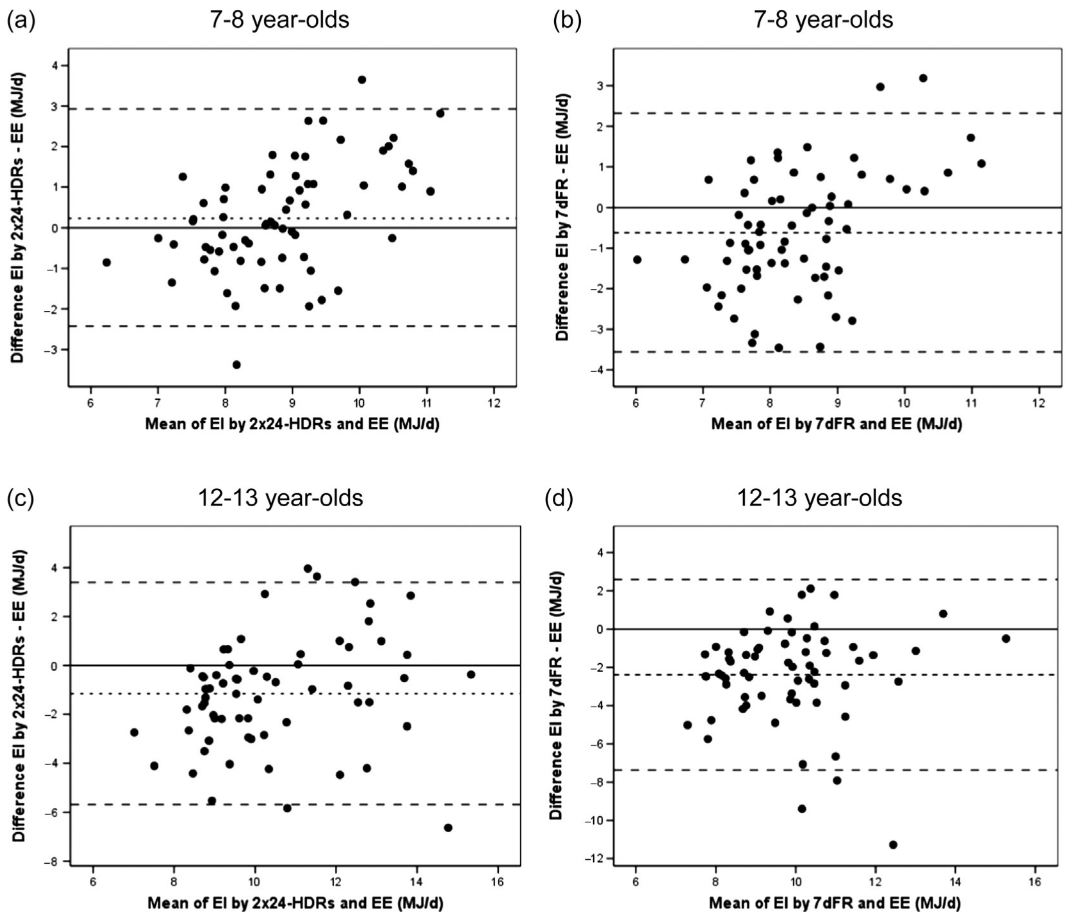

Fig. 2. Bland-Altman plots: the difference between estimated energy intake (EI) and energy expenditure (EE) estimated with ActiReg®, plotted against the mean of EI and EE: a and b) 7–8 year-old children ($n = 67$); c and d) 12–13 year-old children ($n = 64$). (—) upper and lower limits of agreement; (. . .) mean difference between EI and EE.

degree of under-reporting in the two Norwegian studies might partly be related to the use of a school class setting, which, in contrast to the present study, may have caused the children to become more physically active because of competition with each other.

Both the 2 × 24-HDRs and the 7-dFR had a high ability to rank subjects in correct and adjacent quartiles in both age groups. Moreover, the 2 × 24-HDRs appeared to perform slightly better in ranking of individuals. As illustrated in the Bland-Altman plots, large variation at the individual level occurred in both age groups. However, accuracy at the individual level is generally poor in validation studies of EI (2). Furthermore, since the use of objective measurements of EE as a reference for evaluation of EI measurements is based on the assumption of energy balance, exact agreement between EI and EE at the individual level is unlikely during a short recording period due to normal day-to-day variation in both EI and EE (14).

In studies like the present one, where data from a dietary assessment method, a reference method and a biomarker, or another objective method is available, the method of triads can be used. This method is a triangular approach that uses the correlations between each of the three methods to estimate a validity coefficient (VC). This coefficient expresses the correlation between reported intake and the unknown 'true' intake (19). In accordance with the other analyses from the present study, the higher validity coefficients of $EI_{2 \times 24\text{-HDR}}$

Table 3. Proportions of individuals correctly classified in the same quartile for EI estimated with 2 × 24-HDRs ($EI_{2 \times 24\text{-HDR}}$) and energy expenditure estimated with ActiReg® (EE), and for EI estimated with a seven-day food record ($EI_{7\text{-dFR}}$) and EE, respectively, in each age group, (% (n))

	7–8 years old ($n = 67$)		12–13 years old ($n = 64$)	
	$EI_{2 \times 24\text{-HDR}}$	$EI_{7\text{-dFR}}$	$EI_{2 \times 24\text{-HDR}}$	$EI_{7\text{-dFR}}$
Same quartile	46 (31)	30 (20)	36 (23)	34 (22)
Same or adjacent quartile	76 (51)	73 (49)	83 (53)	70 (45)
Gross miss classification	3 (2)	7 (5)	3 (2)	11 (7)

Table 4. Proportions of acceptable reporters, under-reporters and over-reporters defined for the 2 × 24-HDRs and the seven-day food record (7-dFR) in each age group*, (% (n))

	7–8 years old (n = 67)†		12–13 years old (n = 64)‡	
	2 × 24-HDRs	7-dFR	2 × 24-HDRs	7-dFR
Acceptable reporters	93 (62)	81 (54)	70 (45)	58 (37)
Under-reporters	2 (1)	16 (11)	23 (15)	42 (27)
Over-reporters	6 (4)	3 (2)	6 (4)	0 (0)

*Participants were classified as acceptable reporters, under-reporters, or over-reporters according to whether the individual's EI:EE ratio was within, below or above the 95% confidence limits of agreement between the two measurements.
†Proportions were significantly different between methods (P = 0.005).
‡Proportions were significantly different between methods (P = 0.015).

(VC: 0.81) than of $EI_{7\text{-dFR}}$ (VC: 0.46) indicated that EI was closer to the unknown 'true' value when estimated with the 2 × 24-HDRs than with the 7-dFR. The method of triads assumes that the random measurement errors of the three methods are uncorrelated, however, it must be recognised, that some degree of correlation cannot be ruled out between the two dietary assessment methods.

A possible reason for why reported EI was higher with the 2 × 24-HDRs than with the 7-dFR, is that the design with a comprehensive interview incorporates a great effort in collecting every detail of the dietary intake. This includes a thorough question technique using systematic probing questions and a personal contact with the interviewer during the recalls, which may help both children and their parents in reporting all relevant information and in keeping their motivation high.

Although these aspects of the recalls may have several advantages, social desirability is a prominent source of bias in dietary assessment that may be enhanced by the personal contact with an interviewer and thus have more influence on the reporting with the 2 × 24-HDRs than with the 7-dFR (25, 26). Both children's self-reported dietary intake as well as their actual intake may be biased by the awareness of the reporting. Moreover, parents may wish to appear as having good parenting skills and let this influence the children's food intake on reporting days. With both methods, participants knew in advance which days the dietary intake was going to be reported. As it may be easier to keep a more socially desirable diet on two non-consecutive days than during seven consecutive days, modification of the children's dietary intake might have been more likely with the 2 × 24-HDRs. This notion was supported by analyses of the nutrient and food intake, which showed a tendency for the participants to report a healthier diet with the 2 × 24-HDRs than with the 7-dFR, as discussed by Trolle et al. (8).

Similar to findings from other studies (23, 27), a tendency towards increasing underreporting with increasing BMI was observed. Understanding why and how misreporting occurs is complicated, and the psychosocial and behavioural aspects related to misreporting is difficult to assess (25).

The reference method and the test method should preferably cover the same time period, however, this was only possible with the 7-dFR and not the 2 × 24-HDRs. Due to the logistic difficulties of getting the ActiReg® to the participants before each recall, as well as the high participation burden, the EE measurements were obtained only on the same days as the food record was filled in. Recording over a week is often used to reflect the habitual behaviour in studies of dietary intake and physical activity (9).

EE measurements in the present study was obtained by use of ActiReg®, as this was a validated method (10), which has been used to measure total EE in other validation studies in children (16, 17). The ActiReg® system uses the combined recording of body position and movement to assess energy expenditure, and has demonstrated a close relationship at group level with DLW in young adults (10). However, like other objective instruments used to measure EE in free-living subjects, ActiReg® shows considerable variation at the individual level, and the use of ActiReg® has some limitations, including the ability to detect high intensity physical activity, arm work, carrying loads and water activities, while certain moderate intense physical activities such as walking and running slowly may tend to be overestimated (10, 28). These issues might introduce a larger source of measurement error in children than in adults since the algorithms used, were initially developed for adults.

Strengths of the present study include that EE was measured with an objective method that is likely to have a minimum of correlated errors with the two dietary assessment methods. Moreover, the design allowed two dietary assessment methods to be compared with objective measurements of EE, which also enabled us to use the method of triads. The method of triads has been used in other studies for validation of nutrient intake and for validation of biomarkers for intake of different nutrients (29, 30), but to our knowledge, use of the method of triads to compare EI from two different dietary recording methods with objective measurements of EE has not been presented before.

Given the heavy workload of the study, it must be recognised that the sample of participants are volunteers, higher educated than the general Danish population and most probably more motivated and health conscious than usual.

Citation: Food & Nutrition Research 2012, **56**: 12221 - DOI: 10.3402/fnr.v56i0.12221

Conclusion

At group level, misreporting of EI seemed modest with both the 2 × 24-HDRs and the 7-dFR in the 7–8 year-olds when compared to EE measured with ActiReg®. Under-reporting appeared to be more evident in the 12–13 year-olds, especially with the 7-dFR. Compared to measurements of EE, the 2 × 24-HDRs seemed to perform slightly better than the 7-dFR in terms of ranking of individuals according to EI.

Acknowledgements

The authors are grateful to the interviewers Anne Arendt, Mia Hjort Frandsen and Inger Merete Licht Hansen, the data management team, Karsten Kørup, Henrik Hartkopp, Karin Hess Ygil and Tue Christensen, and to Majken Ege for taking care of coordinating activities. Furthermore, the authors express their appreciation to all the participating children, parents and other proxy persons. The authors acknowledge community funding under the Sixth Framework Program for the EFCOVAL project (FOOD-CT-2006-022895). The content of this article reflects only the author's views and the Community is not liable for use that may be made of the information contained therein. B.W.R. participated in the data collection, analysed the data and wrote the manuscript. E.T. and L.F.A., as part of the EFCOVAL consortium, were responsible for the study design. J.M., M.V.G., P.B.B., L.F.A. and E.T. participated in critical revision of the manuscript and the statistical analyses.

Conflict of interest and funding

None of the authors had a financial or personal conflict of interest. There was community funding under the Sixth Framework Program for the EFCOVAL project (FOOD-CT-2006-022895).

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*Berit W. Rothause
Division of Nutrition, National Food Institute
Technical University of Denmark
Mørkhøj Bygade 19
DK-2860 Søborg
Denmark
Tel: +45 3588 7158
Fax: +45 3588 7119
Email: bewro@food.dtu.dk

Paper II

Differences in Danish children's diet quality on weekdays vs. weekend days

Rothausen BW[1], Matthiessen J[1], Hoppe C[1], Andersen LF[2], Brockhoff PB[3], Tetens I[1]

[1]Division of Nutrition, National Food Institute, Technical University of Denmark, Søborg, Denmark
[2]Department of Nutrition, Institute of Basic Medical Sciences, University of Oslo, Oslo, Norway
[3]Department of Informatics and Mathematical Modeling, Technical University of Denmark, Kongens Lyngby, Denmark

Public Health Nutr. 2012 May 25:1-8

Public Health Nutrition: page 1 of 8 doi:10.1017/S1368980012002674

Differences in Danish children's diet quality on weekdays v. weekend days

Berit W Rothausen[1,*], Jeppe Matthiessen[1], Camilla Hoppe[1], Per B Brockhoff[2], Lene F Andersen[3] and Inge Tetens[1]
[1]Division of Nutrition, National Food Institute, Technical University of Denmark, Mørkhøj Bygade 19, DK-2860 Søborg, Denmark: [2]Department of Informatics and Mathematical Modeling, Technical University of Denmark, Kongens Lyngby, Denmark: [3]Department of Nutrition, Institute of Basic Medical Sciences, University of Oslo, Oslo, Norway

Submitted 1 December 2011: Final revision received 16 March 2012: Accepted 17 April 2012

Abstract

Objective: To compare differences in children's diet quality on weekdays (Monday–Thursday), Fridays and weekend days.
Design: A representative cross-sectional study in which participants completed a 7 d pre-coded food record. Mean intakes of energy, macronutrients and selected food items (g/10 MJ) as well as energy density were compared between weekdays, Fridays and weekend days for each gender in three age groups (4–6, 7–10 and 11–14 years) using Tobit analysis to account for zero intakes.
Setting: The Danish National Survey of Dietary Habits and Physical Activity 2003–2008.
Subjects: Children (*n* 784; 49·9 % boys) aged 4–14 years.
Results: For both genders in all age groups ($P < 0·05$), energy intake was higher during weekends than on weekdays, and intakes of sugar-sweetened beverages and white bread were higher, whereas intake of rye bread was lower. This contributed to a higher percentage of energy from added sugars, a lower fibre content and a higher energy density on weekend days *v.* weekdays. In children aged 4–6 and 7–10 years, the diet on weekend days was also characterized by higher intakes of sweets and chocolate and lower intakes of fruit and vegetables. Overall, the diet on Fridays appeared as a mix of the diets on weekdays and weekend days.
Conclusions: Significant differences and distinct characteristic patterns were found in children's diet quality during weekdays, Fridays and weekend days. The present study suggests that in prevention of childhood overweight and obesity, more attention should be paid to the higher energy intake, especially from sugar-rich foods and beverages, on Fridays and weekend days.

Keywords
Dietary assessment
Food record
Week

Dietary intake plays an important role in the prevention of chronic diseases[1,2] and the adverse effects of children's unhealthy eating behaviours, in particular the increasing prevalence of childhood overweight and obesity, have become a significant public health challenge[3]. Unfavourable diets in childhood may have long-term implications, especially as tracking of overweight from childhood to adulthood occurs, and thereby increase the risk of subsequent morbidity and mortality[4,5]. The evidence of consistency in relation to dietary habits in children is limited and most studies report only poor to moderate stability over time, indicating that the diets of children are potentially modifiable[6].

Compared with food-based dietary guidelines and nutritional recommendations, many children generally consume too little fruit and vegetables, fish and fibre, and too much of foods high in fat and sugar[7,8]. As improved nutrition is a key factor in promoting health, growth and development in children, there is an obvious need to address this issue.

It has been suggested that family factors and the nature of foods available at home, in schools and in fast-food establishments are some of the most significant determinants of the eating habits of children[9]. In this context, weekdays and weekend days differ in many ways, both structurally and culturally, which may influence dietary intake patterns, for example through more access to food and snacks, together with likely expectations of fewer restrictions on weekend days than during weekdays. Periods of holidays and summer vacations have been associated with increases in weight status in both children[10] and adults[11], and similar differences may apply on a smaller scale to weekends.

*Corresponding author: Email bewro@food.dtu.dk

Previous research in children has suggested that snacking and other daily eating patterns differ on weekdays compared with weekend days in a way that may have an impact on the overall diet quality on these days[12,13]. Moreover, Friday stands out as a weekday on which the diet may resemble both weekdays and weekend days in terms of diet quality. However, few studies have considered these issues of dietary intake. The objective of the present study was therefore to compare differences in diet quality on weekdays (Monday–Thursday), Fridays and weekend days in a simple random sample of Danish children.

Methods

Sample

Data for the present study were derived from the Danish National Survey of Dietary Habits and Physical Activity 2003–2008, which is a nationwide cross-sectional survey. The study population comprised a simple random sample of 4–14-year-old children, retrieved from the Central Office of Civil Registration. Participants received an invitation letter and were afterwards contacted by telephone. For the families who agreed to participate, written informed consent was obtained from a parent of each child prior to their participation. In comparison with census data from Statistics Denmark, the distribution of gender and age of the participants could be characterized as representative for the Danish population of children aged 4–14 years.

Assessment of dietary intake

Dietary intake was recorded every day for seven consecutive days in food records with pre-coded response categories, which included open answer options. Children and their parents were instructed in person by trained interviewers on how to complete the food records. The parents were responsible for completing the records and for deciding to what extent their children were capable of assisting. The food record was organized according to the typical Danish meal pattern (breakfast, lunch, dinner and in between meals). Each meal was divided into sections with headings such as beverages, bread, spreadable fats, meat and vegetables to make it easier to find and record the relevant foods, dishes and beverages. For food items not included in the pre-coded food record, the participants wrote the type of food and portion size eaten in open answer categories. The quantities of foods consumed were given in predefined household measures (cups, spoons, slices, etc.) or estimated from photographs in a picture book containing fourteen series of food photographs, each series showing four to six different portion sizes. As a supplement to the food record, participants also received a food recording booklet for the children to take to school or to other places outside their home on the days of assessment. Intakes of energy, nutrients and food items were calculated for each individual using the software system GIES version 0·995a (developed at the National Food Institute, Technical University of Denmark, Søborg, Denmark) and the Danish Food Composition Databank version 7 (www.foodcomp.dk). Validation of the method for children and adults is described elsewhere[14,15].

Besides energy intake and macronutrients, a number of food items were selected to give an indication of the diet quality. The selection of variables was based on the work of Sepp *et al.*[16] and the Nordic Monitoring project[17], which has shown that the intake of certain food groups explains a considerable part of the variation in the relative content of total fat, saturated fat, added sugars and dietary fibre in the diet. The intake of these food groups is therefore particularly useful in the assessment of overall nutritional quality of the diet. Energy density of the diet was calculated separately for (i) solid foods and liquids consumed as food (e.g. soups and yoghurt) and (ii) beverages, including both energy-containing and non-energy-containing beverages (e.g. milk/juice and water/tea, respectively) and presented as kJ/100 g. Furthermore, dietary intake based on the average intake during the week was compared with the nutritional recommendations for added sugars, saturated fat, fish and fruit and vegetables[18,19].

Definition of weekdays and weekend days

Weekdays and weekend days were defined as Monday to Thursday and as Saturday and Sunday, respectively. Preliminary analysis showed that intakes on Friday differed from those on both Monday to Thursday and Saturday and Sunday. Therefore Friday was kept as a period of its own, instead of making a dichotomous weekday/weekend day variable.

Weight status

Information about the children's height and weight was obtained through a personal face-to-face interview with one of the parents, referred to as the 'responding parent', which was the mother in 87 % of cases. Prevalence of overweight and obesity in the study sample was defined according to international age- and gender-specific BMI cut-off values for children and adolescents[20] corresponding to BMI values of ≥25 and ≥30 kg/m^2, respectively, for adults aged ≥18 years.

Parental education

The educational level of the responding parent was defined in four categories: (i) basic school (10 years or less of total education); (ii) vocational education, upper secondary school (10–12 years); (iii) short higher education (13–15 years, primarily theoretical); and (iv) long higher education (15 + years, primarily theoretical).

Definition of under-reporters and over-reporters

Prevalence of misreporters was assessed by evaluating the 95 % confidence limits of agreement between recorded energy intake and estimated BMR on the individual level. The Goldberg's cut-off 2 criterion was used[21], which takes into account age- and gender-specific values for physical activity. Physical activity level values corresponding to light physical activity were used to define cut-off values for under-reporters and over-reporters, respectively[22]. Estimates of BMR were calculated from equations based on age, gender, height and weight[23].

Statistical analyses

The main analyses were performed separately for the three age groups, 4–6 years, 7–10 years and 11–14, years due to the wide age range of children in the study population and associated different degree of parental influence on the diet and diet recording. Differences between gender regarding height, weight and BMI were analysed using Student's *t* test, whereas differences between age groups regarding height, weight and BMI were analysed using one-way ANOVA and Tukey's *post hoc* test. Differences regarding parental education and weight status were assessed between gender and between age groups using the χ^2 test and Fisher's exact test.

Differences in energy intake, macronutrient intake and energy density for weekdays *v.* weekend days, Fridays *v.* weekdays and Fridays *v.* weekend days were analysed using Student's *t* test. For some of the food items, especially sausages, full-fat cheese, fries and fried potatoes and rye bread, a high percentage of the children (up to 79 % within the three age groups) had zero intakes during the week. To account for zero intakes, these variables were compared between weekdays, Fridays and weekend days using Tobit regression analysis, which includes the zero observations in the analysis by combining the binary information of intake *v.* zero intake with the quantitative intake values for the non-zero cases. Mean values and standard deviations were used to describe the diet, because some of the medians were equal to or close to zero.

Data were analysed separately for boys and girls due to significant gender differences in dietary intake in the preliminary analyses. Since the dietary intake analyses included multiple tests, Bonferroni corrections with $k = 3$ were performed. The unit g/10 MJ was used to take differences in total energy intake into account and to assess the quality of the diet, rather than absolute intakes. Data were analysed with the SPSS for Windows statistical software package version 19·0 (SPSS Statistics, Inc., Chicago, IL, USA) and the R statistical software version 2·13·2 (2009; R Development Core Team, http://www.r-project.org) with a significance level of $P < 0·05$.

Results

Study population

A total of 1294 children were invited to participate and 1006 (78 %) children accepted. After exclusion of incomplete dietary recordings, data from 784 (61 %) children with seven consecutive days of dietary recording and information about BMI and parental educational level were available for analysis. The group of excluded children (*n* 222) comprised 27 % 4–6-year-olds, 32 % 7–10-year-olds and 41 % 11–14-year-olds. Characteristics of the study population are presented for each age group in Table 1. Within each age group no gender differences were found regarding height, weight, BMI and parental education. Furthermore, no gender differences were observed with regard to weight status for the 7–10- and

Table 1 Characteristics of the study population: children aged 4–14 years, the Danish National Survey of Dietary Habits and Physical Activity 2003–2008

	4–6 years (*n* 207)		7–10 years (*n* 287)		11–14 years (*n* 290)		
	Mean	SD	Mean	SD	Mean	SD	*P* value*
Gender, boys/girls (%)	50/50		53/47		47/53		0·303
Height (cm)	118[c]	9	139[b]	9	161[a]	10	<0·001
Weight (kg)	22·0[c]	4·3	32·8[b]	7·5	49·9[a]	10·7	<0·001
BMI (kg/m^2)	15·6[c]	1·9	16·8[b]	2·6	19·1[a]	3·0	<0·001
Weight status† (%)							
Normal weight, boys/girls	91·3/80·6		82·2/81·5		79·3/82·6		0·074/0·981
Overweight, boys/girls	8·7/15·5		13·8/14·1		17·8/14·2		
Obese, boys/girls	0/3·9		3·9/4·4		3·0/3·2		
Parental education‡ (%)							
Basic school	8·7		8·7		11·7		0·117
Vocational education	41·5		43·9		42·4		
Short higher education	8·2		10·1		14·5		
Long higher education	41·5		37·3		31·4		

[a,b,c]Mean values within a row with unlike superscript letters were significantly different between age groups ($P < 0·001$).
*Differences between age groups tested using the χ^2 test for gender distribution and parental education, by one-way ANOVA for height, weight and BMI, and by Fisher's exact test for weight status.
†Weight status according to international cut off values[20]. Weight status differed significantly between genders in the 4–6-year-old children ($P = 0·034$), but not in the 7–10-year-olds ($P = 0·975$) or in the 11–14-year-olds ($P = 0·705$).
‡Parental educational level: basic school = 10 years or less of total education; vocational education, upper secondary school = 10–12 years; short higher education = 13–15 years (primarily theoretical); long higher education = 15 + years (primarily theoretical).

Public Health Nutrition

Table 2 Dietary content by gender on weekdays (Monday–Thursday), Fridays and weekend days (Saturday and Sunday): 4–6-year-old children, the Danish National Survey of Dietary Habits and Physical Activity 2003–2008

	Boys, 4–6 years (*n* 104)						Girls, 4–6 years (*n* 103)					
	Weekdays		Friday		Weekend days		Weekdays		Friday		Weekend days	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Energy and nutrients												
Energy (MJ/d)	7·5^{b}	1·8	8·3^{a}	2·6	8·4^{a}	2·7	6·6^{b}	1·4	7·2^{a}	2·1	7·4^{a}	1·7
Total fat (E%)	33^{b}	5	34^{a,b}	7	35^{a}	6	34^{a}	5	32^{b}	7	35^{a}	6
SFA (E%)	14	3	14	3	15	3	15	3	14	3	15	3
MUFA (E%)	11^{b}	2	12^{a,b}	3	12^{a}	2	11^{a}	2	11^{b}	3	12^{a}	3
PUFA (E%)	5	1	5	1	5	1	5^{a}	1	4^{b}	1	5^{a}	1
Carbohydrates (E%)	52	5	52	7	51	6	51^{b}	5	54^{a}	7	52^{b}	6
Added sugars (E%)	9^{b}	5	14^{a}	8	13^{a}	6	10^{b}	4	15^{a}	8	14^{a}	5
Fibre (g/10 MJ)	25^{a}	6	22^{b}	8	20^{c}	6	25^{a}	6	21^{b}	7	19^{c}	5
Protein (E%)	15^{a}	2	14^{b}	3	14^{b}	3	15^{a}	2	14^{b}	3	13^{c}	2
Foods (g/10 MJ)												
Vegetables	174^{a}	104	144^{a,b}	139	133^{b}	114	178^{a}	94	141^{a,b}	165	129^{b}	90
Fruit	276^{a}	163	255^{a,b}	262	189^{b}	171	273^{a}	164	218^{a,b}	184	205^{b}	198
Fish	18^{a}	21	14^{b}	33	18^{a,b}	27	19^{a}	23	14^{b}	42	14^{a,b}	2
Rye bread	101^{a}	49	83^{b}	58	62^{c}	46	86^{a}	46	86^{a}	63	55^{b}	41
White bread	46^{b}	40	38^{c}	50	69^{a}	53	44^{a}	40	49^{a}	64	69^{b}	47
Butter on bread	14	14	12	17	15	15	16	15	16	15	18	13
Full-fat cheese	4	8	6	13	4	10	6	11	5	13	4	10
French fried potatoes	11	21	22	44	19	34	18^{a}	27	18^{b}	44	29^{a}	44
Sausages	6	14	11	38	12	28	11^{a}	21	7^{b}	31	11^{a,b}	35
Sweets & chocolate	11^{b}	14	38^{a}	44	28^{a}	31	15^{c}	15	55^{a}	52	29^{b}	27
Cakes & biscuits	33	39	46	77	46	50	29^{b}	37	34^{b}	60	50^{a}	49
SSB	183^{b}	234	273^{a,b}	350	274^{a}	245	154^{b}	184	274^{a,b}	330	259^{a}	219
Energy density (kJ/100 g)												
Energy density, foods	704^{b}	127	794^{a}	220	844^{a}	197	712^{b}	140	826^{a}	229	864^{a}	204
Energy density, beverages	100^{b}	42	104^{b}	52	121^{a}	48	112^{b}	49	117^{b}	53	131^{a}	49

E%, percentage of energy intake; SSB, sugar-sweetened beverages.
a,b,c For each gender group, mean values within a row with unlike superscript letters were significantly different ($P<0·05$).

11–14-year-old children, but there were more overweight and obese girls than boys in the 4–6-year-old children ($P=0·034$). Height, weight and BMI were all significantly different between age groups ($P<0·001$), whereas there were no significant differences between age groups regarding gender distribution, weight status and parental education. The prevalence of identified under-reporters was 1·0 % in the 4–6-year-olds, 3·8 % in the 7–10-year-olds and 16·6 % in the 11–14-year-olds. The number of under-reporters did not differ between genders.

Based on the average intake during the week, boys had a significantly higher total energy intake than girls in all three age groups (4–6 years: boys 7·87 (SD 1·87) MJ/d *v.* girls 6·91 (SD 1·34) MJ/d, $P<0·001$; 7–10 years: boys 8·79 (SD 1·94) MJ/d *v.* girls 8·19 (SD 2·03) MJ/d, $P=0·01$; 11–14 years: boys 9·57 (SD 2·83) MJ/d *v.* girls 7·74 (SD 1·99) MJ/d, $P<0·001$).

A large proportion of the children did not meet the nutritional recommendations of keeping the percentage of energy from added sugars below 10 % (66 % of the children) and the percentage of energy from saturated fat below 10 % (96 % of the children)[18]. A total of 89 % of the children did not reach the recommended intake of fish of at least 200 g/week, and the recommended intake of fruit and vegetables was not met by 66 % of the 4–10-year-old children (recommended intake of 400 g/d) and by 91 % of the 11–14-year-olds (recommended intake of 600 g/d)[19].

Food and nutrient intakes

Mean intakes of energy, macronutrients, selected food items and energy density of the diet on weekdays, Fridays and weekend days are presented for each age group in Tables 2–4. The following results were all statistically significant at a significance level of $P<0·05$.

Weekdays v. *weekend days*

For both boys and girls in all three age groups, energy intake was consistently higher on weekend days than on weekdays. Furthermore, the percentage of energy from added sugars was higher, whereas the fibre content and the percentage of energy from protein were lower on weekend days compared with weekdays. The diet also contained a higher amount of sugar-sweetened beverages (SSB) and white bread, and a lower amount of rye bread on weekend days *v.* weekdays. In addition, the energy density of foods as well as of beverages was higher on weekend days than on weekdays. Boys and girls aged 4–6 and 7–10 years also had higher intakes of sweets and chocolate and lower intakes of fruit and vegetables on weekend days compared with weekdays.

Table 3 Dietary content by gender on weekdays (Monday–Thursday), Fridays and weekend days (Saturday and Sunday): 7–10-year-old children, the Danish National Survey of Dietary Habits and Physical Activity 2003–2008

	Boys, 7–10 years (*n* 152)						Girls, 7–10 years (*n* 135)					
	Weekdays		Friday		Weekend days		Weekdays		Friday		Weekend days	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Energy and nutrients												
Energy (MJ/d)	8·4^{c}	1·9	9·8^{a}	3·3	9·0^{b}	2·7	7·8^{b}	2·4	9·0^{a}	2·9	8·6^{a}	2·3
Total fat (E%)	33^{b}	5	32^{b}	7	34^{a}	6	33	5	32	6	33	6
SFA (E%)	14^{a,b}	3	13^{b}	4	14^{a}	3	14^{a}	3	13^{b}	3	14^{a,b}	3
MUFA (E%)	11^{b}	2	11^{b}	3	12^{a}	3	11^{a,b}	2	11^{b}	3	11^{a}	2
PUFA (E%)	5	1	5	2	5	1	5	1	5	1	5	1
Carbohydrates (E%)	52^{b}	6	55^{a}	7	52^{b}	7	52^{b}	5	55^{a}	7	53^{a,b}	6
Added sugars (E%)	11^{b}	5	15^{a}	8	15^{a}	7	10^{b}	4	16^{a}	8	16^{a}	7
Fibre (g/10 MJ)	23^{a}	7	21^{b}	8	18^{c}	6	24^{a}	6	21^{b}	7	18^{c}	5
Protein (E%)	15^{a}	2	14^{b}	3	14^{b}	3	15^{a}	2	13^{b}	3	13^{b}	3
Foods (g/10 MJ)												
Vegetables	167^{a}	103	154^{a,b}	138	130^{b}	118	180^{a}	117	173^{a}	137	118^{b}	103
Fruit	260^{a}	204	197^{b}	235	157^{b}	151	274^{a}	200	215^{b}	221	184^{b}	173
Fish	13	17	16	44	19	39	12	17	17	47	14	22
Rye bread	72^{a}	55	60^{b}	64	46^{b}	45	73^{a}	50	60^{b}	58	44^{b}	42
White bread	54^{b}	48	57^{b}	72	78^{a}	62	61^{b}	47	56^{b}	61	77^{a}	48
Butter on bread	10	11	9	12	12	13	12	11	10	12	12	12
Full-fat cheese	5^{a}	10	3^{b}	10	6^{a}	12	3^{a}	7	3^{b}	10	4^{a,b}	11
French fried potatoes	18	28	23	52	27	43	15^{a,b}	23	16^{b}	45	21^{a}	35
Sausages	6^{a,b}	15	8^{b}	33	13^{a}	36	5	14	6	24	9	23
Sweets & chocolate	13^{c}	16	43^{a}	45	26^{b}	28	18^{b}	23	46^{a}	45	33^{a}	37
Cakes & biscuits	30^{a,b}	38	35^{b}	63	45^{a}	53	35	39	46	75	53	64
SSB	242^{b}	297	348^{a,b}	371	397^{a}	357	175^{b}	183	335^{a}	387	378^{a}	307
Energy density (kJ/100 g)												
Energy density, foods	727^{b}	149	841^{a}	223	879^{a}	191	713^{c}	152	804^{b}	215	859^{a}	182
Energy density, beverages	102^{b}	48	108^{b}	60	116^{a}	52	100^{b}	47	103^{b}	56	122^{a}	55

E%, percentage of energy intake; SSB, sugar-sweetened beverages.

a,b,c For each gender group, mean values within a row with unlike superscript letters were significantly different ($P < 0{\cdot}05$).

Fridays v. *weekdays*

Energy intake was higher on Fridays than on weekdays for both boys and girls in all three age groups. Differences that applied to all groups also included a higher percentage of energy from added sugars, a lower percentage of energy from protein and a lower fibre content of the diet on Fridays than on weekdays. In addition, the intake of fruit was lower for the 4–6-year-olds and the 11–14-year-old girls, and the intake of rye bread was lower for all groups except for the 4–6-year-olds and the 11–14-year-old girls. The diet contained significantly higher amounts of sweets and chocolate on Fridays than on weekdays for all groups, although this was not significant for the 11–14-year-olds. The energy density of foods was higher on Fridays than on weekdays for all age and gender groups, and the 11–14-year-old girls also had a higher energy density of beverages on Fridays compared with weekdays.

Fridays v. *weekend days*

Energy intake did not differ significantly between Fridays and weekend days, except for the 7–10-year-old boys, who had a higher energy intake on Fridays than on weekend days. For both boys and girls in all three age groups intake of white bread was lower on Fridays than on weekend days. The fibre content of the diet was higher on Fridays compared with weekend days, although this was not significant for the 11–14-year-old boys, whereas intake of cakes and biscuits was lower for all groups, except for the 4–6-year-old boys and the 7–10-year-old girls. The energy density of foods was lower on Fridays than on weekend days in the 7–10-year-old girls, whereas the energy density of beverages was lower in the 4–6-year-olds and 7–10-year-old girls.

Discussion

Results from the present study showed that there were significant, distinct differences and characteristic patterns in the children's diet quality during weekdays, Fridays and weekend days. Results of the present study indicate that quality of the diet consumed during weekend days was lower than on weekdays, whereas the diet quality on Fridays appeared to be at an intermediate level. Furthermore, average energy intake and energy density were consistently higher on weekend days than on weekdays and intermediate on Fridays. The tendency of increasing energy density from weekdays to weekend days further supports the finding of decreasing diet quality from weekdays to weekend days, because higher energy density has previously has been associated with lower

Table 4 Dietary content by gender on weekdays (Monday–Thursday), Fridays and weekend days (Saturday and Sunday): 11–14-year-old children: the Danish National Survey of Dietary Habits and Physical Activity 2003–2008

	Boys, 11–14 years (*n* 135)						Girls, 11–14 years (*n* 155)					
	Weekdays		Friday		Weekend days		Weekdays		Friday		Weekend days	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Energy and nutrients												
Energy (MJ/d)	9·0[b]	2·8	10·5[a]	4·6	10·3[a]	3·8	7·4[b]	2·0	8·1[a]	3·4	8·2[a]	2·5
Total fat (E%)	33	6	32	8	34	7	31	5	31	9	32	6
SFA (E%)	14	3	14	4	14	3	13	2	13	4	14	3
MUFA (E%)	11	2	11	3	12	3	11	2	11	4	11	3
PUFA (E%)	5[a]	1	5[b]	2	5[a,b]	1	5	1	5	1	4	1
Carbohydrates (E%)	52[b]	6	54[a]	9	52[a,b]	7	54	6	55	9	54	7
Added sugars (E%)	11[b]	6	15[a]	10	14[a]	8	11[b]	5	14[a]	9	15[a]	7
Fibre (g/10 MJ)	23[a]	7	20[b]	9	19[b]	6	23[a]	7	21[b]	8	18[c]	6
Protein (E%)	15[a]	3	14[b]	3	14[b]	3	15[a]	2	14[b]	4	14[b]	3
Foods (g/10 MJ)												
Vegetables	155	105	171	144	139	137	179[a]	132	178[a]	171	131[b]	112
Fruit	200	209	164	246	164	188	244[a]	190	159[b]	186	177[b]	161
Fish	12[a]	20	14[b]	43	15[a]	32	12[a]	21	11[b]	32	12[a]	24
Rye bread	67[a]	61	53[b]	67	46[b]	78	54[a]	54	50[a,b]	67	36[b]	44
White bread	57[b]	53	45[c]	56	79[a]	66	71[b]	63	76[b]	89	88[a]	66
Butter on bread	8	13	8	15	10	15	8	10	8	13	9	10
Full-fat cheese	4[a]	10	3[a,b]	10	7[a]	16	3	6	4	11	4	13
French fried potatoes	22[a]	32	22[b]	55	27[a,b]	47	19[a]	33	32[a]	79	23[a]	42
Sausages	8[a]	22	6[b]	26	4[a,b]	15	6	22	6	36	5	25
Sweets & chocolate	18	23	40	56	26	32	25	31	37	54	34	39
Cakes & biscuits	31[a]	44	32[b]	66	43[a]	74	36[b]	44	29[c]	55	61[a]	71
SSB	254[b]	302	422[a,b]	488	409[a]	352	224[b]	231	343[a,b]	400	351[a]	367
Energy density (kJ/100 g)												
Energy density, foods	775[b]	167	854[a]	244	868[a]	217	734[b]	165	840[a]	236	864[a]	236
Energy density, beverages	95[b]	54	104[a,b]	62	115[a]	56	88[c]	49	104[b]	65	107[a]	59

E%, percentage of energy intake; SSB, sugar-sweetened beverages.
[a,b,c]For each gender group, mean values within a row with unlike superscript letters were significantly different ($P < 0·05$).

dietary quality in children[24]. Moreover, a high intake of energy-dense foods has been convincingly identified as a factor promoting weight gain[2].

The majority of the children did not meet the dietary recommendations for added sugars, saturated fat, fish and fruit and vegetables on a weekly basis. The present results therefore further emphasize the importance of considering the unfavourable dietary intake patterns during weekends and Fridays.

To the authors' knowledge, the present study is the first on the diet quality on weekdays *v.* weekend days in a representative sample of children in Europe. Although few studies have addressed this issue specifically in school-aged children, similar findings for certain key variables such as SSB and the percentage of energy from fat have been presented previously[12,13]. The tendency towards less healthy dietary habits during weekends compared with weekdays is also in accordance with other studies in pre-school children[25–27]. A Scottish study of 5–17-year-olds showed no significant differences in energy intake, total fat, saturated fat and non-milk extrinsic sugars between weekdays and weekend days[28]; however, the overall findings suggested that the weekend is a period with less healthy dietary patterns compared with weekdays.

In the present study, the significantly higher energy intake on Fridays and weekend days compared with weekdays stresses that not only did the children have less healthy dietary habits on Fridays and weekend days, they also consumed more in total rather than compensating by eating less amounts of more regular foods. This is of concern in the prevention of overweight in children because these dietary habits may promote positive energy balance, thereby increasing the risk of becoming overweight and obese. Furthermore, the finding that especially sugar-rich foods and beverages contributed more to the energy intake on Fridays and weekend days compared with weekdays is of concern. Findings from epidemiological studies clearly indicate that regular consumption of SSB may lead to weight gain and substantially increase the risk of developing chronic diseases[29]. In addition, a high intake of added sugars may increase the risk of a nutritionally inadequate diet[30] and is found to be positively associated with multiple measures known to increase CVD risk in adolescents[31].

Some general environmental and structural differences between schooldays and non-schooldays may in part explain the findings that the dietary quality is lower on weekend days. Schooldays may be more structured and supervised, while parents' attitudes towards healthy eating habits and the availability of different foods and beverages during weekends are most likely very important factors for the variation in dietary quality during the week[9]. The perception that it is acceptable to lessen the restrictions during weekends on food groups that should be limited in the diet has been described in a combined qualitative and quantitative Danish study concerning parents' motives to give their children sugar-rich foods[32]. The interviewed parents expressed the view that they felt capable of controlling their children's sugar intake. However, the dietary intake data revealed that the children had a considerably higher intake of added sugars than recommended. The parents also expressed the view that it has become a tradition to give children sugar-rich foods during weekends and that a 'culture of cosiness' is seen as a legitimized cause for this. The promotion of healthy eating habits might benefit from more focus on changing this attitude.

Weekends also include a tendency for children to be less physically active than on weekdays and spend more time in sedentary behaviours, including television viewing and other screen time[33–35], thereby further increasing the risk for weight gain during weekend days. Moreover, extended periods spent watching television has been associated with generally having less healthy food preferences and food habits in school-aged children[36]; thus these factors may act together in an undesirable direction.

In dietary assessment, Fridays are usually considered equal to other weekdays. However, results from the present study showed that the diet on Fridays appeared as a mix of the diet on weekdays and weekend days. Furthermore, according to the variables analysed in the present study, there were more significant differences between Fridays and weekdays than between Fridays and weekend days. This suggests that in assessment of dietary intake, the weekend is not necessarily limited to Saturdays and Sundays, but may include Fridays as well. The issue of whether dietary intake on Fridays should be considered as belonging to weekdays or weekend days needs to be addressed in future dietary assessment studies.

As for all dietary assessment studies, a limitation of the present study is that self-reported food recording may potentially be subject to misreporting. However, the degree of under-reporting seemed to be rather limited with the exception of the group of children aged 11–14 years, which is recognized as a particularly challenging age group when assessing dietary intake[37]. While parents take the full responsibility for the dietary recording of younger children, older children often record their intakes with less parental assistance. This is reasonable from the point of view that older children may have more frequent snacking outside the home and less structured eating patterns, which the parents may not know in detail. However, this combination also means that food items or eating occasions may be more prone to be forgotten or missed out by the older children. In addition, sensitivity to social desirability and possibly decreased interest in dietary recording may increase the susceptibility to under-reporting among older children[37].

Acknowledging that dietary under-reporting is a well-recognized, ubiquitous concern in dietary assessment, we assessed the prevalence of under-reporters using the Goldberg method. Although this approach has some limitations in that it only identifies the most extreme misreporters and is considered to have a low specificity at the individual level[38], it is the most commonly used approach when the doubly labelled water method or other objective measurements of energy expenditure are not available.

One strength of the present study is the separate analyses of data for the three age groups to allow for different eating patterns and different challenges in dietary assessment represented by the age span of 4–14 years. Another major strength is the comprehensive dietary data amassed from daily recordings of dietary intake for seven consecutive days by each participant. These data enabled detailed analyses of the diet quality across the week, including specific distinction of the diet on Fridays. Other strengths include the nationwide character of the study and the wide age span of the sample that render the results more generalizable to children in the general population.

Conclusions

Significant differences and distinct characteristic patterns were found in children's diet quality during weekdays, Fridays and weekend days. The present study suggests that in the prevention of childhood overweight and obesity, more attention should be paid to the higher energy intake, especially from sugar-rich foods and beverages, on Fridays and weekend days.

Acknowledgements

This work was supported by the university PhD scholarships under DTU Food, Technical University of Denmark. The authors declare no conflict of interest. B.W.R. designed the analyses of the present study, performed the statistical analyses and was responsible for writing the manuscript. J.M. was responsible for the design and collection of data in the Danish National Survey of Dietary Habits and Physical Activity. P.B.B. contributed with statistical counselling. B.W.R., C.H., J.M., P.B.B., L.F.A. and I.T. all participated in the discussion of the results and revision of the manuscript. The authors are grateful to researcher Anja Biltoft-Jensen, senior advisor Sisse Fagt and senior researcher Margit Velsing Groth, who are responsible for the design and development of questionnaires to the Danish National Survey of Dietary Habits and Physical Activity. The authors are also grateful to senior advisor Tue Christensen, dietitian Karin Hess Ygil, data scanning manager Hanne-Jette Hinch and data warehouse manager Karsten Kørup, for their contributions to the data processing.

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Public Health Nutrition

Paper III

Dietary patterns on weekdays and weekend days in 4-14 year-old Danish children

Rothausen BW[1], Matthiessen J[1], Brockhoff PB[2], Andersen LF[3], Tetens I[1]

[1]Division of Nutrition, National Food Institute, Technical University of Denmark, Søborg, Denmark
[2]Department of Informatics and Mathematical Modeling, Technical University of Denmark, Kongens Lyngby, Denmark
[3]Department of Nutrition, Institute of Basic Medical Sciences, University of Oslo, Oslo, Norway

Submitted 2012

Dietary patterns on weekdays and weekend days in 4-14 year-old Danish children

Berit W Rothausen[1], Jeppe Matthiessen[1], Lene F Andersen[2], Per B Brockhoff[3], Inge Tetens[1]

[1] Division of Nutrition, National Food Institute, Technical University of Denmark, Mørkhøj Bygade 19, DK-2860 Søborg, Denmark
[2] Department of Nutrition, Institute of Basic Medical Sciences, University of Oslo, PB 1046 Blindern N-0316 Oslo, Norway
[3] Department of Informatics and Mathematical Modeling, Technical University of Denmark, Richard Petersens Plads, Build. 321, DK-2800 Kongens Lyngby, Denmark

Correspondence: Berit W Rothausen, Division of Nutrition, National Food Institute, Technical University of Denmark, Mørkhøj Bygade 19, DK-2860 Søborg, Denmark, Tel: +45 35 88 71 58, Fax: +45 3588 7119. E-mail: bewro@food.dtu.dk

Running title: Dietary patterns on weekdays and weekend days

Key words: Dietary assessment; Principal component analysis; Energy density

Abbreviations: PCA, Principal component analysis; SSBs, sugar sweetened beverages

Abstract

Little is known about dietary patterns on weekdays and weekend days in children, and the aim of this study was to investigate 4-14 year-old children's dietary patterns specifically on weekdays (Monday-Thursday) and weekend days (Saturday-Sunday). Dietary data were derived from the Danish National Survey of Dietary Habits and Physical Activity 2003-2008, where a total of 784 children aged 4-14 years completed a 7-day pre-coded food record. Principal component analysis was used to identify dietary patterns in the age groups 4-6, 7-10 and 11-14 years. Consistently, two dietary patterns, labelled "processed" and "health conscious", emerged on both weekdays and weekend days. Factor scores from corresponding dietary patterns were significantly correlated between weekdays and weekend days with exception of the "health conscious" pattern in the 7-10 year-olds. Within each age group, children with high agreement for the "processed" pattern had a significantly higher dietary energy density, which was reflected in significantly higher intakes of sugar sweetened beverages and lower intakes of fruit and vegetables, compared to children with high agreement for the "health conscious" pattern (P<0·05). Moreover, these variables indicated less healthy dietary intakes on weekend days than on weekdays for both patterns. In conclusion, two distinct dietary patterns, labelled "processed" and "health conscious", were identified on both weekdays and weekend days for each age group. While overall major dietary patterns may somewhat track between weekends and weekdays, the specific foods actually eaten become less healthy during weekends.

Introduction

Dietary habits play an important role for health, growth and development in children. Assessment of children's dietary habits is therefore essential in numerous aspects of nutritional research including the development of evidence based initiatives for use in health promotion. Different approaches have been used to describe dietary habits depending on the study objectives and the quality of data available. Acknowledging that foods are eaten in combination, analyses of the overall dietary pattern may provide a more comprehensive approach to the assessment of dietary intake than simple descriptions of intake levels of individual foods or nutrients[1, 2].

The use of statistical methods to define dietary patterns in a population has facilitated more extensive analyses of dietary intake, and among the data-driven methods, principal component analysis (PCA) is a frequently used exploratory approach to identify dietary patterns. PCA allows inclusion of many food items and uses the correlations between a large number of variables to identify underlying dimensions in the data. In this way, PCA reduces the dimensionality of the data while retaining as much of the relevant information as possible by creating patterns of food intake[3].

Although the use of dietary pattern analysis has been applied most widely in studies of adult populations, several dietary studies have investigated PCA derived dietary patterns in children and the associations of these patterns with various health outcomes and socio-economic indicators[4-7]. Furthermore, PCA has been used to assess the stability of dietary patterns over time during childhood as well as in adulthood[8-11].

Previous research in children has shown that snacking and other daily dietary habits differ on weekdays compared to weekend days[12, 13]. In our earlier study of Danish children, the intake of key food groups and the dietary energy density was found to differ significantly between weekdays and weekends[14]. Among others, the World Health Organization assessed that there is convincing evidence that a high intake of energy-dense foods promotes weight gain and overweight[15]. It therefore seems obvious to consider energy density in relation to dietary intakes between weekdays and weekends further. Little is known about dietary patterns on weekdays and weekends in children, and to the authors knowledge no study has used PCA to investigate the dietary patterns that emerge specifically on weekdays and weekend days. As a more holistic approach may provide new insights to this issue, the aim of the present study was to investigate dietary patterns obtained by use of PCA on weekdays and weekend days in a representative sample of Danish children, 4-14 years of age.

Methods

Sample

The present study is based on data from the Danish National Survey of Dietary Habits and Physical Activity 2003-2008, which is a nation-wide, representative cross-sectional survey. The survey was on-going, with all seasons being equally represented. The study population comprised a simple random sample of 4-14 year-old children, retrieved from The Central Office of Civil Registration. In comparison with census data from Statistics Denmark, the distribution of gender and age of the participants could be characterised as representative for the Danish population of children aged 4-14 years.

Dietary intake

Dietary intake was recorded every day for 7 consecutive days in food diaries with pre-coded response categories, which included open answer options. Children and their parents were instructed in person by trained interviewers on how to complete the food diaries. The parents were responsible for completing the diaries and for deciding to what extent their children were capable of assisting. The food record was organised according to the typical Danish meal pattern (breakfast, lunch, dinner and in-between meals). Each meal was divided into sections with headings such as beverages, bread, spreadable fats, meat, and vegetables to make it easier to find and record the relevant foods, dishes and beverages. For food items not included in the pre-coded food record, the participants wrote the type of food and portion size eaten in open answer categories. The quantities of foods consumed was given in predefined household measures (cups, spoons, slices, etc.) or estimated from photos in a picture book containing 14 food photo series, each series showing four to six different portion sizes. Participants also received a food recording booklet for the children to take to school or to other places outside their home on the days of assessment as a supplement to the food record. Data were scanned using The Eyes & Hands program (version 5.2, 2005; Readsoft Ltd, Milton Keynes, Buckinghamshire, UK). Intakes of energy, nutrients and food items were calculated for each individual using the software system GIES (version 0.995a; developed at the National Food Institute, Technical University of Denmark), and the Danish Food Composition Databank (version 7; Søborg; Denmark; www.foodcomp.dk). Validation of the method for children and adults is described elsewhere[16, 17].

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and was approved by the Danish Data Protection Agency. The Danish National Committee on

Health Research Ethics decided that the Danish National Survey of Dietary Habits and Physical Activity did not require their approval. Written informed consent was obtained from all participants.

Before conducting the principal components analyses, dietary intake data were aggregated into a total of 32 food groups based on relevant similarities in type of food and macronutrient composition. Certain food items that were only consumed sporadically (alcoholic beverages, coffee and tea) were excluded from the analyses. Furthermore, energy density (kJ/100g) of the diet was calculated for solid food and liquids consumed as food (for example, soups and yoghurt). Energy density was included in the PCA together with the other dietary variables, as it may provide an indication of the diet quality and is of importance in relation to energy balance[15, 18].

Weight status

Information about height and weight was obtained through a personal face-to-face interview with one of the parents, referred to as the responding parent, which was the mother in 87% of the cases. Prevalence of overweight and obesity in the study sample was defined according to international age- and gender-specific BMI cut-off values for children and adolescents[19] corresponding to BMI values of 25 and 30 kg/m^2, respectively, for adults aged ≥18 years.

Parental education

The educational level of the responding parent was defined in four categories: 1: Basic school (10 years or less of total education); 2: Vocational education, upper secondary school (10-12 years); 3: Short higher education (13-15 years); 4: Long higher education (15+ years). No information about the educational level of the other parent was obtained in the present study.

Definition of weekdays and weekend days

From analyses of dietary habits in the same sample of Danish children it was previously found that the dietary intakes on Fridays appeared as a mix of the diet on the other weekdays (Monday to Thursday) and weekend days (Saturday to Sunday)[14]. In order to obtain more distinct patterns and strengthen the present analyses, weekdays were defined as Monday to Thursday and weekend days as Saturday to Sunday.

Statistical analysis

Due to the wide age range of children in the study population and associated different degree of parental influence on the diet and diet recording, the main analyses were performed separately for the three age groups 4-6, 7-10, and 11-14 years[20]. Differences between gender regarding height, weight and BMI were analysed using Student's *t*-test, whereas differences between age groups regarding height, weight and BMI were analysed using one-way ANOVA and Tukey´s post hoc test. Differences regarding parental education and weight status were assessed between gender and between age groups using the χ^2 test and Fisher's exact test.

Dietary patterns were identified for each age group on weekdays and weekend days by use of PCA with varimax rotation[21]. Whether to adjust for energy intake before entering foods into a PCA is a matter of debate[22], and the initial analyses for the present study were conducted with and without adjustment for energy, which showed somewhat similar tendencies. However, the patterns obtained using the unadjusted values seemed to appear slightly more clearly defined, and the further analyses were conducted on the mean intake (g/d).

PCA sequentially creates linear combinations, called components, of the input variables that exhibit maximal possible variance. Used on a correlation matrix it is a way to explain the overall correlation structure by a few key components, and with dietary data, the components can be perceived as dietary patterns. The correlations of each food item with a dietary pattern are called component loadings. A negative value of a component loading indicates an inverse impact on the pattern. Food variables with component loadings >0·2 or <-0·2 were considered to have a strong association with the corresponding pattern, and were used to identify and label the specific dietary patterns. The labels summarise characteristic features of the patterns that are general for all three age groups, although some variation in the patterns occurred between the age groups. The chosen number of patterns on weekdays and weekend days was primarily based on examination of the scree-plots, and the interpretability of the components. The effect of adding or removing one or more components was also assessed, however, for all three age groups, a solution with two patterns ("processed" and "health conscious") was considered as best representing the data.

For each child, a factor score for each of the patterns was calculated. The factor score indicates how closely the child's individual dietary pattern is in agreement with the overall dietary pattern. Positive factor scores indicate higher consumption of the positively loaded food items in a given dietary pattern, while negative factor scores indicate low consumption of the positively loaded food items (and vice versa for the negatively loaded food items).

The derived factor scores were all approximately normally distributed. Pearson correlation coefficients between these factor scores were calculated to assess the associations between dietary patterns on weekdays and weekend days. Furthermore, the factor scores were used to define groups of children with high agreement for each pattern. In each age group, the children were divided into tertiles for each of the two dietary patterns based on their individual factor scores for the relevant pattern. To clarify further the possible differences between the patterns, groups of children with high agreement for a pattern and also low or intermediate agreement for the other pattern were defined. Thus, within each age group, the group of children with factor scores in the highest tertile for the "processed" pattern and factor scores in the lowest or intermediate tertiles for the "health conscious" pattern was named "High PP". The group of children with factor scores in the highest tertile for the "health conscious" pattern and in the lowest or intermediate tertiles for the "processed" pattern was named "High HCP".

Energy density and intake of fruit and vegetables, sugar sweetened beverages (SSBs) and sweets and chocolate on weekdays and weekend days, were compared between the "High PP" group and the "High HCP" group in each age group using Student's *t*-test. These variables were selected on the basis of key findings from previous analyses based on indicator variables on weekdays and weekend days in the same population of Danish children[14]. Differences between "High PP" and "High HCP" groups regarding the distribution of gender, weight status and parental educational level were tested by use of Fisher's exact test.

Data were analysed with the Statistical Package for the Social Sciences software (version 19; IBM SPSS Statistics, Inc., Chicago, USA). Statistical differences were considered significant at $P<0{\cdot}05$.

Results

Study population

A total of 1294 children were invited to participate and 1006 (78%) children accepted. After exclusion of incomplete dietary recordings, data from 784 (61%) children with 7 consecutive days of dietary recording and information about BMI and parental educational level were available for analysis. Characteristics of the study population are presented in Table 1. There were no significant differences between age groups regarding weight status as overweight or obese and parental education. Within each age group no gender differences were found regarding height, weight, BMI, weight status as overweight or obese and parental education. On a weekly basis, boys had a significantly higher mean total energy intake than girls in all three age groups (4-6 y: boys 7·87 ± 1·87 MJ/d vs. girls 6·91 ± 1·34 MJ/d, *P*<0·001; 7-10 y: boys 8·79 ± 1·94 13 MJ/d vs. girls 8·19 ± 2·03 MJ/d, *P*=0·01; 11-14 y: boys 9·57 ± 2·83 MJ/d vs. girls 7·74 ± 1·99 MJ/d, *P*<0·001).

Dietary patterns

In all three age groups, two distinct dietary patterns were identified on both weekdays and weekend days. The patterns were labelled “processed” and “health conscious” based on the general characteristics of the foods with the highest component loadings within each pattern. The dietary variables with high loadings (>0·2 or <-0·2) on these patterns are presented in Table 2-4. The patterns differed slightly between age groups and between weekdays and weekend days, however, consistently for all age groups and periods, the principal component labelled “processed” was characterised by high positive loadings on energy density, white bread, fat on bread, and jam, honey and chocolate spreads on both weekdays and weekend days. SSBs, cakes and biscuits and sweets and chocolate also had high loadings in the “processed” pattern on both weekdays and weekend days for all age groups, except for weekend days in the 4-6 year-olds. The other principal component labelled “health conscious” was consistently characterised by high loadings of fruit, vegetables and water on both weekdays and weekend days for all age groups, whereas the other variables with high component loadings in the “health conscious” pattern varied to some extent between age groups.

Pearson correlation coefficients between the factor scores from each dietary pattern showed significant positive correlations between corresponding patterns on weekdays and weekends with exception of the “health conscious” pattern in the 7-10 year-olds (Table 5). Overall, correlation coefficients for the “processed” patterns were slightly higher than for the “health conscious” pattern.

Comparisons of “High PP” groups with “High HCP” groups (i.e. groups of children with factor scores in the highest tertile for one pattern and factor scores in the lowest or intermediate tertile for the other pattern), showed that energy density of the diet as well as intake of sweets and chocolate and SSBs were significantly higher, whereas intake of fruit and vegetables was significantly lower, in the “High PP” groups than in the “High HCP” groups (*P*<0·05) (Table 6). These differences were evident on both weekdays and weekend days for all age groups, except for intake of sweets and chocolate on weekend days in the 7-10 year-olds. Moreover, the differences between the ”High PP” and the “High HCP” groups seemed slightly amplified on weekend days compared to weekdays.

No significant differences regarding BMI, weight status, gender and parental educational level were found between the ”High PP” and the “High HCP” groups within each age group (data not shown).

Discussion

In this sample of Danish children, two dietary patterns labelled “processed” and “health conscious” were identified on both weekdays and weekend days. Although not completely identical, these dietary patterns were consistently found in all three age groups. The shared characteristics for the “processed” pattern on both weekdays and weekend days in all age groups were high loadings on energy density and white bread, fat on bread, and jam, honey and chocolate spreads, whereas the shared characteristics of the “health conscious” pattern were high loadings on fruit, vegetables and water. Energy density, which was included in the identification of dietary patterns as an overall indicator of the diet quality, loaded highly on the “processed” pattern, thus, indicating that this dietary pattern is characterised by a high dietary energy density and an overall lower dietary quality.

PCA has previously been used to assess the stability of dietary patterns during periods of several months to years in childhood, adolescence and adulthood[8-10, 23-25]. Types and numbers of patterns comparable to the present findings have been found in other studies in children and adolescents, including patterns with similarities to the "processed" and “health conscious” pattern[6, 23]. However, since this is the first study to assess dietary patterns obtained using PCA specifically on weekdays and weekend days these results are not directly comparable to those of other studies.

Results of the present study showed that in general, factor scores from corresponding dietary patterns on weekdays and weekend days were significantly positively correlated. No significance was observed for the “health conscious” pattern in the 7-10 year-olds, however, there is no obvious explanation for this finding. The initial analyses with varying numbers of included food groups did not show a tendency for the patterns of this age group to differ from the patterns of the other age groups. The lower correlations between corresponding dietary patterns that are presented for this age group seem rather to be an exception to the general findings.

Other studies that have examined stability of dietary patterns over time using correlations have identified patterns on the basis of estimates of usual consumption including both weekdays and weekend days. Findings from these studies have shown similar or somewhat higher correlations between corresponding patterns[10, 26, 27]. However, there is a difference in comparing dietary patterns of usual consumption and comparing the patterns on weekdays and weekend days, and comparable correlations are not necessarily expected. Although not completely consistent, the present results suggest that overall major dietary patterns may somewhat track between weekends and weekdays, while the specific foods actually eaten become less healthy during weekends.

Some general environmental and structural differences between schooldays and non-schooldays may in part explain the findings that the dietary quality is lower on weekend days. Schooldays may be more structured and supervised, while parents' attitudes towards healthy eating habits and the availability of different foods and beverages during weekends is most likely a very important factor for the variation in the dietary quality during the week[28].

In the same study population, a tendency of a lower diet quality on weekend days compared to weekdays has previously been presented[14]. These findings combined imply that subgroups with differences in dietary habits of nutritional concern exist, and that these differences are maintained on weekdays as well as on weekend days. This notion was further supported by the findings of significant and health relevant differences in the energy density of the diet and in intakes of fruit and vegetables, SSBs and sweets and chocolate, when comparing "High PP" groups with "High HCP" groups (i.e. comparing groups of children with high agreement for the "processed pattern" with groups of children with high agreement for the "health conscious" pattern). These results were found for both weekdays and weekend days with minor differences between the age groups. Moreover, within each of the "High PP" groups and the "High HCP" groups, a significant higher energy density was observed on weekend days than on weekdays. This was also reflected in several of the selected key variables with overall tendencies of lower intakes of fruit and vegetables and higher intakes of SSBs and sweets and chocolate.

Similar findings for certain key variables have been presented previously in studies of children[12, 13], and the tendency towards less healthy dietary habits during weekends compared to weekdays is also in accordance with other studies in pre-school children[29-31]. This detection of significantly unfavourable dietary patterns during weekends points at a considerable potential for dietary improvement, and the present findings suggest that focusing attention on the differences between weekdays and weekend days could prove useful for enhancing public health initiatives.

The World Cancer Research Foundation and the American Institute for Cancer Research recommend the average energy density of diets to be lowered towards approximately 525 kJ/100g excluding beverages[32]. In light of this, the observed differences in energy density between "High PP" and "High HCP" groups were considerable, and especially high on weekend days where the median energy density were of 617 to 740 kJ/100g in the "HCP" groups and as high as around 1000 kJ/100g in the ”High PP” groups. In line with this, intake of fruit and vegetables in the “High PP” groups was substantially below the recommended levels (100-147 g/day on weekdays and 55-85 g/day on weekend days), whereas intake of SSBs was high (113-213 g/day on weekdays and 272-400 g/day on weekend days).

High levels of dietary energy density are of concern from a public health perspective as there is convincing evidence that a high intake of energy-dense foods, high in fat, added sugars or starch, promote weight gain and overweight[(15)]. Furthermore, high energy density levels of the diet have been associated with lower dietary quality in both children[(18)] and adults[(33)]. The present results as well as previous analyses of the diet in this sample of children, substantiate these findings, and underscore the need for improvement of dietary habits especially in children with high intake of energy dense foods, high in fat, added sugars or starch, and low intake of fruit and vegetables, and especially to focus on the dietary intake on weekends[(14)]. As unfavourable diets in childhood may have long-term implications, especially in terms of development of overweight and subsequent morbidity[(34)], these consistent findings may be of importance for health promotion strategies.

Methodological issues

As with other methods there are several methodological issues of the use of PCA[(3, 35)] and results should be interpreted in the light of this. PCA has the advantage of combining food items across the diet, and may provide a useful approach for summarising extensive dietary data into fewer interpretable combinations, thereby taking into account the complexity of the diet. However, although the PCA method is a data driven method that explore existing dietary patterns without preconceived patterns, it is a major consideration that it involves subjective decisions that can influence the final interpretation. This includes for example preselecting and aggregation of food items into food groups, determining the value of component loadings considered to have a strong association with the patterns, the number of patterns to retain and the labelling of each pattern[(1, 35)]. These decisions may make the results less data-driven than assumed theoretically. Also the comparability with other studies is limited by the differences between studies regarding data treatment and interpretation of the analyses.

Inherently, the results represent the optimal model with respect to the explained proportion of variability between individuals. However, when interpreting a limited number of dietary patterns as is often the case, caution should be taken as other patterns also exist within the dataset, although each of these explain progressively less of the variance than the first emerging patterns[(35)].

Furthermore, if all participants have a high intake of a certain food item or food group, this will not appear as an important part of any pattern. It seems therefore useful to combine the findings from PCA with other analyses of the diet, depending on the study objectives, to support and extent the dietary pattern analyses. In that way, PCA and traditional nutritional analysis can be seen as complementary approaches that can be used together. Additionally, validity of the dietary patterns and results could be strengthened if a second method of extracting dietary patterns is used.

In the present analyses, the dietary intake data were included as means over four and two days, respectively. Day-to-day variation is therefore larger in the weekend data than in the weekday data. However, the potential influence of this in the PCA is considered to be of minor importance. Only differences in individual day-to-day structures, or correlations between these that are different from the overall correlations could change the interpretability of the PCA derived patterns.

As for all other dietary assessment studies, a limitation of the present study is that the self-reported food recording may potentially be subject to misreporting. In dietary assessment in children, the use of parent report of a child's diet may also be seen as a limitation. However, the degree of under-reporting seemed to be rather limited in the present sample, with the exception of the group of children aged 11-14 years(14), which is recognised as a particularly challenging age group when assessing dietary intake. Thus, there is a higher risk of misreporting in the dietary intake data from the 11-14 year-olds compared to the youngest age groups. Separate analyses for each gender were not conducted due to the limited sample sizes in each age group, and specific gender differences were therefore not part of the scope for this paper.

Strengths of the present study include the comprehensive dietary data, for which each of the participants has provided daily recordings of dietary intake for 7 days, which allowed us to analyse dietary patterns across the week. PCA has been applied on data from different dietary assessment methods, with food-frequency questionnaires as one of the primary dietary assessment methods, however, the patterns generated have generally been similar despite the dietary assessment method used(3, 36). Furthermore, strengths lie in the nationwide character of the study as it is based on a nationally representative study and in the wide age span of the sample that render the results more generalisable to children in the general Danish population.

Conclusion

In this sample of Danish children, two distinct dietary patterns, labelled “processed” and “health conscious”, were identified on both weekdays and weekend days for each of the age groups 4-6, 7-10 and 11-14 years. While overall major dietary patterns may somewhat track between weekends and weekdays, the specific foods actually eaten become less healthy during weekends.

Acknowledgements

This work was supported by the university PhD scholarships under DTU Food, Technical University of Denmark. The authors are grateful to researcher Anja Biltoft-Jensen, senior advisor Sisse Fagt and senior researcher Margit Velsing Groth who are responsible for the design and development of questionnaires to the Danish National Survey of Dietary Habits and Physical Activity. The authors are also grateful to senior advisor Tue Christensen, dietician Karin Hess Ygil, data scanning manager Hanne-Jette Hinch and data warehouse manager Karsten Kørup, for their contributions to the data processing. B.W.R. designed the analyses of this study, performed the statistical analyses and was responsible for writing the manuscript. J.M. was responsible for the design and collection of data in the Danish National Survey of Dietary Habits and Physical Activity. P.B.B. contributed with statistical counselling. B.W.R., J.M., P.B.B., L.F.A., and I.T. all participated in the discussion of the results and revision of the manuscript. The authors declare no conflict of interest.

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Table 1. Characteristics of the study population

	4-6 y (*n* 207)		7-10 y (*n* 287)		11-14 y (*n* 290)	
	Mean	SD	Mean	SD	Mean	SD
Gender, boys/girls (%)	50/50		53/47		47/53	
Height (cm)	118	9	139	9	161	10
Weight (kg)	22·0	4·3	32·8	7·5	49·9	10·7
BMI (kg/m^2)	15·6	1·9	16·8	2·6	19·1	3·0
Weight status* (%)						
Overweight, boys/girls	8·7/15·5		13·8/14·1		17·8/14·2	
Obese, boys/girls	0/3·9		3·9/4·4		3·0/3·2	
Parental education† (%)						
1: Basic school	8·7		8·7		11·7	
2: Vocational education	41·5		43·9		42·4	
3: Short higher education	8·2		10·1		14·5	
4: Long higher education	41·5		37·3		31·4	

BMI, body mass index.

*Weight status according to international cut off values[(19)]. The presented proportions of overweight children do not include obese children.

†Parental educational level. 1: Basic school (10 years or less of total education); 2: Vocational education, upper secondary school (10-12 years); 3: Short higher education (13-15 years) (primarily theoretical); 4: Long higher education (15+ years) (primarily theoretical)

Table 2. Variables of foods (g/day) and energy density (kJ/100g) with loadings > |0·2| for the two dietary patterns in children aged 4-6y (*n* 207)

Food item	"Processed" pattern		"Health conscious" pattern	
	Weekdays	Weekend days	Weekdays	Weekend days
White bread	0·61	0·45		-0·34
Energy density	0·60	0·37	-0·58	-0·80
Fats on bread	0·55	0·76		
Jam, honey and chocolate spreads	0·55	0·47		
Cold cuts	0·48	0·64	0·43	0·24
Beverages, sugar sweetened	0·41		-0·30	-0·25
Rye bread	0·36	0·55	0·53	0·31
Sweets and chocolate	0·34		-0·22	-0·34
Sauce and gravy	0·31	0·39	0·21	
Cakes and biscuits	0·29		-0·27	-0·32
Juice	0·27			
Dairy products, fat*	0·22	0·23		
Potatoes	0·21	0·31	0·37	
Oatmeal	-0·24			0·26
Water		0·25	0·56	0·43
Vegetables			0·51	0·48
Fruit			0·50	0·61
Dairy products, low fat†			0·23	0·34
Red meat, fat			0·23	0·21
Nuts and dried fruit			0·32	
Salty snacks			-0·23	-0·22
Fast foods			-0·32	-0·23
Coarse bread & crisp bread				0·30
Variation explained, %	7·8	7·5	7·9	8·1

*Dairy products with ≥1·5% fat
†Dairy products with <1·5% fat
Food groups with component loadings < |0.2| for both principal components included Beverages, light; Coarse bread & crisp bread; Fish and seafood; French fries; Ice-cream and desserts; Juice; Nuts and dried fruits; Other breakfast cereals than oatmeal; Pies and egg dishes; Poultry; Red meat, lean; Rice, pasta and polenta and Soups.

Table 3. Variables of foods (g/day) and energy density (kJ/100g) with loadings > |0·2| for the three dietary patterns in children aged 7-10y (*n* 287)

	"Processed" pattern		"Health conscious" pattern	
Food item	Weekdays	Weekend days	Weekdays	Weekend days
White bread	0·65	0·40		
Energy density	0·47	0·84	-0·76	
Sweets and chocolate	0·44	0·22		
Jam, honey and chocolate spreads	0·43	0·33		
Beverages, sugar sweetened	0·37	0·28		
Salty snacks	0·37			
Cakes and biscuits	0·34	0·23		
Red meat, fat	0·29		0·28	0·53
Fast foods	0·29			-0·41
Juice	0·28		0·30	
Fats on bread	0·23	0·47	-0·35	0·28
Cold cuts	-0·27		-0·34	0·49
Oatmeal	-0·31	-0·26		
Dairy products, low fat*	-0·36	-0·27		0·25
Other breakfast cereals†	-0·37	-0·25		
Rye bread	-0·39		-0·26	0·51
French fries		0·28		
Soup		-0·22		
Water		-0·23	0·37	0·30
Nuts and dried fruit		-0·27	0·33	0·22
Vegetables		-0·49	0·62	0·39
Fruit		-0·62	0·72	0·31
Potatoes				0·57
Sauce and gravy				0·46
Fish and seafood				0·33
Ice-cream and desserts			0·21	
Beverages, light			-0·32	
Variation explained, %	7·5	7·9	8·0	7·1

*Dairy products with <1·5% fat

†Other breakfast cereals than oatmeal

Food groups with component loadings < |0.2| for both principal components included Beverages, light; Coarse bread and crisp bread; Dairy products, fat; Fish and seafood; French fries; Ice-cream and desserts; Juice; Pies and egg dishes; Potatoes; Poultry; Red meat, lean; Salty snacks; Soups and Rice, pasta and polenta.

Table 4. Variables of foods (g/day) and energy density (kJ/100g) with loadings > |0·2| for the two dietary patterns in children aged 11-14y (*n* 290)

	"Processed" pattern		"Health conscious" pattern	
Food item	Weekdays	Weekend days	Weekdays	Weekend days
Energy density	0·74	0·81	-0·40	
Fats on bread	0·66	0·48	0·31	0·52
Jam, honey and chocolate spreads	0·60	0·45		
White bread	0·41	0·55		
Cold cuts	0·34		0·54	0·56
Beverages, light	0·29	0·21		
Rye bread	0·28		0·60	0·59
Cakes and biscuits	0·26	0·26		
Sweets and chocolate	0·25	0·24		
Juice	0·24			0·39
French fries	0·23			
Poultry	0·23			
Vegetables	-0·25	-0·37	0·59	0·32
Fruit	-0·29	-0·44	0·23	0·42
Soup	-0·32			
Other breakfast cereals	-0·40	-0·27		
Red meat, fat		0·23	0·32	
Potatoes			0·57	
Sauce and gravy			0·38	
Water			0·32	0·47
Dairy products, fat*			0·29	0·31
Nuts and dried fruit			0·29	
Fish and seafood			0·25	
Fast foods			-0·32	
Salty snacks			-0·24	
Coarse bread & crisp bread				0·46
Variation explained, %	8·0	7·1	7·9	6·5

*Dairy products with ≥1·5% fat

Food groups with component loadings < |0.2| for both principal components included Beverages, light; Coarse bread and crisp bread; Dairy products, low fat (≤1·5%); Fast food; Fish and seafood; French fries; Ice-cream and desserts; Nuts and dried fruit; Oatmeal; Pies and egg dishes; Potatoes; Poultry; Red meat, lean; Rice, pasta and polenta; Salty snacks; Sauce and gravy and Soups.

Table 5. Pearson correlation coefficients (*r*) between the factor scores obtained on weekdays and weekend days in 4-6, 7-10 and 11-14 year-old children

	"Processed" pattern		"Health conscious" pattern	
	Weekdays vs. weekend days		Weekdays vs. weekend days	
	r	95% CI	*r*	95% CI
4-6y (*n* 207)	0.34	0.21-0.45	0.32	0.19-0.43
7-10y (*n* 287)	0.17	0.05-0.28	0.09	-0.02-0.21
11-14y (*n* 290)	0.48	0.39-0.56	0.35	0.28-0.45

Table 6. Mean energy density (kJ/100g) and intake of selected foods (g/d) on weekdays and weekend days for the "High PP" and the "High HCP" groups within each age group

	Weekdays					Weekend days				
	"High PP"		"High HCP"		*P*-value*	"High PP"		"High HCP"		*P*-value*
	Median	(P_5; P_{95})	Median	(P_5; P_{95})		Median	(P_5; P_{95})	Median	(P_5; P_{95})	
4-6y			*n* 46					*n* 44		
Energy density†	848	(668; 1148)	570	(501; 768)	<0·001	999	(767; 1445)	617	(473; 839)	<0·001
Fruit & vegetables	147	(19; 387)	382	(184; 735)	<0·001	85	(0; 401)	331	(93; 685)	<0·001
Sweets & chocolate†	7	(0; 42)	2	(0; 20)	0·001	25	(0; 108)	10	(0; 41)	0·002
SSBs‡	113	(0; 744)	0	(0; 244)	<0·001	272	(0; 750)	100	(0; 513)	0·001
7-10y			*n* 67					*n* 58		
Energy density†	832	(684; 1121)	571	(402; 701)	<0·001	1056	(913;1301)	740	(447; 935)	<0·001
Fruit & vegetables§	155	(31; 327)	427	(194; 1051)	<0·001	55	(0;216)	313	(102; 1196)	<0·001
Sweets & chocolate†	13	(0; 53)	6	(0; 34)	0·003	15	(0;81)	15	(0; 81)	0·454
SSBs†	163	(0; 1100)	100	(0; 323)	<0·001	350	(0;1300)	263	(0; 805)	0·047
11-14y			*n* 64					*n* 66		
Energy density†	894	(748; 1152)	638	(437; 823)	<0·001	1053	(788;1382)	720	(453; 981)	<0·001
Fruit & vegetables§	100	(0; 371)	348	(84; 753)	<0·001	64	(0;203)	383	(86; 947)	<0·001
Sweets & chocolate‡	22	(0; 135)	5	(0; 47)	<0·001	31	(0;159)	13	(0; 91)	0·003
SSBs†	213	(0; 738)	50	(0; 919)	0·011	400	(0;1100)	125	(0; 1278)	0·013

"High PP", children with factor scores in the highest tertile for the "processed" pattern and in the lowest or intermediate tertiles for the "health conscious" pattern; "High HCP", children with factor scores in the highest tertile for the "health conscious" pattern and in the lowest or intermediate tertiles for the "processed" pattern; P_5, 5th percentile; P_{95}, 95th percentile; SSBs, sugar sweetened beverages

*Comparing "High PP" groups with "High HCP" groups within each age group

†Significant differences between weekdays and weekend days for both the "High PP" and the "High HCP" group: $P<0·05$

‡Significant differences between weekdays and weekend days for the "High HCP" group: $P<0·05$

§Significant differences between weekdays and weekend days for the "High PP" group: $P<0·05$

Paper IV

Relationship between sleep duration, dietary intake and BMI in 4-14 year-old Danish children

Hoppe C[1], Rothausen BW[1], Biltoft-Jensen AP[1], Matthiessen J[1], Groth MV[1], Chaput J-P[2], Tetens I[1]

[1]Division of Nutrition, National Food Institute, Technical University of Denmark, Søborg, Denmark
[2]Healthy Active Living and Obesity Research Group, Children's Hospital of Eastern Ontario Research Institute, Ottawa, Ontario, Canada

Submitted 2012

Relationship between sleep duration, dietary intake and BMI in 4- to 14-year-old Danish children

Camilla Hoppe[1], *Berit W Rothausen*[1], *Anja Biltoft-Jensen*[1], *Jeppe Matthiessen*[1], *Margit V Groth*[1], *Jean-Philippe Chaput*[2], *Inge Tetens*[1]

[1]Division of Nutrition, National Food Institute, Technical University of Denmark, Søborg, Denmark
[2]Healthy Active Living and Obesity Research Group, Children's Hospital of Eastern Ontario Research Institute, Ottawa, Ontario, Canada

Correspondence

Camilla Hoppe, Division of Nutrition, National Food Institute, Technical University of Denmark, Mørkhøj Bygade 19, DK-2860 Søborg, Denmark, Tel: +45 35 88 73 37, Fax: +45 35 88 71 19, Email: cahop@food.dtu.dk

Sources of support

This study was part of the OPUS project. OPUS is an acronym of the project "Optimal well-being, development and health for Danish children through a healthy New Nordic Diet" and is supported by a grant from the Nordea Foundation.

Running title

Sleep, diet and BMI in Danish children

Abstract

Aims: A negative association between sleep duration and BMI has been observed in children. However, knowledge about the association between sleep duration and diet is limited. The objective was therefore to examine the association between sleep duration and intake of foods and nutrients in children. *Materials and methods:* In this cross-sectional study, dietary intake and sleep duration were recorded for seven consecutive days in a pre-coded food and sleep record in a representative sample of 802 4-14-year-old children. Height and weight were reported by one of the parents. Short and long sleep duration were defined within three age groups: 4-6, 7-10 and 11-14 years using median sleep duration as cut-off values. *Results*: No gender differences were found regarding age, sleep duration and parental education. Sleep duration was negatively correlated to age (rho=-0.68, P<0.001) and to BMI (rho=-0.41, P<0.001). In multiple linear regression analyses, sleep duration was not associated with energy intake (beta=-0.044, P=0.097), but solely with intake of vegetables (beta=0.057, P=0.027), dietary fibre (beta=0.054, P=0.041) and liquid "empty calories" (beta=-0.055, P=0.035). Furthermore, groups of short sleepers had significantly higher intakes of added sugars and liquid "empty calories" and lower intakes of vegetables (4-6 y), higher intakes of sweets & chocolate and poultry (7-10 y) and lower intakes of rye bread (11-14 y), (all P<0.05). However, the magnitude of the differences in dietary intakes between short and long sleepers was of a relatively small size and not consistent across age groups. *Conclusions*: Sleep duration was negatively associated with BMI. However, sleep duration was not associated with energy intake and the conception that children with short sleep duration have less healthy eating habits than children with longer sleep duration was only weakly supported by the present findings.

Introduction

The prevalence of childhood obesity is emerging as a major health problem [1]. In several studies, a negative or U-shaped relationship between sleep duration and weight status has been observed in infants [2], children [3,4], adolescents [4,5] and adults [3,6]. Moreover, meta-analyses analysing data from studies in children, have concluded that short sleep duration was associated with higher odds of being obese [3]. This association might have long-term implications [7] because tracking of overweight from childhood to adulthood occurs [8], thereby increasing the risk of developing certain non-communicable diseases [9]. The potential influence of short sleep duration on body weight balance is not fully understood. One of the possible underlying mechanisms is that short sleep duration impacts the hormonal regulation of appetite. Indeed, lack of sleep has been reported to decrease leptin levels, increase ghrelin levels, alter glucose homeostasis, and activate the orexin system [10]. Furthermore, short sleep duration might also promote overeating and weight gain by increasing the time available for eating, especially in the evening where sedentary activities, such as watching television and snacking on highly palatable and energy dense foods is common [11].

When shortened sleep duration leads to sleepiness and/or fatigue during daytime this may limit the motivation for being physically active and promote sedentary behaviours instead. It has therefore also been speculated that there is an association between sleep duration, BMI and physical activity, however, results from studies concerning this have been contradictory [5,12]. Only a few studies have examined the association between sleep duration and dietary quality [13-15], and, to our knowledge, this has not been done in Danish children. This issue is particularly relevant from a public health standpoint because increased energy intake appears to be the most plausible explanation as to why short sleepers have a higher risk of becoming obese.

The main aim of this study was to examine the relationship between intake of different foods and nutrients, BMI and sleep duration in Danish children. We hypothesized that short sleepers have higher energy intake and less healthy food consumption patterns compared to long sleepers.

Materials and methods

Sample

This study was based on data from the Danish cross-sectional dietary survey called the National Survey of Dietary Habits and Physical Activity 2003-2008. The data collection was evenly distributed during the period. The study population comprised a simple random sample of 802 children aged 4-14 years from The Central Office of Civil Registration. In comparison with census data from Statistics Denmark, the distribution of gender and age of the participants could be characterized as representative for the Danish population of children aged 4-14.

Anthropometric variables

Information about height and weight was obtained through a personal face-to-face interview with one of the parents. The prevalence of overweight and obesity in the study population was defined according to international age- and gender-specific BMI cut-off values [16], corresponding to BMI values of 25 and 30 kg/m^2, respectively, for adults aged ≥18 years.

Sleep duration

Sleep duration was reported in hours and minutes in a diary integrated in a food record. Every day, on the same seven days as the food record was completed, a simple question about sleep duration during the last night and day was answered. Children and their parents were instructed in person by trained interviewers on how to complete food and sleep recordings. The parents were responsible for completing the records and for deciding to what extent their children were capable of assisting. Mean sleep duration per day was calculated and used for subsequent analyses. Days where children were in bed with illness were omitted. For each child, a minimum of four days with measurements of diet and sleep duration was required for inclusion in the statistical analyses. Groups of children with short and long sleep duration were defined within each of three age groups according to the median sleep duration. The median sleep duration cut-off values were 10.15 h/d for the 4-6 year-old children, 9.63 h/d for the 7-10 year-old children, and 8.88 h/d for the 11-14 year-old children.

Dietary intake

Dietary intake was recorded every day for seven consecutive days in food records with pre-coded response categories, which included open answer options. For food items not included in the pre-coded food record, the participants wrote the type of food and portion size eaten in open-answer categories. The amount of foods eaten was given in predefined household measures (cups, spoons, slices, etc.) or estimated from photos of various portion sizes. Children also received a food record booklet to take to school or to other places outside of the home on the days of assessment. Details about the method and calculation of intake of food and nutrients are described elsewhere [17].

Dietary variables included in the analyses were energy intake, macronutrients, major food groups and energy-dense foods.

Statistical analysis

All data were analysed with the Statistical Package for the Social Sciences software (version 19; IBM SPSS Statistics, Inc., Chicago, USA) and a significance level of $P<0.05$ was used (2-tailed tests). Normality was checked visually with histograms as well as with Kolgomorov-Smirnoff tests. As commonly found, the data for most foods and nutrients were not normally distributed (positively skewed). Logarithmic and square root transformations were attempted, but did not produce distributions with sufficient normality. For this reason and insufficient homogeneity of variance, non-parametric analyses were performed. BMI Z-scores were calculated. Spearman's rho correlation coefficients were calculated to analyse associations between sleep duration and BMI and between sleep duration and age. The χ^2 test was used to analyse differences between weight status, parental education and sleep duration and gender. The Kruskal-Wallis test was used to analyse differences in BMI between parental education. Multiple linear regression analyses were performed separately for each dietary variable with sleep duration as the dependent variable and age and BMI as forced covariates in the models. In order to further elucidate the dietary patterns in relation sleep duration, the Mann-Whitney U-test was applied to test for statistically significant differences in dietary intake between groups with short and long sleep duration. Results are provided as means (SD).

Results

Descriptive characteristics

Because of the wide age range in the study population, the children were divided into three age groups: 4-6 years, 7-10 years, and 11-14 years. Characteristics of the study population are given in Table I. Within each age group, no differences between boys and girls were found regarding age ($P \geq 0.29$), height ($P \geq 0.52$), weight ($P \geq 0.30$), BMI ($P \geq 0.17$), parental education ($P \geq 0.39$), and sleep duration ($P \geq 0.95$). Therefore, further analyses were conducted with both genders combined.

Prevalence of overweight and obesity

Prevalence of overweight and obesity is given in Table I. No gender differences were observed with regard to weight status for the 7-10 and 11-14 year-old children (*P*=0.59 and *P*=0.93), but there were more overweight and obese girls than boys in the 4-6 year-old children (*P*=0.004).

Sleep duration, age and BMI

Age was negatively correlated to sleep duration (rho=-0.68, *P*<0.001). An inverse relationship between sleep duration and BMI Z-scores (rho=-0.41, *P*<0.001) was also observed. Furthermore, length of parental education was negatively correlated with BMI of the child (*P*<0.05). However, there were no differences between short and long sleepers regarding parental education (*P*=0.41).

Sleep duration and dietary intake

In multiple linear regression models, sleep duration was positively associated with vegetables (beta=0.057, *P*=0.027) and dietary fibre (beta=0.054, *P*=0.041), and negatively associated with liquid "empty calories" (beta=-0.055, *P*=0.035), but not with energy intake (beta=-0.044, *P*=0.097) nor with any of other the dietary variables, as shown in Table II.

There were no differences between children with sleep duration above and below the median for age group regarding energy intake or macronutrient (protein, fat, carbohydrate) contribution to energy in all three age groups. In 4-6 year-old children, intake of liquid "empty calories" was significantly higher in short sleepers compared to long sleepers, whereas intake of vegetables were lower in short sleepers than in long sleepers. Additionally, the energy percentage from added sugars was significantly higher in short sleepers compared to long sleepers (Table III). In 7-10 year-old children, intakes of and sweets & chocolates and poultry were significantly higher in short sleepers than in long sleepers (Table IV), while in the 11-14 year-old children, intake of rye bread was significantly lower in short sleepers compared to long sleepers (Table V).

Discussion

This is the first publication with representative population data on sleep duration and its relationship with dietary intake in Danish children. We found a negative association between sleep duration and BMI in children aged 4-14 years, which is in accordance with several other studies [2-4,6].

There was no significant association between sleep duration and energy intake, and the groups of short and long sleepers did not differ with regard to energy intake. This observation is in agreement with what has been found previously in adults [6], implying that a small chronic energy gap associated with short sleeping is difficult to capture with the dietary assessment methods that are normally used in epidemiological research. When assessing the relationship between sleep duration and dietary variables with multiple linear regression analyses with age and BMI as covariates, we only found that vegetables and dietary fibre were positively associated with sleep duration, and that liquid "empty calories" were negatively associated with sleep duration. Furthermore, groups of short sleepers had significantly higher intakes of added sugars and liquid "empty calories" and lower intakes of vegetables (4-6 y), higher intakes of sweets & chocolate and poultry (7-10 y) and lower intakes of rye bread (11-14 y). However, the magnitude of the differences in dietary intakes between short and long sleepers was of a relatively small size and not consistent across age groups.

With increasing age, there is an increasing autonomy on the dietary intakes in children. In the teenage period, which is a period of high autonomy, the children have a generally poorer dietary quality than the younger groups, e.g. less milk, rye bread, fruits and fish and more fast food. Subsequently, in this age group, the generally poorer dietary quality may be stronger than a difference between short and long sleepers. Other factors should also be considered, such as family upbringing, personal values and attitudes towards healthy eating habits and sleep hygiene, late-night activities such as screen time, e.g. television viewing and computer games, daytime napping, and physical activity. Furthermore, compensating for insufficient week day sleep during the weekends also may in part ameliorate the risk of childhood overweight [18]. Further studies are needed to elucidate this.

Only few other studies have examined the relationship between sleep duration and dietary patterns [4,13-15,19,20]. The results from these studies are concordant with those found in the present study, suggesting that inadequate sleep may partly be associated with less healthy food habits in children.

In 10-11 year-old Finnish children, inadequate sleep was associated with a greater likelihood of consuming energy-rich foods and less likelihood of consuming nutrient-dense foods [15]. Further, sleepiness during daytime was associated with daily snacking in Japanese school girls, and with skipping breakfast and evening snacks in boys [19]. In another study on Taiwanese adolescents, adequate sleep was associated with adopting a healthy diet, including eating breakfast daily, eating three meals a day, choosing foods with little oil, and drinking at least 1.5 litres of water a day [20]. In 14-18 year-old Americans, a positive association between daytime sleep, which may have reflected an increased need for nocturnal sleep, and greater food cravings was found [14]. Finally, among Iranian school girls, those who were overweight had shorter sleeping times and consumed "less nutritious food", such as candies, chocolates and potato chips, more often than normal weight girls [13]. However, in a study of German children and adolescents no association was observed between sleep duration and a nutrition quality score reflecting consumption of healthy and unhealthy foods [4]. Since the hedonic value of food intake might play a crucial role in the association between short sleep duration and overweight, this is an important target of future research [11].

The observed inverse association between BMI and parental education is consistent with the results from other studies in children and adolescents [21]. However, the fact that parental education was not associated with sleep duration in this study is inconsistent with the findings of others [22], and might be explained by the fact that only 10% of the participating children had parents with educational level 1 (the lowest level, basic school). This might be insufficient to detect a difference. Although gender differences have been observed in some other studies examining the association between diet and sleep [4,14,15], there were no gender differences regarding sleep duration, and adjusting for gender did not change the results markedly.

Among the limitations of this study is its cross-sectional nature that cannot disentangle cause and effect. To confirm a causal relationship between sleeping habits and eating patterns, randomized controlled trials are needed. Moreover, we have no data on pubertal status, which might also influence both BMI [16], sleep duration as well as eating habits. Additionally, BMI was calculated from parent-reported height and weight, and might therefore be underestimated, since parental reporting tends to overestimate height and underestimate weight in children with a high BMI. However, several studies have found relatively good relationships between measured and self-reported estimates of children's and adolescents' height and weight [23,24]. Possibly, underreporting may have blurred the results particularly in this age group, as it has been well documented that underreporting increases with age of children [25], and occurs especially with food items perceived as unhealthy [26]. In addition, the fact that we did not have information about pubertal status might influence the results in this age group, as puberty may influence both BMI, diet and sleep [27]. However, no association between sleep duration and pubertal status has been found in obese children [28].

The strengths of the present study include its nationwide character as it is based on a nationally representative population study. We also had access to very detailed dietary data that enabled us to analyse the association of sleep duration with specific dietary variables. An additional strength of this study is that sleep duration was reported every day for seven consecutive days and reported as a mean of seven days and not as a measure of usual sleep duration. However, sleep duration was self-reported and not measured, but self-reported sleep duration has been found to be positively correlated with polysomnographic measurements [29]. There may be a potential overestimation of sleep duration in our data because parental reports of sleep duration may be determined by the time of going to bed and getting up rather than on actual time of sleeping. However, sleep diaries have been found to have better agreement with objective measurements than sleep questionnaires [30], and therefore the quality of the sleep data in the present study may be considered relatively high.

In conclusion, there was a negative association between sleep duration and BMI in the present sample of 4-14 year-old Danish children. However, sleep duration was not associated with energy intake and the conception that children with short sleep duration have less healthy eating habits than children with longer sleep duration was only weakly supported by the present findings. Although the causality needs to be elucidated further, the present findings are contributory to gaining a better understanding of the link between sleep duration, dietary intake and body weight, which may be valuable for further research and health strategies related to prevention of overweight and obesity.

Acknowledgements

The authors are grateful to Tue Christensen, Karin Hess Ygil and Karsten Kørup (Division of Nutrition, National Food Institute, Technical University of Denmark) for developing the software system and databases used in the processing of the data and for contributing to data processing. The authors designed the analyses of this study (CH and BR) and were responsible for the design and collection of data from The Danish National Survey of Dietary Habits and Physical Activity (MVG, AB-J, JM). CH and BR were responsible for analyses of data and writing the manuscript. All authors participated in the discussion of the results and revision of the manuscript. The authors declare no conflict of interest.

Funding

The study is part of the OPUS project 'Optimal well-being, development and health for Danish children through a healthy New Nordic Diet' supported by a grant from the Nordea Foundation.

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Table I. Characteristics of the study population

	4-6 y (*n* = 212)	7-10 y (*n* = 289)	11-14 y (*n* = 301)
	Mean (SD)	Mean (SD)	Mean (SD)
Gender, M/F (%)	50/50	54/46	45/55
Height (cm)	118.6 (8.9)	139.4 (9.3)	161.4 (9.7)
Weight (kg)	22.1 (4.1)	33.0 (7.4)	50.5 (10.9)
BMI (kg/m^2)	15.6 (1.9)	16.8 (2.6)	19.3 (3.1)
Weight status[a] (%)			
Overweight, M/F	7.5/16.0	12.9/14.9	19.4/15.0
Obesity, M/F	0/3.8	3.8/4.5	2.2/4.2
Sleep duration (h)	10.2 (0.6)	9.6 (0.5)	8.9 (0.7)
Parental education[b] (%)			
1: Basic school	9	9	11
2: Vocational education	41	43	42
3: Short higher education	8	10	15
4: Long higher education	42	38	32

M, males; F, females; BMI, body mass index.

[a]Weight status according to international cut off values [16].

[b]Parental educational level, *n* = 731. 1: Basic school (10 years or less of total education); 2: Vocational education, upper secondary school (10-12 year); 3: Short higher education (13-15 year) (primarily theoretical); 4: Long higher education (15+ years) (primarily theoretical).

Table II. Coefficients from multiple linear regression analyses performed separately for each dietary variable with sleep duration (h/d) as the dependent variable and age (y) and BMI (kg/m^2) as forced covariates in the models (*n* = 802)

	Beta	*P*
Energy (MJ/d)	-0.044	0.097
Protein[a] (E%)	0.018	0.492
Fat[a] (E%)	-0.008	0.776
- SFA[a] (E%)	-0.009	0.738
- MUFA[a] (E%)	-0.020	0.453
- PUFA[a] (E%)	0.004	0.875
Carbohydrate[a] (E%)	0.002	0.953
- Added sugars[a] (E%)	-0.041	0.112
Dietary fibre (g/10 MJ)	0.054	0.041
High fat milk and milk products (g/10 MJ)	0.028	0.286
Low fat milk and milk products (g/10 MJ)	-0.021	0.426
Rye bread (g/10 MJ)	0.050	0.061
Wheat bread (g/10 MJ)	0.010	0.713
Sugary breakfast cereals[b] (g/10 MJ)	0.012	0.645
Fruit (g/10 MJ)	-0.005	0.855
Vegetables (g/10 MJ)	0.057	0.027
Meat and meat products (g/10 MJ)	0.025	0.332
Poultry (g/10 MJ)	-0.026	0.329
Fish and seafood (g/10 MJ)	0.031	0.234
Fast food & light meals[c] (g/10 MJ)	-0.024	0.363
Snacks[d] (g/10 MJ)	-0.025	0.331
Sweets & chocolate (g/10 MJ)	0.001	0.981
Solid “empty calories” [e] (g/10 MJ)	-0.037	0.151
Liquid “empty calories” [f] (g/10 MJ)	-0.055	0.035

E%, energy percentage; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

[a]Macronutrient energy percentages are calculated including alcohol.

[b]Sugar content > 10g/100g.

[c]Burger, toast, spring roll, hotdog, French hotdog, sandwich, filled croissant, pizza, falafel, humus, filled patty shell.

[d]Chips, popcorn, peanuts, pistachio nuts, almonds, cheese dippers, pretzels.

[e]Sum of the variables Snacks and Sweets & chocolate as well as chips, confectionary, ice cream and desserts.

[f]Sugar sweetened beverages, cider, ice tea.

Table III. Dietary variables in 4-6-year-old children (n = 212) above and below the median sleep duration

	Sleep duration				
	Below median		Above median		
	Mean	(SD)	Mean	(SD)	P^a
Energy (MJ/d)	7.7	(1.8)	7.3	(1.5)	0.31
Protein[b] (E%)	14	(2.0)	14	(1.8)	0.45
Fat[b] (E%)	34	(4.0)	35	(4.7)	0.32
- SFA[b] (E%)	15	(2.2)	15	(2.7)	0.36
- MUFA[b] (E%)	12	(1.6)	12	(1.8)	0.46
- PUFA[b] (E%)	5	(0.8)	5	(0.7)	0.06
Carbohydrate[b] (E%)	52	(3.9)	51	(4.6)	0.21
- Added sugars[b] (E%)	12	(4.5)	11	(3.8)	0.04
Dietary fibre (g/10 MJ)	22	(4.6)	23	(4.7)	0.18
High fat milk and milk products (g/10 MJ)	20	(48)	30	(112)	0.52
Low fat milk and milk products (g/10 MJ)	276	(296)	286	(298)	0.71
Rye bread (g/10 MJ)	79	(40)	81	(34)	0.45
Wheat bread (g/10 MJ)	81	(43)	76	(41)	0.49
Sugary breakfast cereals[c] (g/10 MJ)	4	(8)	3	(7)	0.48
Fruit (g/10 MJ)	242	(137)	248	(141)	0.83
Vegetables (g/10 MJ)	144	(80)	170	(84)	0.03
Meat and meat products (g/10 MJ)	99	(3)	102	(3)	0.63
Poultry (g/10 MJ)	20	(24)	20	(18)	0.45
Fish and seafood (g/10 MJ)	16	(16)	19	(18)	0.21
Fast food & light meals[d] (g/10 MJ)	63	(58)	72	(70)	0.41
Snacks[e] (g/10 MJ)	10	(13)	8	(10)	0.25
Sweets & chocolate (g/10 MJ)	24	(19)	23	(17)	0.92
Solid “empty calories” [f] (g/10 MJ)	112	(50)	102	(49)	0.10
Liquid “empty calories” [g] (g/10 MJ)	237	(212)	182	(133)	0.002

E%, energy percentage; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

[a]Mann-Whitney U test for difference between sleep duration groups.

[b]Macronutrient energy percentages are calculated including alcohol.

[c]Sugar content > 10g/100g.

[d]Burger, toast, spring roll, hotdog, French hotdog, sandwich, filled croissant, pizza, falafel, humus, filled patty shell.

[e]Chips, popcorn, peanuts, pistachio nuts, almonds, cheese dippers, pretzels.

[f]Sum of the variables Snacks and Sweets & chocolate as well as chips, confectionary, ice cream and desserts.

[g]Sugar sweetened beverages, cider, ice tea.

Table IV. Dietary variables in 7-10-year-old children (n = 289) above and below the median sleep duration

	Sleep duration				
	Below median		Above median		
	Mean	(SD)	Mean	(SD)	P^a
Energy (MJ/d)	8.5	(2.1)	8.7	(2.0)	0.45
Protein[b] (E%)	14	(2.1)	14	(2.0)	0.12
Fat[b] (E%)	33	(4.3)	33	(4.8)	0.93
- SFA[b] (E%)	14	(2.4)	14	(2.5)	0.87
- MUFA[b] (E%)	11	(1.7)	11	(1.8)	0.68
- PUFA[b] (E%)	5	(0.8)	5	(1.0)	0.52
Carbohydrate[b] (E%)	52	(4.5)	53	(4.8)	0.50
- Added sugars[b] (E%)	13	(4.5)	13	(4.9)	0.61
Dietary fibre (g/10 MJ)	21	(5.3)	21	(5.2)	0.61
High fat milk and milk products (g/10 MJ)	32	(105)	41	(130)	0.48
Low fat milk and milk products (g/10 MJ)	268	(274)	245	(288)	0.30
Rye bread (g/10 MJ)	58	(40)	65	(42)	0.14
Wheat bread (g/10 MJ)	89	(49)	87	(42)	0.98
Sugary breakfast cereals[c] (g/10 MJ)	4	(8)	4	(9)	0.99
Fruit (g/10 MJ)	220	(161)	228	(157)	0.59
Vegetables (g/10 MJ)	151	(83)	156	(91)	0.69
Meat and meat products (g/10 MJ)	112	(3)	111	(3)	0.57
Poultry (g/10 MJ)	25	(23)	18	(18)	0.004
Fish and seafood (g/10 MJ)	15	(20)	13	(14)	0.87
Fast food & light meals[d] (g/10 MJ)	106	(83)	94	(82)	0.12
Snacks[e] (g/10 MJ)	9	(10)	8	(10)	0.09
Sweets & chocolate (g/10 MJ)	28	(20)	22	(16)	0.01
Solid “empty calories” [f] (g/10 MJ)	113	(56)	108	(45)	0.54
Liquid “empty calories” [g] (g/10 MJ)	290	(213)	293	(253)	0.60

E%, energy percentage; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

[a]Mann-Whitney U test for difference between sleep duration groups.

[b]Macronutrient energy percentages are calculated including alcohol.

[c]Sugar content > 10g/100g.

[d]Burger, toast, spring roll, hotdog, French hotdog, sandwich, filled croissant, pizza, falafel, humus, filled patty shell.

[e]Chips, popcorn, peanuts, pistachio nuts, almonds, cheese dippers, pretzels.

[f]Sum of the variables Snacks and Sweets & chocolate as well as chips, confectionary, ice cream and desserts.

[g]Sugar sweetened beverages, cider, ice tea.

Table V. Dietary variables in 11- to 14-year-old children (n = 301) above and below the median sleep duration

	Sleep duration				
	Below median		Above median		
	Mean	(SD)	Mean	(SD)	P^a
Energy (MJ/d)	8.7	(2.6)	8.3	(2.3)	0.18
Protein[b] (E%)	14	(2.2)	15	(2.3)	0.47
Fat[b] (E%)	32	(5.2)	32	(4.7)	0.84
- SFA[b] (E%)	14	(2.5)	14	(2.4)	0.83
- MUFA[b] (E%)	11	(2.2)	11	(1.9)	0.92
- PUFA[b] (E%)	5	(1.0)	5	(0.9)	0.74
Carbohydrate[b] (E%)	53	(5.5)	53	(5.0)	0.82
- Added sugars[b] (E%)	13	(5.4)	12	(5.4)	0.41
Dietary fibre (g/10 MJ)	21	(6.0)	21	(5.9)	0.37
High fat milk and milk products (g/10 MJ)	10	(49)	17	(84)	0.53
Low fat milk and milk products (g/10 MJ)	214	(284)	202	(248)	0.83
Rye bread (g/10 MJ)	48	(46)	56	(43)	0.03
Wheat bread (g/10 MJ)	91	(53)	98	(54)	0.20
Sugary breakfast cereals[c] (g/10 MJ)	3	(7)	3	(8)	0.32
Fruit (g/10 MJ)	199	(166)	198	(158)	0.99
Vegetables (g/10 MJ)	158	(96)	165	(100)	0.50
Meat and meat products (g/10 MJ)	114	(4)	114	(4)	0.50
Poultry (g/10 MJ)	26	(27)	27	(28)	0.70
Fish and seafood (g/10 MJ)	11	(14)	14	(18)	0.26
Fast food & light meals[d] (g/10 MJ)	120	(97)	112	(107)	0.27
Snacks[e] (g/10 MJ)	9	(20)	8	(12)	0.67
Sweets & chocolate (g/10 MJ)	26	(22)	29	(27)	0.59
Solid “empty calories” [f] (g/10 MJ)	104	(56)	107	(59)	0.67
Liquid “empty calories” [g] (g/10 MJ)	325	(261)	276	(250)	0.07

E%, energy percentage; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

[a]Mann-Whitney U test for difference between sleep duration groups.

[b]Macronutrient energy percentages are calculated including alcohol.

[c]Sugar content > 10g/100g.

[d]Burger, toast, spring roll, hotdog, French hotdog, sandwich, filled croissant, pizza, falafel, humus, filled patty shell.

[e]Chips, popcorn, peanuts, pistachio nuts, almonds, cheese dippers, pretzels.

[f]Sum of the variables Snacks and Sweets & chocolate as well as chips, confectionary, ice cream and desserts.

[g]Sugar sweetened beverages, cider, ice tea.

National Food Institute
Technical University of Denmark
Mørkhøj Bygade 19
DK - 2860 Søborg

Tel. 35 88 70 00
Fax 35 88 70 01

www.food.dtu.dk

ISBN: 978-87-92763-30-3