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## Effects of a multi-component community-based health promotion intervention on eating behaviour and overweight in children

*Results from the SoL project*

Buch-Andersen, Tine

DOI (link to publication from Publisher):  
[10.5278/VBN.PHD.ENGSCI.00090](https://doi.org/10.5278/VBN.PHD.ENGSCI.00090)

Publication date:  
2016

Document Version  
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

Citation for published version (APA):

Buch-Andersen, T. (2016). *Effects of a multi-component community-based health promotion intervention on eating behaviour and overweight in children: Results from the SoL project*. Aalborg Universitetsforlag. <https://doi.org/10.5278/VBN.PHD.ENGSCI.00090>

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**EFFECTS OF A MULTI-COMPONENT  
COMMUNITY-BASED HEALTH PROMOTION  
INTERVENTION ON EATING BEHAVIOUR AND  
OVERWEIGHT IN CHILDREN**

RESULTS FROM THE SoL PROJECT

**BY  
TINE BUCH-ANDERSEN**

DISSERTATION SUBMITTED 2016



**AALBORG UNIVERSITY**  
DENMARK



# Effects of a multi-component community-based health promotion intervention on eating behaviour and overweight in children.

Results from the SoL project

by

Tine Buch-Andersen



**AALBORG UNIVERSITY**  
DENMARK

Dissertation submitted 2016

Dissertation submitted: March 18, 2016

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PhD committee:

PhD Series: Faculty of Engineering and Science, Aalborg University

ISSN (online): 2246-1248

ISBN (online): 978-87-7112-535-1

Published by:  
Aalborg University Press  
Skjernvej 4A, 2nd floor  
DK – 9220 Aalborg Ø  
Phone: +45 99407140  
aauf@forlag.aau.dk  
forlag.aau.dk

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Printed in Denmark by Rosendahls, 2016

# PREFACE AND ACKNOWLEDGEMENTS

The present PhD project was a part of a larger research and development project, the SoL project, which involved three research institutions and local partners.

The work presented in this thesis was carried out between 2012 and 2016 at Aalborg University and at the Research Centre for Prevention and Health. The project was financed by Nordea-fonden and the Faculty of Engineering and Science, Aalborg University. My work during these years included questionnaire development, conducting a validation study, data collection, data entry, data management and data analysis. A two-month stay at the WHO Collaborating Centre for Obesity Prevention at Deakin University during spring 2015 gave me an opportunity to work with international experts and study process evaluation of community projects.

Doing a PhD project within the frames of a cross-disciplinary project and conducted in real-life settings has been challenging but also inspiring and fun. Importantly, the work holds public relevance and that has been very motivating for me.

Several people, and in particular my supervisors Bent Egberg Mikkelsen, Ulla Toft and Federico J.A. Pérez-Cueto, have contributed to this thesis in different ways with valuable advice and guidance. A special thanks to Ulla for hosting me and for your commitment throughout the PhD project. I was fortunate to spend some of my PhD time at FCFS and I am grateful to have had the opportunity to work with excellent data managers and researchers with experience in all areas of questionnaire survey design. I also thank the rest of the SoL team for good times and their contributions to articles. I owe much thanks to Frank Eriksson for his invaluable and thorough statistical inputs to articles.

Special thanks to the children and families that have participated in the project and to the staff of schools and childcare centres that welcomed us and made it all possible.

I would also like to thank Anne Ahrendt Bjerregaard from SSI for the good discussions on validation methodologies and talks about life as a PhD student; the waterfront staff at Deakin University for introducing me to an excellent research environment full of warmth; my previous colleagues at IPM, especially Britt Wang Jensen, for her experienced advice on various subjects; and my AAU colleagues for being great office mates and enriching my life with new friendships.

Finally, I wish to thank my family and friends for their support throughout the process.

Tine Buch-Andersen  
Copenhagen, March 2016



# ENGLISH SUMMARY

**Background** The high prevalence of non-communicable diseases and obesity is a major public health concern. Given that lifestyle factors such as diet and physical activity are established in childhood and track into adulthood, prevention should start early. Emerging evidence suggests that the implementation of a more comprehensive approach that includes multiple levels, components and settings represents the most promising direction for prevention. In view of this, the Danish SoL (from the Danish Sundhed og Lokalsamfund / Health and Local Community) project was designed as a multi-component health promotion intervention in selected local communities. Within the frames of the SoL project, the objectives of the thesis were to 1) assess the relative validity and reproducibility of the semi-quantitative food-frequency questionnaire (SFFQ) applied in the SoL project (Paper I); 2 and 3) determine the effects of the SoL intervention on eating behaviour (Paper II) and overweight (Paper III) among three- to eight-year-old children.

**Methods** Data were collected as a part of the SoL project, a quasi-experimental study with a 19-month intervention period. Intervention and control communities were located in two Danish municipalities (three intervention and three control communities). A total of 861 children were enrolled at baseline from seven childcare centres and six schools. The intervention was based on the supersetting approach and was designed to promote healthier eating and physical activity among children. Key behaviours included the consumption of fruits, vegetables, fish, whole grains, candy and sweet drinks. Eating behaviour was assessed three times (at baseline, after one year and after 19 months) with a parent-administered SFFQ. The SFFQ was validated in a study testing relative validity and reproducibility using four-day estimated food records as the reference and administering the SFFQ twice separated by a one-month period. Anthropometric data (height, weight, waist circumference) was collected at baseline and at the final follow-up to measure childhood overweight. BMI z-scores were calculated using the LMS method with the use of national reference data. Information on socio-economic and family status was obtained from national registries. Data were analysed using a longitudinal linear mixed model.

**Results** Fifty-four completed the first SFFQ (100%), forty-eight completed the second SFFQ (89%) and fifty-three completed food records (98%) were available. The SFFQ generally overestimated intakes compared with the food records, especially for vegetables. For most intakes, a lower agreement was observed at high intakes. Gross misclassification was on average 8% for foods. Spearman correlation coefficients were significant for 12 out of 14 intakes and highest for foods ( $r=0.29$  to  $0.63$ ). Comparing the repeated SFFQ administrations, the intakes of the first SFFQ were slightly higher than those of the second. Agreement was lower at high intakes. Gross misclassification was on average 6% for foods. Intra-class correlations were significant for all intakes ( $r=0.30$  to  $0.82$ ).



In the SoL study, 147 (33%) from the intervention group and 105 (26%) from the control group completed the SFFQ at baseline. There were no differences between the intervention and the control group in changes over time for consumption of vegetables, fruit, fish, whole grains, candy and sweet drinks.

A total of 238 (54%) children from the intervention group and 214 (51%) from the control group participated in the anthropometric measurements at baseline. The development in BMI z-scores ( $P=0.001$ ), BMI ( $P<0.0001$ ) and weight ( $P=0.01$ ) of the intervention children was significantly different from the control group. BMI z-scores increased over time in the intervention group in contrast to the control whose BMI z-scores decreased (difference in change between groups 0.19 z-scores, 95% CI 0.08 to 0.31). Similar patterns were observed for BMI and weight. No significant differences were observed for waist circumference.

**Conclusions** The results of the validation study indicated that the relative validity of the SFFQ was overall low to moderate, which is similar to findings of other validation studies conducted in young children. We also found that the SFFQ gave reproducible estimates. Lower validity was observed for energy intake in particular, but also for candy and sweet drinks, which necessitates caution when intervention results are interpreted.

The findings of the present study showed no evidence of effects of the SoL multi-component community-based intervention on measured eating behaviours. The study was, however, insufficiently powered to detect a difference (small sample size) and was like other studies limited by the methodological challenges of parental reports of child behaviour. Another explanation may relate to the limited implementation of environmental and policy change interventions. The anthropometric study indicated that the SoL intervention had no favourable effects on childhood overweight. The SoL project was, however, not designed to impact on overweight or obesity status, and it is very likely that the changes observed in weight and BMI were influenced by secular trends. The limited effects on eating behaviour and overweight prevention may also relate to insufficient follow-up time. The SoL project applied the action research methodology, and it is possible that this approach requires more time for the project to unfold and impacts to occur.

Future research should further explore dietary evaluation methodologies adapted to community-based complex interventions. Based on the experiences of the present study, it is also highly recommended to reconsider the recruitment and retention strategies in order to increase participation rates, especially for the evaluation of self-reported behaviours. Finally, a greater attention to process evaluation and subgroups of the population could provide interesting data on intervention implementation and effects.

# DANSK RESUME

**Baggrund** Den høje forekomst af livsstilssygdomme og fedme er bekymrende for folkesundheden. Livsstilsvaner som kost og fysisk aktivitet grundlægges i barndommen og trækker spor ind i voksenalderen hvorfor forebyggelse bør starte tidligt. Ny forskning peger på at en bred tilgang, der omfatter flere niveauer, komponenter og arenaer, har det mest lovende potentiale inden for forebyggelse. Det danske projekt ”Sundhed og Lokalsamfund” (SoL) bygger på denne tilgang og blev designet som en multi-komponent sundhedsfremmende intervention i udvalgte lokalsamfund. Inden for rammerne af dette projekt var formålet med afhandlingen at: 1) Undersøge relativ validitet og reproducerbarhed af det semi-kvantitative fødevarerfrekvensspørgeskema, der blev anvendt i projekt SoL (Paper I), 2) og 3) Undersøge effekten af SoL-projektet på spisevaner (Paper II) og overvægt (Paper III) blandt 3-8-årige børn.

**Metoder** Data blev indsamlet i forbindelse med SoL-projektet, som var et kvasi-eksperimentelt studie med en 19 måneders intervention. Tre lokalsamfund på Bornholm deltog som intervention, og tre lokalsamfund i Odsherred deltog som kontrol. Syv børnehaver og seks skoler deltog med i alt 861 børn. Interventionen var baseret på supersætning tilgangen og havde til formål at fremme sundere spisevaner og fysisk aktivitet hos børn. Nogle adfærdsmål inkluderede frugt, grøntsager, fisk, fuldkorn, slik og søde drikke. Spisevaner blev målt tre gange (ved baseline, efter 1 år, efter 19 måneder) med et semi-kvantitativt fødevarerfrekvensspørgeskema, der blev udfyldt af forældre. Fødevarerfrekvensspørgeskemaet blev valideret i et studie som testede relativ validitet og reproducerbarhed. Kostdagbøger udgjorde referencen og fødevarerfrekvensspørgeskemaet blev udsendt to gange med en måneds mellemrum. Antropometriske data (højde, vægt, taljeomkreds) blev målt ved baseline og ved den sidste opfølgning for at måle overvægt og fedme. BMI z-scores blev beregnet ved brug af LMS metoden med brug af nationale reference data. Information om socioøkonomisk og familiestatus blev indhentet fra nationale registre. Data blev analyseret med en longitudinel lineær mixed model.

**Resultater** 54 komplette fødevarerfrekvensspørgeskemaer fra første udsendelse (100%), 48 komplette fødevarerfrekvensspørgeskemaer fra anden udsendelse (89%) og 53 komplette kostdagbøger (98%) var til rådighed. I gennemsnit overestimerede fødevarerfrekvensspørgeskemaet kostindtag sammenlignet med kostdagbøger. For de fleste indtag blev der observeret en dårligere overensstemmelse imellem metoder ved høje indtag. I gennemsnit blev 8% af fødevarergruppeindtagene misklassificeret. Korrelationskoefficienter var signifikante for 12 ud af 14 indtag og højest for fødevarergruppeindtag ( $r=0,29$  til  $0,63$ ). Ved gentagne udsendelser af fødevarerfrekvensspørgeskemaet sås det ligeledes at overensstemmelsen generelt blev dårligere ved høje indtag. Hertil sås det også at indtagene fra det første skema var lidt højere end fra den anden udfyldning. Misklassificering af indtag var i

gennemsnit 6% for fødevarergrupper. Intra-klasse korrelationer var alle signifikante ( $r=0,30$  til  $0,82$ ).

I SoL studiet besvarede 147 (33%) fra interventionsgruppen og 105 (26%) fra kontrolgruppen fødevarerspørgeskemaet ved baseline. Der var ingen påviselige forskelle mellem interventionsgruppen og kontrolgruppen i ændringer over tid for indtag af grøntsager, frugt, fisk, fuldkorn, slik og søde drikke.

238 (54%) børn fra interventionsgruppen og 214 (51%) fra kontrolgruppen deltog i de antropometriske målinger ved baseline. Udviklingen i BMI z-score ( $P=0.001$ ), BMI ( $P<0.0001$ ) og vægt ( $P=0.01$ ) var signifikant forskellig mellem intervention og kontrol. BMI z-score øgedes over tid i interventionsgruppen modsat kontrolgruppen, hvor BMI z-score faldt (forskell i ændring mellem grupper var  $0,19$  z-score, 95% CI  $0,08$  til  $0,31$ ). Lignende udviklingsmønstre sås for BMI og vægt. Der var ingen signifikante forskelle for taljeomkreds.

**Konklusion** Resultaterne fra valideringsstudiet indikerede at den relative validitet generelt var lav til moderat, hvilket også ses i andre studier udført blandt mindre børn. Fødevarerfrekvensspørgeskemaet var i stand til at producere reproducerbare estimater. Der var en lavere validitet af især energiindtag, men også for slik og søde drikke, og derfor bør resultater angående disse indtag fortolkes varsomt.

Der kunne ikke påvises en effekt af en multi-komponent sundhedsfremmende lokalsamfundsintervention på spisevaner. Studiet havde dog ikke en tilstrækkelig power til at måle forskel (lille stikprøve) og var som andre studier begrænset af metodiske udfordringer ved at måle spisevaner blandt mindre børn. En anden forklaring kunne være den begrænsede implementering af strukturelle indsatser og ændringer i politikker. Resultaterne vedrørende de antropometriske målinger indikerede at SoL-interventionen ikke kunne forebygge overvægt og fedme blandt børn. Studiet var dog ikke designet til at påvirke overvægt eller fedme og det er sandsynligt at ændringerne afspejler sekulære tendenser i de to områder. Den begrænsede effekt på spisevaner og fedmegrad kan også skyldes at opfølgningstiden var for kort. SoL-projektet anvendte aktionsforskning og det er muligt at denne tilgang kræver længere tid til implementering og at effekter først skabes på den lange bane.

Der er brug for yderligere forskning i kostmålingsmetoder tilpasset komplekse interventionsstudier i lokalsamfund. På basis af erfaringerne fra nærværende studie anbefales det desuden at gentænke rekruttering og fastholdelsesstrategier for at øge deltagelsesraten, især i forbindelse med evaluering af selv-rapporteret adfærd. En større fokus på procesevaluering og undergrupper af populationen kunne tilvejebringe interessante data om implementering og hjælpe med at forstå effekter.

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# LIST OF PAPERS

- i. Buch-Andersen, T; *Pérez Cueto, Federico JA; Toft, U (2015): Relative validity and reproducibility of a parent-administered semi-quantitative FFQ for assessing food intake in Danish children aged 3-9 years.* Public Health Nutrition, 2015 Oct 5:1-11.
- ii. Buch-Andersen, T; Madsen, AL; Eriksson, F; Bloch, P; Glümer, C; Mikkelsen, BE; Toft, U (2016): *Effects of a multi-component community-based health promotion intervention on eating behaviour in 3–8-year-old children. The Danish SoL project.* Submitted to Public Health Nutrition.
- iii. Buch-Andersen, T; Eriksson, F; Bloch, P; Glümer, C; Mikkelsen, BE; Toft, U (2016): *Effects of a multi-component community-based health promotion intervention on prevention of overweight in 3–8-year-old children. The Danish SoL project.* Submitted to Public Health Nutrition.



# ABBREVIATIONS

|      |  |
|------|--|
| BMI  | Body Mass Index                                      |
| CI   | Confidence Interval                                  |
| CPR  | Civil Registration Number                            |
| FFQ  | Food-Frequency Questionnaire                         |
| ICC  | Intra-class Correlation Coefficient                  |
| IOTF | International Obesity Task Force                     |
| LOA  | Limits of Agreement                                  |
| LMS  | Skewness-L, Median-M and Coefficient of Variation-S  |
| MAR  | Missing at Random                                    |
| SoL  | Sundhed og Lokalsamfund / Health and Local Community |
| SD   | Standard Deviation                                   |
| SES  | Socio-economic Status                                |
| SFFQ | Semi-quantitative Food-Frequency Questionnaire       |





# CHAPTER 1. INTRODUCTION

The high prevalence of non-communicable diseases and obesity is a major public health concern (1,2). Although there appears to be an overall levelling off of the obesity epidemic among children from Denmark and other developed countries, the prevalence is still high and low socio-economic groups remain disproportionately affected (3,4). Overweight and obesity in childhood have short-term health and psychosocial consequences and are known to track into later childhood and adulthood causing the development of chronic diseases such as type 2 diabetes and cardiovascular disease (5,6).

Obesity and chronic lifestyle diseases are largely preventable as they are associated with lifestyle factors (7). Lifestyle factors such as diet and physical activity are modifiable and therefore particularly interesting in terms of health promotion and prevention. These behaviours are established in childhood and research shows that they track into later life (8). Hence, early prevention is important.

Half of Danish children consume too much added sugar and most children fail to meet the recommendations for fruit and vegetables, fish and whole grains (9,10). Furthermore, Danish children's sedentary activity has increased over time (11).

Schools are considered an attractive setting to reach a large number of children from all society levels and as a suitable medium to reach parents. Therefore, past health promotion initiatives targeting children's eating and physical activity behaviour have mostly been carried out in the school setting. The results of these studies have been mixed and the effects mostly short-term (12,13). The limited success could be due to the narrow focus of the interventions that were based on a single setting, mostly focusing on individual behaviour and not so much on environments and the capacity building of communities. Accordingly, emerging evidence supports the implementation of a more comprehensive approach that includes multiple levels, components and settings (14,15). A community-based approach offers great potential for prevention and health promotion among children. It can be designed as a complex intervention organized at different levels, including a variety of components, involving multiple stakeholders and implemented in numerous settings that are relevant to the everyday life context of children and their families. Furthermore, community interventions can be made sustainable if they include proper capacity-building elements, structural change and organizational integration (16).

The feasibility and effectiveness of community-based studies in promoting the healthy nutritional status of children have been demonstrated in some studies, mainly implemented in American and Australian contexts. These studies have mostly used primary schools as the dominant setting, and adiposity as the main outcome measure

(17,18). Studies examining the effects of complex integrated interventions on eating and physical activity behaviour, carried out in multiple settings and involving multiple stakeholders are scarce.

The Danish SoL (from the Danish Sundhed og Lokalsamfund / Health and Local Community) project sought to fill this gap by implementing a multi-component and integrated health promotion intervention in selected local communities based on the principles of the supersetting approach (19).

## **1.1. AIM AND RESEARCH OBJECTIVES**

The overall aim of the present PhD project was to examine the effects of the SoL intervention on eating behaviour and overweight among three- to eight-year-old children.

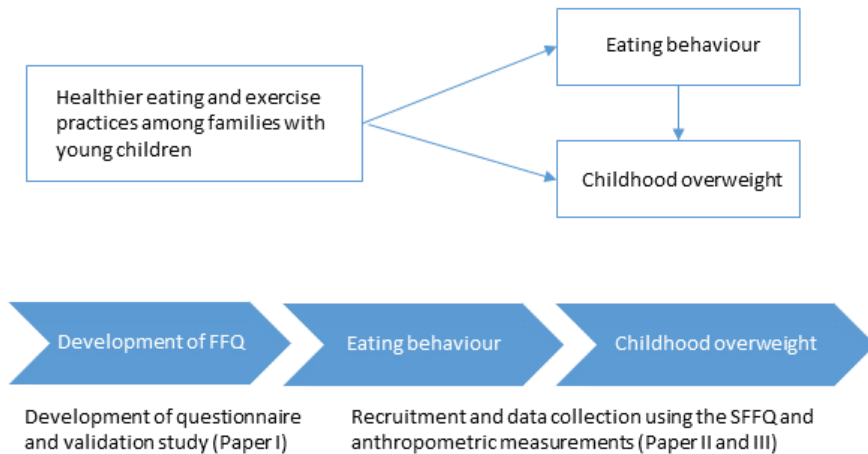
The specific research objectives for each of the papers were:

- |           |  |
|-----------|--|
| Paper I   | To assess the relative validity and reproducibility of the semi-quantitative food frequency questionnaire used in the SoL project                                |
| Paper II  | To determine the effects of a multi-component community-based health promotion intervention on the eating behaviour of three- to eight-year-old children.        |
| Paper III | To determine the effects of a multi-component community-based health promotion intervention on prevention of overweight among three- to eight-year-old children. |

# CHAPTER 2. OVERVIEW OF THE PHD PROJECT

The PhD project was based on three substudies (Papers I–III) and the flow of these studies is illustrated below (Figure 1). First, a tool was developed to measure the eating behaviour of young children. This tool, a parent-administered semi-quantitative food-frequency questionnaire (SFFQ), was validated in a study testing relative validity and reproducibility (Paper I) (20). Second, the SFFQ was used to collect data on eating behaviour and these data were then analysed in order to determine the intervention effects of the SoL project. Third, data on overweight and obesity status were collected using anthropometric measurements. The anthropometric data were analysed in order to determine whether the SoL project could prevent childhood overweight and obesity.

The following chapter, Background, will briefly review literature regarding prevalence, interventions and evaluation methodologies related to the assessment of dietary intake and overweight in children. In Chapter four, the conceptual framework and the implementation of the SoL intervention are described. Furthermore, the evaluation methodologies of Papers I–III are summarized, and detailed if necessary. A summary of results is presented in Chapter five and these results are discussed and put into perspective in the final chapter of this thesis.



**Figure 1** Visual presentation of the PhD project. Arrows between squares show the direction of effects. Bold arrows show the flow of the PhD project.



## CHAPTER 3. BACKGROUND

### 3.1. NUTRITIONAL STATUS OF CHILDREN

#### OVERWEIGHT AND OBESITY AMONG CHILDREN

Overweight and obesity in children have increased rapidly in recent decades (5,21). Approximately 10% of children worldwide are estimated to be overweight or obese (1). In Europe, the prevalence of overweight and obesity was estimated to be in the order of 20–30 % among school-aged children in 2006. Similarly, the level of overweight and obesity has increased among preschool children, but on a lower level. In Denmark, a prevalence of 16% in girls and 12% in boys for overweight and obesity was observed at school entry (five- to eight-year-olds) (22).

The increase in prevalence is unfortunate since being overweight in childhood has both short- and long-term health consequences for the child. Besides physical effects, overweight and obesity are often related to stigma and poorer mental health (23,24). Childhood overweight and obesity are known to track into later childhood and adulthood causing chronic disease (6).

Recent research in Denmark found that since the year 2000 there has been a levelling off in the prevalence of overweight in Danish girls aged 4 to 14 years, but an increase in boys from socio-economic disadvantaged families (4). Internationally, there is also strong evidence that children from disadvantaged families are especially prone to overweight and obesity (25).

#### THE IMPORTANCE OF HEALTHY EATING IN CHILDHOOD

It is well documented that a healthy diet is associated with a lower risk of certain diseases and the development of overweight and obesity (7,26,27). Some food patterns or individual foods have been associated with obesity in children. A dietary pattern that is high in energy-dense, high-fat, low-fibre foods has been associated with later obesity risk in children and adolescents (28).

Sweet drinks (sugar-sweetened beverages, soft drinks, squash drinks) are associated with obesity in children (29,30). In the so-called healthy food category, protective effects are suggested for vegetables, fruits, whole grains and fish as these foods are associated with decreased disease risk (31-33).

A healthy diet in childhood may also benefit other important aspects of child health such as improved cognitive performance/learning and well-being (34). Lifestyle behaviours are established in childhood and will often persist into later life (8).

Therefore, the development of healthy eating habits from a young age is of great importance.

According to the National Dietary Survey, Danish children's dietary intake is too high in high-fat meat and milk products, soft drinks and sugary foods, and too low in fish, vegetables and whole-grain products (9,35). Danish children consume on average 10 grams of fish daily, which is less than a quarter of the recommended amount. The average consumption of vegetables among children is 136 grams, which should be increased to at least 150–250 grams to comply with the recommendations for children aged four to ten years. The sugar consumption is high and mostly in the form of sweets, cakes, ice cream and sweet drinks. The average daily consumption has been estimated at 322 ml of sweet drinks (excl. drinks with artificial sweeteners) and 29 grams of sweets (incl. chocolates). To comply with the recommendations, children's diet should contain a maximum of 30 grams of sugar for preschool children and a maximum of 45–55 grams for schoolchildren. The intake of sweet drinks such as soft drinks and lemonade should be limited and not exceed half a litre weekly.

### **3.2 COMMUNITY-BASED DIETARY INTERVENTIONS**

#### **HISTORY AND BASIC CONCEPTS**

The understanding of health has evolved over time. It has moved from a narrow understanding of health (absence of disease) to a broad understanding acknowledging several aspects of health and viewing the individual within a context. In the mid 1980s a movement started with the Ottawa Charter for Health Promotion that stated “health is created and lived by people within the settings of their everyday life; where they learn, work, play and love” (36). The movement emphasized the role of supportive environments, community action, public health policies and the development of personal skills. This was also the start of the Healthy Cities programme involving thousands of healthy cities and communities worldwide (37). The so-called “settings approach” is also rooted in the Ottawa Charter for Health Promotion. Key characteristics of the settings approach have been described by Mark Dooris (38). They include: an ecological model of health promotion, systems perspective and whole system organization development and change. The settings approach has recently been further developed and renewed into the so-called “supersetting approach” (19). This approach was developed to better harmonize it with the contemporary realities (and complexities) of health promotion and public health action. The supersetting approach was developed and tested in the SoL project and will be further described in Chapter four.

The shift towards more ecological models of health was also reflected in the pioneering programmes such as the one in North Karelia, which worked with community programmes to prevent non-communicable disease (39). The North

## CHAPTER 3. BACKGROUND

Karelia programme was comprehensive and integrated with local services. Intervention strategies were based on low-cost lifestyle modifications and community participation. Similar large-scale community projects were carried out in the US (40).

The concept of community-based and setting-based interventions within health has evolved over time and covers a wide range of definitions and approaches. The present thesis will not list the different definitions, approaches or models, but a brief definition of community and setting will be given in the following.

Community as a concept can be defined in different ways: 1) as geographic areas (neighbourhoods, cities or regions) or 2) as social groups that share a common culture or identity. Often the two definitions overlap. The concept of settings is closely related to community-based interventions. Settings are “The place or social context in which people engage in daily activities in which environmental, organizational and personal factors interact to affect health and well-being” (41). A setting can be a school, a workplace or entire cities. A community-based intervention is usually implemented in selected settings. Community-based interventions vary with regard to intervention design, but can: 1) be based in one or several community settings, 2) be tailored to the local context, 3) include community participation and/or partnerships, and 4) use multi-component intervention methods, e.g. combining educational and environmental intervention strategies (42,43). These characteristics of community-based studies will most likely place them within the category of complex intervention (44). The UK Medical Research Council defines complex interventions as follows: “Complex interventions are built up from a number of components, which may act both independently and interdependently. The components usually include behaviours, parameters of behaviours (e.g. frequency, timing) and methods of organising and delivering those behaviours (e.g. type(s) of practitioner, setting and location)” (45). According to literature, the complex intervention design, involving multiple components, levels and settings, has the best potential to promote healthy lifestyles and to prevent childhood obesity (14,15).

The evaluation of complex and community-based interventions poses substantial challenges for evaluators. A number of frameworks for the evaluation of such interventions exist. Examples include frameworks for complex interventions (44,46), for real-world interventions (47), for systems interventions (48,49) or realist evaluation (50). The realist evaluation approach was used by the SoL project and will be briefly described in Chapter four. When evaluating complex interventions, it is recommended to use a mixture of qualitative and quantitative methods, and ideally the evaluation should also include both outcome and process evaluation measures (44,46). Furthermore, it is recommended to use a participatory approach for developing evaluation outcomes (51).



## PREVIOUS INTERVENTION STUDIES AMONG CHILDREN

The increasing focus on healthy settings and supportive environments has led to a growing body of evidence on complex interventions for health promotion and prevention. The following section will briefly review the evidence base on community-based interventions similar to the SoL project. To identify relevant intervention studies the present study used the following criteria:

Inclusion criteria:

- Children as target group (0–18 years)
- Complex intervention that is community based or implemented in one or more community settings
- Measuring eating behaviour, and/or overweight and obesity
- Control or comparison group

Exclusion criteria:

- No participatory or capacity-building approach (community consultation or engagement processes)

A limited number of studies were identified (52-58). An overview of the study characteristics and results is given in Appendix I. All of them were obesity prevention studies. Four of the studies targeted solely or partly preschool age children (52,54,55,58), whereas three others exclusively targeted schoolchildren (53,56,57). Most of the interventions were implemented in a school setting (incl. preschool and after-school). Other settings included childcare centres, health services, restaurants and sports clubs. Intervention strategies varied but were in general multi-component and multilevel. Participation rates varied from 29 to 90 %.

All but one study measured intervention effects on eating behaviour (52-57) (Appendix I). The results were mixed and overall little or no effect was found for eating behaviour. No effects were observed in two of the studies (52,56). The Australian Romp and Chomp intervention implemented in childcare centres, preschools and health services did observe a decrease in the intake of packaged snacks, fruit juice and cordials compared to the comparison group, but not for other foods (55). Another Australian study, the BAEW intervention implemented in preschools and schools, observed improvements for some eating behaviours, especially in the comparison area (54). For some, intakes improved significantly more in the comparison area. The American Shape Up Somerville intervention, targeting six- to eight-year-old children, observed a significant decrease in the intake of sugar-sweetened beverages, but not in fruit and vegetable intake (59). The decrease in the consumption of sugar-sweetened beverages was primarily ascribed to the limited availability in schools and in selected restaurants. One of the studies focused primarily on implementing non-curriculum school activities through the use of employed activity coordinators (53). This study observed improvements in the intake

of sweet drinks and fruit, but not in vegetable intake. Summing up, no clear evidence exists regarding the effects of complex community-based studies on children's eating behaviour. The number of studies are limited and the effects mixed. Furthermore, the dietary assessment method, intervention design, and statistical analysis approach of studies varied.

More encouraging results were observed in relation to the prevention of childhood overweight and obesity. All of the identified studies showed small favourable effects on one or more indicators of childhood overweight or obesity compared to control (52-58) (Appendix I). BMI z-scores were measured in all studies and significant post-intervention differences between intervention and control varied from 0.07 to 0.26 z-scores (53,54,60). Significant pre-post-intervention differences were from 0.10 to 0.13 z-scores (55,59). One study reported only pre-post-intervention prevalence estimates (a 2% reduction in overweight and obesity) (58). In one study, no effect was observed on BMI z-score in the total sample, but there was a significant decrease in the community with low socio-economic status (52).

A French study was originally planned as a school-based nutrition education programme (therefore not included in Appendix I), but developed into a whole-community programme that had a focus on nutrition as well as physical activity (61). The entire duration of the programme was 12 years. Interestingly, it took more than 10 years before the prevalence of overweight and obesity started to decrease in the intervention community. Based on these results, the authors concluded that long-term results may be achieved through ongoing support from society as a whole, including parents, schools and government agencies.

### **3.3 ASSESSMENT OF NUTRITIONAL BEHAVIOUR AND STATUS**

#### **DIETARY ASSESSMENT IN CHILDREN**

Dietary assessment in young children is particularly challenging. Below the age of eight, children are not capable of reporting their own dietary intake due to limited cognitive and literacy levels. Therefore, a proxy reporter, typically the parent, needs to be involved, which presents additional challenges (62,63).

When choosing a dietary assessment method different aspects need to be considered. The considerations are many and could include: characteristics of the target group, possibilities for administration, costs, detail level, individual or group assessment, number of subjects etc. Magarey and colleagues (64) present a summary of important issues relevant to method selection in their article.

There are limited validated dietary assessment tools for use with paediatric populations (64,65). Estimated food records and 24-hour dietary recalls are the most

## CHAPTER 3. BACKGROUND

commonly used dietary assessment tools for children (65). Other frequently used methods are food-frequency questionnaires (FFQs), weighed food records and the dietary history method.

There are generally two types of food records: the estimated and the weighed. The estimated food record uses household measures and/or photos to estimate portion sizes, whereas the weighed record requires weighing of all foods and drinks. The estimated food record has been recommended for dietary assessment among young children (66). The use of food records is labour-intensive, but enables the use of several proxy persons, for example parents and childcare centre staff, to provide accurate collection of dietary information. In addition, it is prospective, i.e. it does not rely on memory. However, it requires participant instruction, it has a large respondent burden and the diet is likely to change during the recording period (attention bias) (65,66). Weighed food records are rarely used as they are very time-consuming and difficult for respondents. Twenty-four-hour dietary recalls are suitable for populations with low literacy skills and place a smaller burden on respondents. They are, however, more challenging in relation to young children as some parents do not know what their child eats away from home. In addition, they place a high administration burden on the researchers.

An FFQ consists of a food list with different options for frequencies and sometimes amounts (semi-quantitative food-frequency questionnaire (SFFQ)). FFQs are often preferred because of the low administration burden, lower subject burden and lower costs. FFQs can evaluate long-term intake and can be adapted to a local study population, e.g. designed to measure specific local foods (67). The drawbacks of FFQs are the dependence on memory (recall bias), overestimation and the fact that it is hard to measure energy intake (65,68). Other self-report methods, however, have also been criticized for poor energy intake estimation (69). FFQs vary in length and it has been shown that FFQs with longer food lists (200 items) are better than shorter FFQs at ranking subjects (70). A longer food list will unfortunately also increase subject burden, so the final length must depend on the required method sensitivity.

Validation of an FFQ is essential when it has not previously been used in a target group or when changes are introduced (67). The term “validity” can be divided into two aspects: 1) whether it is measuring what it is supposed to measure, usually tested by comparing with a gold standard, the reference measure (comparative validity), and 2) whether the results can be repeated (reproducibility), usually tested by administering the FFQ at two points in time to the same group of people. Ideally, the test instrument (the FFQ) should be administered prior to the reference to avoid any influences from the use of the reference measure. Moreover, the period between the first and second administration of the FFQ (for testing reproducibility) should be long enough to avoid the risk of participants remembering their previous answers and preferably during the same season of the year. The sample population should be

similar to the main study population and optimally a subsample from the main study (67).

Biomarkers are another means of evaluating food intake. They provide an objective measure of the intake, but are only suitable for measuring certain foods (71) and are usually costly.

### **ANTHROPOMETRY TO MEASURE CHILDHOOD OVERWEIGHT**

Different measures of childhood overweight and obesity exist and optimally a combination of measures should be used to classify a child as overweight or obese, especially in a clinical setting (72). A frequently used measure is the body mass index (BMI), since it is practical, non-invasive and relatively inexpensive. When BMI measurements are used within research to measure the overweight or obesity of children, the values are often converted to BMI z-scores, also called “BMI standard deviation (SD) scores”, which are age- and sex-specific. The normal growth pattern of children varies with age and between boys and girls, and therefore BMI cannot be used in the same way as with adults. BMI z-scores are calculated based on the distribution of the reference population (mean and standard deviation), and reflect the reference distribution. The BMI z-score is a standardized measure that allows for comparisons across ages and sexes (73). A BMI z-score above zero indicates that the BMI is higher than the average (the median) for a certain age and vice versa. BMI z-scores can be calculated by the LMS method (74). Usually, anthropometric data do not follow a Gaussian distribution; they can, for example, be skewed, and therefore we need to transform data before BMI z-scores can be correctly used. This can be done using the LMS method. The LMS method summarizes the changing distribution with three curves representing the skewness (expressed as box power), median and coefficient of variation (skewness-L, median-M and coefficient of variation-S). The calculation of the z-score is based on the following equation:

$$z - score = \frac{X/M^L - 1}{L * S}, \text{ if } L \neq 0,$$

where X equals BMI and L, M and S are the values for a certain age for boys or girls. The L, M and S values are available for Danish girls and boys based on contemporary national data (75). BMI z-scores can then be calculated, usually by using a software program.

The use of BMI has limitations. BMI is a measure of excess weight and it does not distinguish overweight due to excess fat mass from overweight due to “excess lean mass”. In addition, BMI does not assess the distribution of body fat. Despite these limitations, BMI is a valid indicator of overweight or obesity in groups of children and high BMI levels have consistently been found to be associated with cardiovascular disease risk factors (76).

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In contrast to BMI, measures of waist circumference provide information on abdominal body fat. Measuring waist circumference requires more training, is more prone to measurement errors, and some argue that it does not perform better than BMI as an indicator of overweight and obesity (76). However, it may add additional information.

There are different approaches to classifying overweight and obesity in children, and in general, it is more difficult than in adults. In children, you need to consider both a) the short-term health outcomes during childhood and adolescence and b) the long-term health outcomes in adulthood. In addition, when dealing with child growth, you also need to consider differences in maturation, ethnicity, gender etc. Currently, there is no consensus on the best approach (77,78).

For now, percentiles for classifying weight status (e.g. 5th, 85th and 95th) are mostly used in clinic settings and by the public. Within research, SD scores and the International Obesity Task Force (IOTF) BMI cut-off points are mostly used for the classification of weight status among children. The World Health Organization (WHO) has cut-offs for children below the age of five and between five and 19 years, both based on SD scores. The reference population for children below five years was based on the Multicentre Growth Reference Study (MGRS), and included only “healthy” (e.g. breastfed, non-smoking mothers, affluent) children, taking the approach “how children should grow” (79). The reference population for school age children and adolescents is based on US data (80). The IOFT has taken a different approach to defining cut-off values. In the IOFT model, sex- and age-specific BMI cut-offs are used to define overweight and obesity. The cut-offs were constructed using adult cut-offs for overweight and obesity, BMI 25 and 30, respectively, at age 18, based on an international survey of six large nationally representative cross-sectional growth studies. These cut-offs were tracked back along the centile lines to the age of two years, for boys and girls separately, resulting in a set of values at six-month intervals (78). The IOFT cut-offs were later extended to include cut-offs for thinness and morbid obesity in children (81,82).

## CHAPTER 4. METHODS

In the following section, a brief description of the SoL intervention is provided, and the methods of the present PhD study are summarized and detailed if relevant.

### 4.1. THE SOL PROJECT

The SoL project was developed to promote healthier lifestyles among young children and their families. The intervention focused especially on promoting healthier eating and physical activity behaviour, but also on mobilizing community resources and strengthening social networks. A secondary objective was to prevent childhood overweight and obesity. The conceptual foundation of the project is described elsewhere (19), but will be summarized in the following.

#### CONCEPTUAL FOUNDATION

The intervention is conceptually rooted in the supersetting approach (19). This approach is based on holistic, ecological and whole-system thinking, and builds on five principles: first and foremost integration, but also participation, empowerment, context and knowledge-based interventions. Integration refers to three main concepts: 1) the coordination and, if possible, co-implementation of activities that share features in relation to applied methods, targeted populations, timing, expected outcomes etc., 2) the assimilation of values, approaches, procedures and standards in established structures and cultures of organizations in the local community and larger society, and 3) the cooperation of stakeholders with diverse backgrounds and professions, but acknowledging the interrelatedness and intersectoral nature of challenges facing society in the twenty-first century (19). An intervention strategy based on the supersetting approach is defined by coordinated activities carried out in a variety of different settings and involving a variety of different stakeholders within a local community. In addition, it promotes synergistic effects and sustainable impacts (19).

The SoL project was also based on the action research approach (83,84). Action research originated in the social sciences and has developed into a reflective research methodology that crosses and bridges various disciplines. It challenges the standard method of scientific inquiry and the role of science within society. When applied, action research is an iterative and dynamic inquiry process involving one or several cycles that include problem definition, planning, implementation and evaluation. In the SoL project this co-creational process involved researchers as well as practitioners and local stakeholders from each community and setting. The benefit of this approach is that it can serve as a way of bridging theory and practice.

A theory-driven evaluation approach, realist evaluation, guided the development of a programme theory (50). The realist approach is concerned with the identification of underlying causal mechanisms and how they work: “What works for whom in what circumstances and in what respects, and how?” (50). Realistic evaluation research assumes that determinants and causal pathways are embedded within particular contexts and social systems. Pawson and Tilley (50) explain the relationship as: context (C) + mechanism (M) = outcome (O). On the basis of the realist evaluation approach, the SoL researchers developed a programme theory (Appendix II).

### **INTERVENTION DEVELOPMENT AND IMPLEMENTATION**

The SoL intervention was primarily based on the supersetting approach (19). Additionally, action research was used as a main framework for the development of interventions (84). This was done in order to promote participation, capacity building and local ownership of the intervention.

The main focus of the intervention development was to promote healthier eating and physical activity behaviour among children and families. More specifically, intervention activities were developed to: increase the intake of fruit, vegetables, fish and whole grains; decrease the intake of sweet drinks and sweets; and reduce television viewing and increase active play.

The intervention was implemented in a number of selected settings relevant to the target group: childcare centres, schools, supermarkets, local mass media and the local community. The main intervention strategies were participatory learning methods (Future Workshop Scenario, Mosaic Method), educational activities, environmental strategies, press coverage, health campaigns, social media engagement, local community activities and public events. An overview of the intervention is presented in Appendix III. The intervention activities were structured according to different themes (e.g. fish) and implemented at the same time across multiple levels and settings in a coordinated manner aimed at creating synergy and hence enhancing the intervention intensity and effect (Appendix III). The intervention was driven by a participatory approach using action research methods. Accordingly, planning, implementation and evaluation occurred in iterative processes involving targeted children and families as well as professional stakeholders in the local community. The final intervention activities therefore differed between communities and settings (Appendix III).

A local project coordinator and local action groups were a central part of the intervention. The local project coordinator, in the role of a local champion, was active in all settings and communities and contributed significantly to the local integration and coordination of activities across settings and levels. Local action groups were established during the intervention period (spring 2013) in each of the three

communities. Their members included professional stakeholders (e.g. schoolteachers, shop owners, fitness instructors etc.) and citizens working and/or living in each of the three selected local communities. The aim of these local action groups was to promote even more local integration, coordination and sustainability of actions across settings within the community, and to allow the development and implementation of activities that are community based and community involving rather than setting-specific.

### **4.2. DEVELOPMENT OF DIETARY ASSESSMENT METHOD**

Prior to intervention, a dietary assessment tool was developed. This was done to measure the intakes of certain food groups that were especially focused on during the intervention. Some of these food groups are consumed as a part of a meal, and for some, the intake may vary considerably over a week or a month (e.g. for fish). To ensure the best data possible, the assessment tool should therefore be able to cover the usual diet, i.e. the whole diet. Data on the individual level was not a requirement, but the method should be able to provide a group mean for the intervention and the control group – to test the difference between groups. In addition, the tool should allow for repeated measurements. It was also considered important that the method did not put too much workload on the parents, since families with young children presumably have little time available to register dietary intake. Other measures were collected through questionnaires, e.g. physical activity, which also influenced the decision of the assessment tool. Finally, limited resources were a significant consideration.

Based on a feasibility analysis, an SFFQ was chosen as the dietary assessment tool. The SFFQ was validated during spring 2013. The purpose of the validation study was to test the relative validity and reproducibility of the SFFQ developed for the SoL project.

### **4.3. STUDY DESIGN AND SUBJECTS**

#### **STUDY DESIGN**

##### *Validation study*

The SFFQ was developed from an SFFQ previously used and validated in a nationwide survey among children in Norway (85). It was translated into Danish, and adapted to Danish food culture and the age group using data from national Danish food intake surveys among children (35). The relative validity of the SFFQ was tested using estimated food records as the reference measure and repeated administration of the SFFQ (app. one month apart) was used for testing the reproducibility.



### *Intervention study*

The study design was quasi-experimental. Intervention and control sites were located in two different municipalities of Denmark and were chosen based on a number of similarities: number of childcare centres, primary schools, supermarkets, sociodemographic characteristics and prevalence of non-communicable diseases (86). Three communities in the Danish Regional Municipality of Bornholm, an island, were selected for intervention while another three communities in Odsherred Municipality were selected as controls. In the SoL project, a community was defined geographically as a town and its catchment area. The target group was children enrolled in participating childcare centres (app. three to six years old) and primary schools, year zero to two (app. six to eight years old) and their parents.

## **RECRUITMENT AND SAMPLING**

### *Validation study*

A convenience sample was recruited through postings on school intranets, in childcare centres in the SoL communities, and in neighbourhoods around the Capital Region of Denmark. Further details of the sampling procedure are available in Paper I. A total of 54 children were enrolled. Throughout the study, the parents received reminders by e-mail or text messages, and telephone support if necessary. The study was carried out at the Research Centre for Prevention and Health, Glostrup University Hospital.

### *Intervention study*

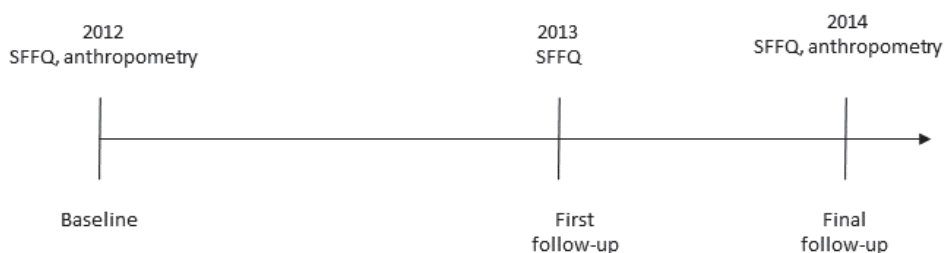
All children in the participating childcare centres and primary schools were invited to participate in measurements of eating behaviour (questionnaire) and weight status (anthropometry) at baseline in September 2012, at the first follow-up in September 2013 (questionnaire only) and at the final follow-up in April 2014 (Figure 2). During the same period, parents were also invited to answer another questionnaire on child and family behaviours (media, eating/shopping, physical activity), the child's well-being and their neighbourhood.

Prior to baseline and the first and final follow-up, all parents of participating children received an invitation letter. The parents also received an additional folder containing detailed plain-language information on the SoL project and the measurements. The dietary assessment tool, the SFFQ, was administered in primary schools (handed out to the children by the teacher) and in childcare centres (handed out to parents by staff). Within the questionnaire, a single page of information was provided. It contained brief but detailed information on how to fill out the questionnaire. It also encouraged parents to seek information on the child's intake of foods and beverages when meals were eaten outside of the home. The parents could return the SFFQs in a postage-prepaid return envelope.

## CHAPTER 4. METHODS

The SoL project used different strategies to increase participation at baseline and follow-up. Distribution of the SFFQs was planned in close collaboration with schools and childcare centres. Reminders were sent to parents on all three occasions (one month after administration). If parents needed support in relation to answering the questionnaires, they could contact the SoL coordinator and the research team.

The number of eligible children at baseline totalled 443 children from the intervention communities and 418 from the control communities. However, the number of eligible children varied from year to year because of changes in the sample population caused by families' in- and out-migration to or from communities or the child's change of school or childcare centre. The intervention was setting based and therefore included all children in the involved communities. However, only children enrolled at baseline were included in the evaluation of eating behaviour and weight status. Further details on the sampling process and exact numbers of children included in the measurements are provided in Papers II and III.



**Figure 2** Overview of measurements over time. Anthropometry was assessed twice at baseline and at the final follow-up. Eating behaviour (semi-quantitative food-frequency questionnaire (SFFQ)) was assessed at all three time points.

### 4.4. ETHICS

Parental informed written consent was obtained for all children participating in the validation study (Paper I) and the anthropometric measurements (Paper III). The SoL project was approved by the Danish Data Protection Agency according to the Danish Act on Processing of Personal Data. A separate ethics approval was obtained from the Institutional Review Board, the Ethical Committee of the Capital Region (H-3-2013-036), for the validation study.

Control communities in Odsherred Municipality were offered a full implementation package for the most successful activities implemented in the Regional Municipality

of Bornholm. This was done shortly after completion of the 19-month intervention period.

### **4.5. ASSESSMENT OF EATING BEHAVIOUR**

#### **FOOD RECORDS**

For the validation of the SFFQ, estimated food records were chosen as the reference method. The food records covered four consecutive days, including three weekdays and one day during the weekend (Wednesday to Saturday). The parents were asked to register in detail all foods and beverages consumed by their child using photos of portion sizes or household units. The food records were filled out by parents shortly after the first administration of the SFFQ.

#### **SEMI-QUANTITATIVE FOOD-FREQUENCY QUESTIONNAIRES**

In short, the SFFQ included 22 main questions covering 183 food items grouped together according to the Danish meal pattern. The recall period was the past four weeks, and the frequency alternatives varied from never/less than once per month to five or more times a day. A photographic booklet including 16 series of colour photographs with four differently sized portions of meals or food items ranging from small (A) to large (D) was used by the parents when reporting the amounts of food eaten by the child. When no photograph was available for a food item, household units were used, e.g. slices, pieces and spoons. The questionnaire consisted of seven sections: introductory questions (height, weight, birthdate), breakfast, bread (including toppings on bread), fruits, hot meals (including vegetables), snacks/sweets, and beverages. Summary questions about entire food groups were added to the questionnaire to prevent misreporting. A summary question was, for example, “How many pieces of fruit does your child eat?”(weekly and daily frequencies reported). Further details on the SFFQ are provided in Paper I.

#### **DATA ENTRY AND CLEANING**

A nutritionist (the PhD student) entered intake data from food records and SFFQs used in the validation study following standardized procedures (87). All records and questionnaires were screened for completeness and parents were contacted to provide clarification in the case of missing data or misunderstanding.

The SFFQs from the SoL project were scanned by an external company. Data cleaning was performed using standardized procedures previously used in large questionnaire surveys.

### **NUTRITIONAL CALCULATIONS**

Answers from the summary questions were used for calculating weighting factors for each child. The weighting factor was calculated as: the value from the summary question divided by the sum of values from the individual food items in the SFFQ. This was done in order to reduce under- and overestimation of intakes. Previous studies have shown that applying weighting factors often leads to better estimates of nutrient and food intakes (88,89). Details on calculations and an example of a calculation are provided in Paper I.

Nutritional calculations were performed to calculate the daily intake in grams. This was done using standard weights (87,90) and the Danish Food Composition Databank version 7 (91). Additional calculations were performed to enable estimation of intakes of food groups relevant to the SoL project. In total, eight food groups were developed specifically to be used for the evaluation of the SoL project: fruits, vegetables (total intake), coarse vegetables, fish (total intake), canned fish, whole grains, sweet drinks and candy (also known as sweets and chocolates). The grouping of foods into food groups was based on the standards developed by the National Food Institute, Technical University of Denmark (91). These food groups were then modified and supplemented to be more comparable with the Danish dietary guidelines (92) and to suit the SoL project. The adaptations and precise content of these food groups are described in Paper I.

### **4.6. MEASUREMENT OF ANTHROPOMETRY**

Prior to measurements, all parents received a consent form for participation in the anthropometric measurements. Written consent forms were collected by staff and handed over to data collectors on the measurement day. Measurement days were planned in close collaboration with schools and childcare centres and extra measurement days were added in case of too high non-attendance.

The height, weight and waist circumference of children were measured by research staff, with participants barefooted and in light clothing. This was done in a separate space that allowed for privacy. Height was measured to the nearest 0.1 cm using a portable stadiometer (Leicester Height Measure) and body weight was measured to the nearest 0.1 kg using a digital scale (Tanita BWB-800). If the children wore clothes or a nappy, the weight of these items was subtracted from the recorded body weight. Waist circumference was measured to the nearest 0.5 cm midway between the lowest rib and iliac crest. Waist circumference was measured in triplicate and the mean was calculated.

BMI was calculated as weight in kilograms divided by height in metres squared and converted to z-scores using the LMS method (74,93) with use of the Danish reference data (75) and the software LMSgrowth (93). The International Obesity Task Force

age-specific BMI cut-offs were used to classify children's weight status as underweight (thinness grades 1–3), healthy weight, overweight or obese (78,81).

### 4.7. SOCIO-ECONOMIC AND FAMILY STATUS

Information on socio-economic and family status was obtained from national registries. In Denmark, all individuals are assigned a unique 10-digit civil registration number (CPR) at birth or when they receive a permit to stay in Denmark. This number can be linked to national registries with information on sociodemographic characteristics of the entire study population (94). The CPR number was collected from the consent forms, and enabled the use of several important covariates that are available from national register data provided by Statistics Denmark.

Family status, parental education and disposable household income were used to adjust intervention effects for confounding. Parental education was defined as the highest attained education of the primary carer. Data on ethnicity was also available through Statistics Denmark, but was not included in the analyses since 99% of the intervention and control children were ethnic Danes and therefore did not add to the information. Further details on socio-economic and family status are provided in Papers II and III.

### 4.8. STATISTICAL ANALYSES

Statistical analyses were performed using the SAS statistical software package version 9.4 (SAS Institute Inc., Cary, NC, USA). The significance level chosen was  $P < 0.05$ .

#### VALIDATION STUDY

Several statistical methods were used to assess the validity and reproducibility of the SoL SFFQ.

##### *Descriptive statistics*

Descriptive statistics were used to describe baseline characteristics, and average intakes of foods, energy and nutrients. Most of the intake data were non-normally distributed both before and after log transformation, and therefore the mean was presented along with the median and the 5<sup>th</sup> and 95<sup>th</sup> percentile.

##### *Agreement*

The Bland-Altman limits of agreement (LOA) method was used to assess the agreement (or bias) between the two administrations of the SFFQ and between the two methods (95). This method was used to visually inspect agreement using plots of

the mean difference and the 95% LOA. Mean difference was calculated as the mean of all individual differences between methods (or repeated measures), that is, mean  $SFFQ1-SFFQ2/n$ , or mean  $SFFQ-FR/n$  ( $n = 2$ ). The 95% LOA was calculated for each food or nutrient intake as the mean difference  $\pm 1.96$  standard deviation of differences. Bland-Altman plots were drawn using the differences between the two measurements, plotted against the average of the measurements (95). The middle line of the plot represents the mean difference and the two outer lines represent the 95% LOA.

A cross-classification analysis was undertaken to calculate the percentage of observations classified into the same or opposite quartile of intake (later referred to as gross misclassification) (96). This was done for testing the relative validity as well as reproducibility.

### *Linear association*

The linear association between the two dietary methods and between the first and second administration of the SFFQs was described using Spearman's rank correlation coefficients (96). In addition, intra-class correlation coefficients (ICC) were calculated to assess reproducibility. For the assessment of the relative validity, correlations were corrected for the day-to-day within-person variation using the de-attenuation method (97). Additionally, Spearman's rank correlation coefficients were adjusted for energy and person-specific factors. The residual model was used for energy adjustment of correlations between the food record and the first administration of the SFFQ (98). Person-specific factors were defined as the child's age category (preschool or school) or gender. These covariates were included in a model, Spearman's partial rank-order correlation coefficients, which was used for analyses of relative validity and reproducibility.

## **INTERVENTION STUDY**

### *Descriptive statistics*

Descriptive statistics was used to assess baseline characteristics. Differences between intervention and control at baseline were determined by unpaired t-test for continuous data, and  $\chi^2$  tests and Fisher's exact test for categorical data.

### *Intervention effect*

The main research question for the analyses on the intervention effects was whether there was a difference in the outcome between the intervention and the control group over time (anthropometry: baseline – follow-up, SFFQ: baseline – first follow-up – final follow-up). For the analysis of eating behaviour, further subquestions were 1) whether there was a difference in outcome between the intervention and control group at the first follow-up compared to baseline, and 2) whether there was a difference in outcome between the intervention and control group at the final follow-up compared to baseline.

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A longitudinal linear mixed model (SAS PROC MIXED) was used to examine intervention effects (99). The longitudinal model is suitable for measuring within-individual change over time (two or more observations taken at different times).

The present model used an unstructured residual covariance matrix to account for serial correlation of observations from the same individual over time. In addition, to account for similarities among children within the same community and school or childcare centre, the model included two random effects, community and school or childcare centre. The group (intervention/control), visit (baseline/first follow-up/final follow-up), and the interaction between group and visit was included as fixed effects in the model. The test for the group-visit interaction compares the intervention and control groups in terms of their patterns of change from baseline (100). This interaction therefore answered the main research questions of the studies. The model also adjusted for a number of covariates (Table 1). The assumptions underlying the models were tested using residual plots and histograms. Some of the outcome variables were transformed to fulfil assumptions (Table 1).

Only children enrolled at baseline were included in the models to avoid including in-migrated children in the analysis. Sample sizes differed for each of the analyses because of excluded values for certain outcomes and missing data for some covariates (Papers II and III).

The longitudinal linear mixed model used in the present study is unbiased under the assumption of Missing At Random (MAR). That is, the estimates of a correctly specified mixed model are valid when the probability of missingness do not depend on the missing values themselves, conditional on the observed covariates (101). Therefore, the inclusion of covariates associated with missing information on eating behaviours or anthropometric outcomes can help break the dependency between missingness (drop-out) and missing values.

### *Outcomes and covariates*

To examine the intervention effects on eating behaviour a number of food intakes were examined (Table 1). Most of the outcomes were transformed to fulfil the assumptions of the linear mixed model (Table 1). The transformation of food intakes could not easily be back-transformed to original units and therefore estimated median intakes (back-transformed estimated means) for selected covariate levels were used to quantify results.

Different anthropometric measures were used as outcomes for the study about the intervention effects on childhood overweight (Table 1). None of them were transformed.

To account for potential confounding, several covariates were included in the analyses. For a variable to be classified as a confounder, three requirements apply: 1) it must be associated with the outcome, either as a cause or a proxy but not as an

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effect of the outcome, 2) it must be associated with the exposure (the intervention), and 3) it must not be an intermediate variable between the exposure and the outcome.

The covariates were selected a priori based on available literature. An overview of covariates is presented below in Table 1.

**Table 1** Overview of outcomes, covariates, and the transformation of outcomes

| <b>Outcomes</b>                 | <b>Covariates</b>   | <b>Transformation</b> | <b>Paper</b> |
|---------------------------------|---|-----------------------|--------------|
| <b>Vegetables (g/d)</b>         | Age, sex, education, income, family status                | 1/10 power            | II           |
| <b>Coarse vegetables (g/d)</b>  | Age, sex, education, income, family status                | None                  | II           |
| <b>Fruit (g/d)</b>              | Age, sex, education, income, family status                | Square root           | II           |
| <b>Fish (g/d)</b>               | Age, sex, education, income, family status                | Square root           | II           |
| <b>Whole grains (g/d)</b>       | Age, sex, education, income, family status                | None                  | II           |
| <b>Candy (g/d)</b>              | Age, sex, education, income, family status, energy intake | Square root           | II           |
| <b>Sweet drinks (g/d)</b>       | Age, sex, education, income, family status                | Square root           | II           |
| <b>Weight (kg)</b>              | Age, sex, education, income, family status                | None                  | III          |
| <b>BMI (kg/m<sup>2</sup>)</b>   | Age, sex, education, income, family status                | None                  | III          |
| <b>BMI z-score</b>              | Education, income, family status                          | None                  | III          |
| <b>Waist circumference (cm)</b> | Age, sex, education, income, family status                | None                  | III          |

Age and sex are related to the exposure (the intervention) as the delivery and receipt of the intervention may differ across age groups and boys and girls. Parents with young children may, for example, be more interested in health than parents with older children. Age and sex are also related to outcomes as eating behaviour can vary between preschool and schoolchildren and boys and girls. Weight, BMI and waist circumference also vary with age and sex because of the growth pattern of children (BMI z-scores are age- and sex-specific and therefore not adjusted).

Socio-economic inequalities are associated with poorer dietary intake and higher risk of overweight and obesity in children (102,103). Educational status is a measure of early-adulthood socio-economic status and is a relatively stable measure throughout adult life. It relates to knowledge, skills and possibilities of employment. The equalized disposable household income measures the disposable income and



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therefore the financial resources available for shelter, food and health services. Education and household income may relate to the exposure (the intervention) as the receipt of the intervention may vary with education and income. Furthermore, eating behaviour and childhood overweight may differ across educational status categories.

Family status is also relevant when examining the health of young children (104). Divorce is a stressor and families with divorced parents may react differently to the intervention compared to other families. In addition, the child's eating behaviour can be affected if parents have less time and energy to maintain a healthy lifestyle. Some of the categories of family status (as defined by Statistics Denmark) had few or no observations and therefore the variable used for the statistical analysis was recoded into two categories: couples and single parents.

In Paper II, energy intake was additionally included as a covariate in a second model. Energy adjustment is recommended by nutrition researchers to adjust for measurement error, in addition to confounding (105). Energy intake was measured in kilojoules per day (continuous variable) and this data were collected from the baseline SFFQ.

### *Attrition (Paper III)*

An analysis of attrition was undertaken, comparing the baseline characteristics of children who were followed up (baseline and follow-up anthropometric measurement) and children who dropped out (lost to follow-up, i.e. only baseline measurement caused by non-attendance at follow-up) (106). This was done for intervention and control separately and the difference (between children followed up and children that dropped out of the study) was tested using an unpaired t-test and Fisher's exact test.

# CHAPTER 5. SUMMARY OF RESULTS

The main findings of each of the studies I–III are presented in the following sections. For a more detailed description of the results, including tables and figures from each individual study, please see Papers I–III. A few additional figures not presented in Paper I were however included in Appendix IV.

## 5.1. RELATIVE VALIDITY AND REPRODUCIBILITY OF THE SFFQ (PAPER I)

The objective of the study was to assess the relative validity and reproducibility of the SFFQ that was developed during the present PhD project, and applied in the evaluation of the SoL project, for estimating food intakes.

Fifty-four children were enrolled in the study of whom 53 participated in the study of relative validity and 48 in the study of reproducibility.

### RELATIVE VALIDITY

SFFQ intakes were overestimated when compared to the reference, the four-day estimated food record. This was especially evident for vegetables (151 g for total intake (118% overestimation) and 73 g for coarse vegetables (189% overestimation)).

Based on the Bland-Altman plots, it was observed that for most intakes, the differences between methods increased with increasing intakes (Appendix IV). The differences were both positive and negative, implying that the participants both under- and over-reported at high intakes. This was, however, not the case for vegetables and energy, where over-reporting was most prevalent.

The proportion of children correctly classified into the same quartile ranged from 26% (sweet drinks) to 49% (coarse vegetables). Gross misclassification was on average higher for energy and nutrients (17%) than for foods (8%).

Spearman correlation coefficients were significant for 12 out of 14 intakes. The highest degree of linear association was observed for intakes of whole grains and fish products ( $r=0.58$  to  $0.63$ ), there was a less strong association for vegetables and fruit ( $r=0.40$  to  $0.46$ ), and the lowest degree of association was observed for sweet drinks and candy ( $r=0.29$  to  $0.31$ ). The correlation for candy was however improved when adjusted for total energy intake (crude value  $r=0.31$ , energy-adjusted value  $r=0.43$ ) and when corrected for within-person variance (corrected value  $r=0.57$ ). The lowest

correlation was observed for energy intake ( $r=0.12$ ), and this was only slightly improved after correction for within-person variance (corrected value  $r=0.18$ ).

## REPRODUCIBILITY

The intakes of the first SFFQ were slightly higher than those of the second SFFQ, and the largest difference was observed for sweet drinks (35 g (27%) higher).

There was a tendency towards poorer agreement at high intakes (Appendix IV). This was, however, not the case for vegetables and whole grains.

Gross misclassification was low for most intakes. None of the intakes of fish, whole grains and energy were grossly misclassified. The proportion of children correctly classified into the same quartile of intakes was highest for intakes of whole grains (69%) and lowest for candy and vegetables (33 and 38 %, respectively).

Intra-class correlation coefficients between the first and second administration of the SFFQ were above or equal to  $r=0.60$  for eight out of 14 intakes, and all were statistically significant. The food group candy deviated from the rest with a markedly lower correlation ( $r=0.30$ ). Correlations for vegetable intakes were also somewhat lower than the majority (ICC, 0.38).

## 5.2. INTERVENTION EFFECTS ON EATING BEHAVIOUR (PAPER II)

The objective was to determine the effects of a multi-component community-based health promotion intervention on the eating behaviour of three- to eight-year-old children.

At baseline, 147 (33%) participants from the intervention group and 105 (26%) from the control group returned the SFFQ. The response rates dropped to 9% for the intervention group and 13% for the control group at the final follow-up. Overall, 19% of the children had complete measurements (all three SFFQ measurements). A total of 242 children were included in the analysis.

No differences were observed for children's eating behaviour over time when comparing the intervention and the control group. The strongest statistical evidence of a difference between groups was observed for intake of sweet drinks ( $P=0.04$ ). There was a small difference between the intervention and the control group at the first follow-up compared to baseline ( $P=0.01$ ), but not at the final follow-up ( $P=0.42$ ). Intake data relating to sweet drink consumption had a larger number of extreme observations than other outcomes; a few children had a remarkably high reported intake of sweet drinks (1.6 litre). Based on estimated median intakes of

sweet drinks (back-transformed estimated means) it was observed that the intake of sweet drinks decreased over time in both groups, but with a larger decrease in the control group at the first follow-up.

When the model included energy-adjustment, there was still no significant differences between the intervention and the control group for intakes of fruit, vegetables, fish, whole grains, candy and sweet drinks.

### **5.3. INTERVENTION EFFECTS ON OVERWEIGHT (PAPER III)**

The objective was to determine the effects of a multi-component community-based health promotion intervention on the prevention of overweight in three- to eight-year-old children.

Initially, 63% ( $n=277$ ) of the intervention group and 56% ( $n=236$ ) of the control group consented to participate. At baseline, 54% from intervention and 51% from control participated (% of invited). Participant attrition at follow-up was 26% for the intervention group and 21% for the control group. The children who were followed up did not differ significantly from those who dropped out (prior to follow-up) on most variables. However, in the intervention group, younger children and single parents dropped out more. In total, 370 children (intervention group  $n=201$ ; control group  $n=169$ ) were included in the analysis.

The development in anthropometric measures was significantly different between the intervention and the control group for BMI z-scores ( $P=0.001$ ), BMI ( $P<0.0001$ ) and weight ( $P=0.01$ ). BMI z-scores increased over time in the intervention group in contrast to the control group whose BMI z-scores decreased. The difference in change between groups was 0.19 z-scores (95% CI 0.08, 0.31). Similar results were observed for weight and BMI. No significant differences were observed for waist circumference.



# CHAPTER 6. DISCUSSION AND CONCLUSIONS

In this chapter, the main findings of Papers I–III are discussed and put into perspective. Detailed study-specific findings are mostly discussed in each paper, unless a more thorough discussion is warranted. First, the main findings are discussed in relation to existing literature. Next, a discussion on methodological considerations, including strengths and limitations of the design and methods, will follow. Finally, the main findings are put into perspective and implications for future research and practice are considered.

## 6.1. MAIN FINDINGS IN RELATION TO EXISTING LITERATURE

### DIETARY ASSESSMENT METHOD

#### *Relative validity of the SFFQ*

The results of the present study were similar to results of other validation studies in this age group (85,107-114). As in the present study, the relative validity was considered low to moderate for most intakes. The findings of our and other studies can probably be explained by the difficulty of measuring the dietary intake of young children (63). The overestimation of vegetable intakes reported in the SFFQ was larger than that observed in the two other studies (85,111). It is possible that our study was more susceptible to social desirability bias than other studies that had a larger and perhaps more representative sample size. The parents participating in the present study were perhaps more interested in healthy eating than the general population (they received a dietary consultation as thanks) and may have over-reported vegetable intakes in the SFFQ.

Furthermore, the validity of energy intake (measured using correlation coefficients) was lower than that observed in the other studies, even after correction for within-person variance. The study concerning the Norwegian original version of the SFFQ observed a higher correlation coefficient and a lower percentage of gross misclassification. The higher measured relative validity in this study may be explained by factors related to the age group. Parental reports of children's dietary intake are hindered by limited supervision of meals. The target group of the Norwegian study was two-year-old children and it is likely that the parents were able to supervise a higher number of meals than parents with older children. Other validation studies using a food record as the reference method similarly included a younger age group (111,114).

### *Reproducibility of the SFFQ*

The reproducibility of FFQs in assessing children's diet has been tested in a limited number of studies. Overall, the results were comparable to those of the present study (109-111). Compared to mean levels of reproducibility, the reproducibility scores of candy intakes were, however, lower than the average. We speculate whether the occurrence of the Christian holiday Ascension Day during the first administration of the SFFQ influenced the results. Two children had a much lower intake of candy at the second SFFQ (lower than the 95% LOA), which was possibly caused by increased consumption during the holiday.

### **INTERVENTION EFFECTS**

In accordance with other studies, there was a lack of intervention effect on children's eating behaviour (52,54,56). Other studies did however observe an intervention effect on BMI z-scores and other measures of child overweight and obesity (53-56,61,115). We were not able to confirm this effect.

A few studies have reported favourable changes in the consumption of sweet drinks, soft drinks and cordials (sugar syrup) (53,55,59). These findings could not be confirmed by the present study. Yet, the SoL intervention did not focus on the consumption of sweet drinks; rather the focus was on increasing the consumption of healthy foods. Furthermore, other studies had implemented environmental or policy changes to limit availability. These kinds of initiatives were not a part of the SoL intervention.

We were not able to demonstrate any intervention effects on intakes of vegetables, fruit, fish, whole grains or candy, even though intervention activities targeted these key behaviours. None of the other studies examined intakes of fish or whole grains, but for the rest of the intakes, similar findings were observed by other studies (52,53,55,56,59). Only one study observed a significant increase of 0.8 servings of fruit (53).

The general lack of effects on eating behaviour of our and other studies may be explained by some methodological differences and similarities. First, as described in the background chapter, dietary assessment in young children is very challenging (63). Second, all studies used questionnaires (short or FFQ) to assess dietary intakes. The sensitivity of these and other available methods may be too low to detect the small changes observed in eating behaviour in community-based studies. If these assessment tools do not have the desired sensitivity there is a risk of type II errors (false negatives) and this may explain the absence of effects. Other studies observed small favourable effects on at least one indicator of child overweight and obesity. These effects can be explained by factors other than diet such as physical activity, sleep or stress, but it is likely that dietary factors are also involved. In the present study, no favourable effect was observed on childhood overweight or obesity. The

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remaining data on child behaviours have not yet been evaluated, but if looking at eating behaviour in isolation, these data do not contradict our findings relating to childhood overweight.

Our findings relating to childhood overweight may be explained by intervention design. Unlike other studies, the SoL project was not designed to impact on overweight or obesity status, and deliberately minimized the focus on weight status or weight-related themes. The reason was a past history of unsuccessful obesity programmes in the intervention communities and the risk of promoting obesity stigmatization. The other community-based interventions were obesity prevention studies, and included BMI z-scores and other adiposity measures as a primary outcome.

In addition, when comparing the SoL study with other similar complex community-based studies it appears that other projects have generally succeeded in implementing a higher degree of policy and structural changes. When comparing the specific intervention activities it also looks like other studies have had more focus on physical activity, e.g. promoting active transport to and from schools. According to a review of community-based interventions, a combined diet and physical activity intervention conducted in the community with a school component is more effective at preventing obesity or overweight than interventions focused on only diet or physical activity.

Furthermore, unlike other studies, the SoL project was based on the supersetting approach and used action research methods when developing intervention activities. Therefore, the project had a strong focus on building interventions that were integrated, participatory, empowering, context-sensitive and knowledge based. This meant, for example, that schools worked with methods to empower children, and that resources were put into strengthening the SoL partnership and networks across settings. Local stakeholders and citizens participated at all stages and times of the intervention, which initially required large efforts to build trust among locals and researchers. This meant that the intensity of intervention activities was lower during the first stages of the intervention. It is therefore possible that the follow-up time of the SoL study was too short for measuring impacts. In a French school- and community-based programme, it took more than 10 years before they observed an intervention effect on overweight prevalence. The 12-year programme started out as a school-based nutrition education programme but developed into a whole-community programme that included initiatives to promote healthy eating and physical activity. Unfortunately, the study did not measure behaviours.



## 6.2. METHODOLOGICAL CONSIDERATIONS

### ASSESSMENT OF EATING BEHAVIOUR

#### *Validation of FFQs*

The SFFQ was adapted from a Norwegian SFFQ for children and validation was therefore highly recommended as it had not previously been used in a target group and changes had been introduced to the original questionnaire (67). The validation study enabled us to better understand the changes observed in eating behaviour during the SoL project, and especially what limitations may apply.

The relative validity was tested using a food record as the reference, which has the advantage that measurement errors were relatively independent (prospective vs. retrospective FFQ). The food record was therefore considered the best option when choosing between self-report dietary assessment methods. The food record is often regarded as the “gold standard” among dietary assessment methods, even though it also has limitations. Most importantly, the food record is associated with a change of the habitual diet (116). The change can be caused by the practicalities of filling out the food record, e.g. skipping of comprehensive dishes that takes time to register. In addition, attention bias causes a change of diet. The participants become more aware of their eating habits and therefore tend to under-report foods and drinks that are considered unhealthy and may in general try to eat a healthier diet. Accordingly, food records have been associated with underestimation of energy intakes in the range of 19–41 % (65). In contrast, reporting bias of parent-administered FFQs has mostly been related to over-reporting and overestimation of energy intakes in the range of 2–59 % has been reported (65,68). It is therefore possible that these differences in reporting bias have influenced the results of the validation study. Preferably, biomarkers should be included in a validation study in addition to self-report methods as biomarkers are not prone to reporting errors. Such an approach would enable a better understanding of the limitations associated with SFFQs. Inclusion of biomarkers is, however, costly, and was not possible in the context of the SoL project.

Most validation studies have relied on correlation coefficients to assess the validity of FFQs, despite recommendations of more appropriate methods (117). Statisticians have criticized correlation coefficients because they only measure linear association, not agreement or direction of bias (95). Instead, they suggest using the LOA method, which is a graphical presentation of agreement where the mean of the two methods is plotted against the differences between the methods. Experts within the field suggest that correlation coefficients are useful but only when used in conjunction with the LOA method (117). When ranking of subjects is the purpose, combining correlation coefficients with cross-classification methods has been recommended (96). We used a range of statistical methods to assess the relative validity and reproducibility of the SFFQ. This approach strengthened our conclusions as we

## CHAPTER 6. DISCUSSION AND CONCLUSIONS

observed a relatively uniform direction of results across statistical methods. The LOA method helped us to understand the direction of agreement and bias.

### *Measuring eating behaviour of children*

The present study used an SFFQ to assess the eating behaviour of three- to eight-year-old children. Unlike other studies using a few indicators of eating behaviour, this tool enabled assessment of the whole diet. Therefore a number of eating behaviours relevant to the SoL project could be assessed with a higher level of precision and detail than when using a short questionnaire.

The SFFQ was, however, limited by bias related to self-reporting of energy and food intakes. The FFQ method is especially prone to recall bias as subjects are asked to recall long-term intakes (one week to one year). This has also been the main criticism raised by researchers that suggest abandoning the FFQ (118). All FFQs are, however, very different, and the SoL SFFQ asked parents to recall the previous month's intakes and often only weekly frequencies were reported. Retrospective methods like an FFQ are also prone to social desirability bias, especially in the context of an intervention study focused on healthier eating (119).

Furthermore, self-reporting of dietary intake is related to subject-specific misreporting (119,120). A study conducted within the multi-centre IDEFICS study examined factors associated with misreporting in a large sample of two- to nine-year-old European children (121). Dietary information was collected using 24-hour dietary recalls with proxies, mainly parents, as reporters. The results of this study suggested that under-reporting increased with the child's age and BMI z-score, and the household size. Furthermore, under-reporting was higher in low/medium-income groups. Over-reporting was higher in girls and lean children. Our results indicated that the validity was better for children from childcare centres and for boys, but the sample size was too small to adequately examine misreporting of foods in subgroups of children.

When measuring dietary intake among young children, the accuracy of parental reporting is a further concern. According to a review, parents are reliable reporters but only on a group level (63). Baranowski and colleagues observed that mothers were less able to report their child's diet when the child was away from home for more than four hours daily (122). Another study observed that mothers overestimated foods and were less good at reporting vegetable intakes than other foods (123). In the SoL project, most children brought their lunch from home, but some of the childcare centres offered breakfast and/or between-meal snacks. Furthermore, some of the schools had a so-called "salad bar" at lunch or a canteen. The measurement error related to parental reporting is therefore a considerable concern of the present study and may have influenced the results.

We chose to report intervention effects on eating behaviour using analyses with and without energy adjustment. The rationale behind energy adjustment is twofold: 1) adjustment for confounding; 2) reduction of measurement error. For number two, the explanation is that energy adjustment of self-reported dietary data helps to adjust for measurement error because the error in energy reporting is correlated with the error in the reported intakes of all foods and beverages (105). When applied correctly, energy adjustment can therefore strengthen associations/interactions by reducing measurement error. According to Subar and colleagues, even flawed self-reported energy intake estimates are helpful in adjusting for measurement error of other self-reported dietary intakes (105). Energy adjustment should however be applied with caution. Self-reported energy intake is associated with misreporting and we do not know the direction of this. Another concern of energy adjustment is the level of validity. We observed a very low level of validity. However, the level of reproducibility was considered good. Some researchers argue that self-report energy intake is too inaccurate to use as a confounder and that it can lead to spurious findings (type 1 errors; false positives) (69). Finally, baseline energy intakes were not available for all children in the present study. The use of energy adjustment in the present study did change some of the results, but not the conclusions.

### **DESIGN AND EVALUATION OF THE SOL PROJECT**

#### *The quasi-experimental design*

Papers II and III were based on a quasi-experimental evaluation design. The strength of this study design is the use of control or comparison communities, which allows the evaluator to better differentiate between changes in outcomes related to intervention or contemporary countrywide secular trends. In this design, communities are, however, not randomized, and the study is therefore susceptible to bias from baseline differences between intervention and control groups. In the SoL project, intervention and control communities were however selected based on similarities in settings, sociodemographic characteristics and prevalence of non-communicable diseases. Randomization was not feasible or appropriate in the SoL project. The challenges related to randomization of communities are: the large number of communities required for randomization, the lack of control of experimental conditions and the dynamic nature of community programmes (41). Alternatively, instead of randomization, intervention and control groups can be matched to ensure comparable study conditions, for example demographics. But identifying communities with comparable characteristics is often difficult because of the lack of proper data and the complexity of communities as social units (42). Six communities were involved in the SoL project, of which three were intervention communities. It is possible that the number of communities was insufficient in terms of creating the necessary statistical power to detect small changes in outcomes (42,124). It has been suggested that a minimum of 10 communities should be included to reach sufficient power to test differences (42).

### *Secular trends*

Secular trends and compensatory behaviour in control communities are a substantial concern in the community-based study design. It is very likely that the results of the SoL project can be partly explained by different secular trends in the intervention and control communities. According to the Danish national database, Børnedatabasen (125), the prevalence of childhood overweight and obesity increased in Bornholm and decreased in Odsherred during the same time period (measured when entering primary school in 2005 and 2007). It is very likely that the SoL project was not capable of affecting the general rise in overweight and obesity among children from Bornholm. The influence of secular trends cannot be avoided when working in real-life settings, but evaluators can possibly monitor the level of health promotion activity in control communities. This can however be costly and time-consuming (41,124).

### *Non-participation and attrition*

Participation of children and families was low. In particular, the evaluation of eating behaviour was limited by a high non-response and dropout level, and this was the most severe limitation of the study (Paper II). The small sample size increases the risk of type II errors (false negatives). In addition, there is a risk of selection bias if non-respondents differ from respondents. The reasons for low response rates observed in the evaluation of child behaviour (the questionnaire survey) were investigated in a qualitative study and gave us some indications of what to improve in the following follow-ups (Paper II). Consequently, initiatives were established to increase response rates at the first follow-up in 2013 (a so-called “awareness week”, described in more detail in Paper II). Unfortunately, this was not repeated at the final follow-up. According to literature, response rates may be strengthened by decreased questionnaire length and increased personalization (126), and retention improved by offering monetary incentives (127). In regard to the other study (Paper III), participation in the anthropometric measurements was higher than in the questionnaire survey and similar to most other studies. It is likely that families were more likely to participate in this measurement as the subject burden was considerably lower than in the questionnaire survey. However, with a participation rate of approximately 50% there was a risk of selection bias. Some researchers recommend using the so-called OPT-OUT consent in future school- and community-based obesity studies as they believe it will lead to more representative data (128). The OPT-OUT consent assumes parental consent unless the child’s parent indicates otherwise. It places a smaller burden on teachers/staff, but local acceptance and ethics approval should be considered.

### *National reference and register data*

The present study used high-quality national data for the analysis of intervention effects. National reference data were used for the generation of BMI z-scores using the LMS method. The reference data were based on a representative sample of 12,671 anthropometric measurements in healthy Danish children (75). The use of national

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register data enabled the use of relevant covariates that were not available from questionnaires. National register data provide reliable data with a high degree of completeness. Therefore, we had accurate data on socio-economic and family status without recall bias for all children with a CPR number. There are, however, limitations that need to be considered in relation to the information on the socio-economic status of children and their families. We do not know exactly what best describes the socio-economic position of a child. A systematic review found parental education to be the strongest and most consistent dimension of socio-economic status associated with overweight and obesity in children and adolescents in Western developed countries. Other socio-economic status indicators were household income, neighbourhood socio-economic status and parental education. We used the education of the primary carer, which we considered the best option when some of the families were divorced. Nevertheless, we do not know whether the education of the father or the mother is the best proxy.

### *Participatory research methods*

The SoL intervention was developed using action research. This participatory method has likely increased the sustainability of the project, but was also related to challenges. One of these was related to time. Action research is time-consuming and therefore a challenge to use in a relatively short intervention period of a couple of years.

The evaluation of the SoL project was not an integrated part of the participatory approach. It was mainly developed and driven by researchers, but with consultations with relevant local stakeholders. It can therefore be speculated that the evaluation of child health behaviour and status did not sufficiently allow for local ownership, local needs, local limitations etc., and that this perhaps has compromised the evaluation. A stronger local ownership of evaluations could possibly strengthen the commitment of childcare centres and schools to ensure the best possible measurements (incl. higher participation rates). We experienced a high variation in participation rates among childcare centres and schools, which may relate to the commitment of staff.

## **6.3. CONCLUSIONS AND FUTURE PERSPECTIVES**

The present PhD study investigated the effects of a multi-component community-based health promotion intervention that was based on the supersetting approach and the action research methodology. A questionnaire-based tool (the SFFQ) was developed and validated to assess the eating behaviours of children and childhood overweight was measured using valid anthropometric methods.

A limited number of validated dietary assessment tools for use with young children exists and therefore the validation study was an important contribution to literature. The study demonstrated that the SFFQ could be used to assess the consumption of

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fruit, vegetables, fish, whole-grain products and sweet drinks. More caution should be taken when assessing the intake of candy as the relative validity and reproducibility were considered low. Moreover, the SFFQ should not be used to assess absolute intakes, but can be used to examine development in intakes and compare intakes between groups.

The PhD study contributed to the growing body of published studies, evaluating the effects of multi-component community-based dietary and physical activity interventions among children. We were not able to demonstrate favourable effects on measured eating behaviour or overweight in three- to eight-year-old children after a 19-month intervention. Future publications are underway regarding the intervention effects on physical activity.

The intervention was based on the supersetting approach that was developed and tested during the SoL project. The supersetting approach was a renewed version of the setting approach and was developed to better harmonize it with the contemporary realities (and complexities) of health promotion and public health action. More studies are needed to examine the health impacts of projects using the supersetting approach. These studies should be of longer duration as we learned that this approach takes time.

An important lesson learned was the need for sufficient attention and resources for the recruitment of children and families. For future supersetting interventions, the recruitment and retention strategies should therefore be reconsidered. The experiences from the SoL project indicate that the introduction of an “awareness week” (increased involvement, marketing, support and presence of the research group) helps prevent dropout. It is also possible that a more participatory approach to evaluation planning would strengthen the recruitment and participation. In future supersetting studies, it should be examined how a participatory evaluation planning process could be established and how it affects recruitment, participation and evaluation outcomes (e.g. how it combines with the need for high-level evidence building, i.e. rigorous scientific evaluations that can be published in academic journals). Other benefits of participatory evaluation include increased community capacity building and increased sustainability if evaluation or monitoring procedures are integrated into existing practices.

The experiences of the present PhD study and other studies show that there is a need for further research into methods to assess the eating behaviour of children in the context of a community-based complex intervention. The tool should enable the collection of food intakes of children or families with a precision suitable for evaluating small changes in intakes and with minimal use of resources. We learned that the subject burden was too high and future studies should therefore consider measurement tools that are less time-consuming, easier and more motivating to use. We observed a higher participation for anthropometric measurements that put less

## CHAPTER 6. DISCUSSION AND CONCLUSIONS

burden on families than the self-reported measurements. From the qualitative study we also learned that there was a request for more presence of the research group/evaluators. It is likely that more face-to-face contact (the personal factor) will improve participation and the quality of measurements. Finally, more research into misreporting related to parental reporting of dietary intake is needed.

The present PhD study was limited to examining quantitative, single outcomes and can therefore only provide information on these specific health outcomes. Optimally, a mixture of several quantitative and qualitative outputs should be used to determine the effectiveness of complex interventions (44). A range of quantitative and qualitative data were collected by the SoL project, but at this moment, little data has been processed. Process evaluation data could have added important information on contextual factors and barriers that could have influenced the results of the present study. As stated by Craig and colleagues, “Lack of impact may reflect implementation failure (or teething problems) rather than genuine ineffectiveness”. The process evaluation of a community-based project based on the supersetting approach and action research does however require some modifications to the general guideline. Such a project is dynamic and evolves over time and therefore measuring implementation is not straightforward. The standard process evaluation measuring fidelity, reach, adoption and dose (46) is probably only partly applicable, and some measures like dose and fidelity are not relevant, at least not in the traditional form. Future studies should invest resources in the planning and dissemination of process evaluations.

Few studies have investigated how their intervention affected subgroups of the population, e.g. socially disadvantaged groups. The SoL project was based on participation and empowerment principles and recognized that behaviours are deeply rooted in people’s social contexts and systems (19). The SoL project did not, however, have sufficient size or length to study intervention effects among children and families with low socio-economic status or other subgroups. Future projects should address this issue.

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# APPENDICES



APPENDIX I: STUDY OVERVIEW

| Author, year, project name  | N and age (intervention group) | Setting   | Evaluation Design   | Intervention design   | Intervention activities   | Outcomes  | Results <sup>a</sup>   |
|---|--------------------------------|---|---|---|---|---|--|
| <p>Silva-Santoro et al, 2010</p> <p>Rhomp and Chomp</p>   | 12,000, 0-5 y                  | Australia, Victoria<br>Settings: Long Day Care Service, Family Day Care Service, Preschools, the Maternal Child Health Service, regional immunization services, community health services | <p>Repeat cross-sectional with a quasi-experimental design and comparison sample</p> <p>4 y FU</p> <p>Measures:<br/>- Height and weight<br/>- Eating and Physical Activity Questionnaire (EPAQ)</p> | <ul style="list-style-type: none"> <li>- Multi-strategy</li> <li>- Multi-setting</li> <li>- Community capacity building</li> </ul>                                  | <ul style="list-style-type: none"> <li>- Development of partnership, strategic alliances and community organizational networks</li> <li>- Policy changes</li> <li>- Structural changes</li> <li>- Awareness campaign</li> </ul>   | <ul style="list-style-type: none"> <li>- BMI &amp; BMI z-score</li> <li>- Weight status</li> <li>- Eating and PA behaviour</li> </ul>   | <ul style="list-style-type: none"> <li>- Overweight &amp; obesity ↓ by 2.5-3.4% depending on age</li> <li>- BMI z-score ↓ by 0.13 z-scores in 3.5-y-old sample. No change in 2-y-old sample</li> <li>- Intake of packaged snacks, fruit juice, cordial ↓</li> <li>- other foods →</li> </ul> |
| <p>De Coen V et al, 2012</p> <p>Prevention of Overweight among Pre-school and school children (POP)</p> | 1102, 3-6 y                    | Belgium, six communities (town or municipality)   | <p>Cluster-randomized controlled trial</p> <p>2 y FU</p> <p>Measures:<br/>- Height and weight<br/>- 24-item semi-quantitative FFQ<br/>- Parent questionnaire about PA</p>                           | <ul style="list-style-type: none"> <li>- Multi-component</li> <li>- Community stakeholders participated in intervention development (concept mapping)</li> </ul>    | <ul style="list-style-type: none"> <li>- Community meetings</li> <li>- 5 "Healthy weeks" per y per school plus extracurricular activities</li> <li>- School policy changes</li> <li>- Information materials for parents and individual dietary advice (FFQ data)</li> </ul> | <ul style="list-style-type: none"> <li>- BMI z-score</li> <li>- Eating behaviour</li> <li>- Screen-time</li> <li>- Participation in sports club or after-school sport activities</li> </ul> | <ul style="list-style-type: none"> <li>- BMI z-score total sample →</li> <li>- BMI z-score among low-SES children ↓ by 0.11 z-scores (control 0.04)</li> <li>- Eating and PA →</li> </ul>  |
| <p>Vinck J et al, 2016</p> <p>VIASANO</p>   | 1300, 3-6 y                    | Belgium, two pilot towns  | <p>Repeat cross-sectional with intervention towns and comparison sample (the rest of the French speaking community except Brussels)</p>   | <ul style="list-style-type: none"> <li>- The EPODE approach: Large-scale, coordinated, capacity-building approach for communities</li> <li>- Multi-level</li> </ul> | <ul style="list-style-type: none"> <li>- Targeting the environment or community in collaboration with local actors</li> <li>- Social marketing</li> <li>- Educational workshops</li> </ul>  | <ul style="list-style-type: none"> <li>- Prevalence of overweight and obesity</li> </ul>  | <ul style="list-style-type: none"> <li>- Overweight and obesity prevalence ↓ by -2.2 (-4.6 to +0.3)%</li> </ul>  |

APPENDIX I: STUDY OVERVIEW

| Author, year, project name  | N and age (intervention group)                            | Setting                                       | Evaluation Design  | Intervention design  | Intervention activities  | Outcomes   | Results <sup>a</sup>  |
|---|---|---|--|--|--|--|---|
| Sanigorski AM et al, 2008 & Swinburn B et al, 2013<br><br>Be Active Eat Well (BAEW) | 1726, 4-12 y<br>Follow-up 2009 (new cohort, same schools) | Australia, Victoria<br>Preschools and schools | Quasi-experimental longitudinal design with non-randomized intervention and control groups<br>3 y FU (2003-2006)<br><br>Measures:<br>Post intervention (3 y) and follow-up (6 y)<br>- Weight<br>- Height<br>- Waist circumference<br>- 16-question survey about PA, eating and bodyweight self-perception<br>- Lunch box audit (observation)<br>- Parents SES, telephone interview | - Community capacity building<br>- Multi-setting<br>- Multi-strategy | - Partnerships, governance, coordination, training and resource allocation<br>- Policy development and implementation e.g. school nutrition policies<br>- Social marketing e.g. stickers<br>- Health skills and action competencies e.g. school-appointed dietitian support, training of staff, walk to school days etc. | - BMI & BMI z-score<br>- Weight status<br>- Waist circumference<br>- Eating and PA behaviour | Post intervention 2006:<br>- BMI z-score ↓ by 0.11 z-scores<br>- Weight ↓ by 0.92<br>- Waist circumference ↓ 3.14<br>Follow-up 2009:<br>- BMI z-score ↓ in intervention and comparison areas<br>- Overall eating improved, especially in the control area<br>- PA →<br>- 'Spillover' effects into the surrounding communities |

APPENDIX I: STUDY OVERVIEW

| Author, year, project name  | N and age (intervention group)        | Setting  | Evaluation Design   | Intervention design  | Intervention activities  | Outcomes  | Results <sup>a</sup>  |
|---|---------------------------------------|--|---|--|--|---|---|
| Taylor RW et al, 2007<br>A Pilot Programme for Lifestyle and Exercise (APPLE)   | 131, primary school children (5-13 y) | New Zealand, Otago<br>Two semirural geographically separate areas served as intervention and control communities, 4 intervention schools | - Pilot study<br>- Non-randomized controlled community intervention<br>- 1 and 2 y FU<br><br>Measures:<br>- Height, weight and waist<br>- Pulse rate and blood pressure<br>- 33-item short FFQ<br>- Accelerometers and questionnaire to assess PA | - Community consultations<br>- Community activity coordinators (for each school, employed) | - Noncurricular activity with focus on life-style based activities e.g. gardening, beach hikes etc.<br>- Resources for teachers on activity breaks<br>- Science lessons on sugary drinks<br>- Interactive card game on physical activity<br>- Play equipment for "free" play<br>- Free fruit for 6 months  | - BMI z-score<br>- Waist<br>- Overweight prevalence<br>- Eating and PA behaviour<br>- Blood pressure and pulse rate | - Overweight →<br>- BMI z-score ↓ by 0.09 z-scores at year 1 and 0.26 z-scores at year 2<br>- Waist ↓ by -1 cm at year 2<br>- Blood pressure ↓ by -2.9 at year 1<br>- Total sweet drinks ↓ by 1.2 servings at year 2<br>- Fruit ↑ by 0.8 servings at year 2<br>- Vegetable intake →<br>- Overall PA → |
| Folla SC et al, 2013 & Economos SD et al, 2007<br><br>Shape Up Somerville (SUS) | 647 children, 6-8 y                   | US, Massachusetts<br><br>Urban, culturally diverse community<br>Before-, during- and after-school environments                           | - Non-randomized controlled intervention trial<br>- '2 y' FU<br>- first year: Intervention period, second year: Implementation period<br><br>Measures:<br>- Height and weight<br>- 68-item family questionnaire on SES, PA and diet               | - Participatory research (CBPR)<br>- Multi-setting<br>- Multi-level                        | - Breakfast program<br>- Walk to school campaign<br>- School staff training on diet and PA<br>- Structural changes e.g. healthier breakfast program and school food service<br>- School wellness policy development and classroom curriculums e.g. 10-min. daily 'Cool moves'<br>- Parents outreach and education<br>- SUS 'approved' restaurants<br>- Regular local media placement | - BMI z-score (1 y post-intervention)<br>- Selected eating and PA behaviours related to overweight                  | - BMI z-score ↓ by 0.10 z-scores<br>- SSBs ↓ by 2 ounces/day<br>- FV intake →<br>- Screen time ↓ by -0.24 hrs/day<br>- Sports ↑ by 0.2 # per year<br>- Active transport →   |



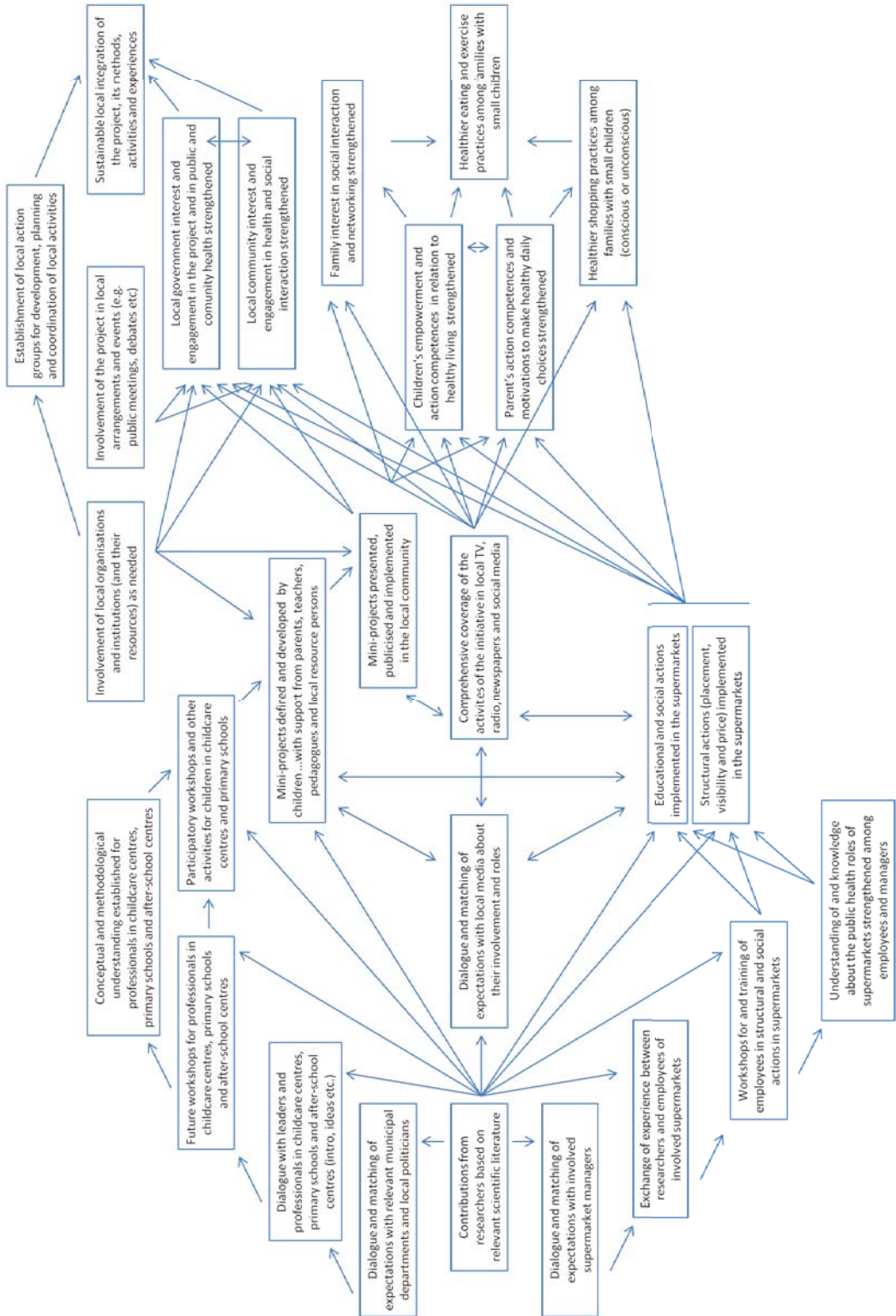
APPENDIX I: STUDY OVERVIEW

| Author, year, project name                   | N and age (intervention group) | Setting                                    | Evaluation Design   | Intervention design  | Intervention activities  | Outcomes  | Results <sup>a</sup>   |
|--|--------------------------------|--|---|--|--|---|--|
| Millar L et al, 2011<br>It's Your Move (IYM) | 1852 adolescents (12-18 y)     | Australia, Victoria<br>5 secondary schools | - Quasi-experimental longitudinal design with non-randomized intervention and comparison groups<br>- 2.3 y FU | - Multi-focused<br>- Multi-site<br>- Community capacity-building | - Capacity building (school project officers and student ambassadors)<br>- Awareness raising (project messages)<br>- Promoting healthy eating (policy change, social marketing, vegetable gardens, removal of soft drinks from vending machines, parent information, staff training)<br>- Promoting active transport and increasing participation in organized sports (school program, education, walking groups)<br>- Promoting acceptance of healthy body size (education, social marketing) | - BMI and BMI z-score<br>- Weight<br>- Overweight prevalence<br>- Body composition/body fat percentage<br>( <u>bioimpedance</u> )<br>- Eating and PA behaviour<br>- Body image<br>- Quality of life | - Weight↓ by 0.74 kg<br>- BMI z-score ↓ by 0.07 z-scores<br>- BMI, overweight prevalence, body fat percentage →<br>- Eating and PA → besides active transport† |

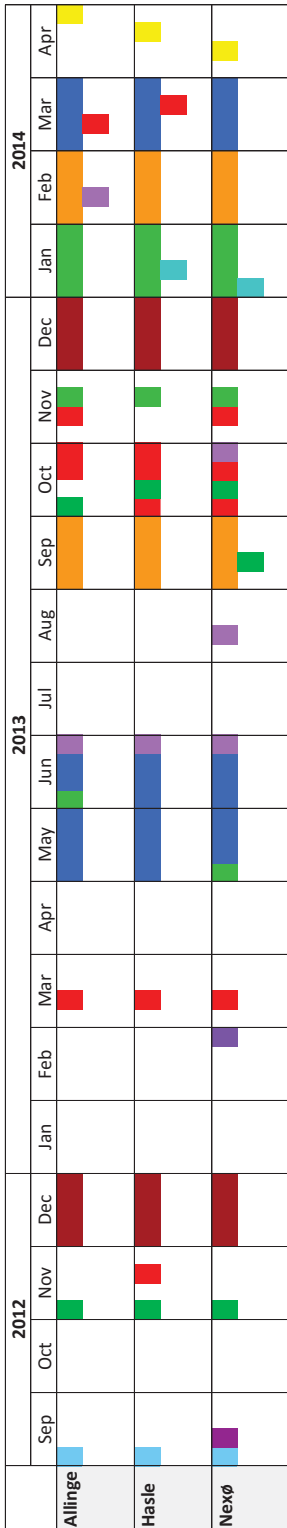
BMI, body mass index; BMI z-score, standardized body mass index; CBPR, capacity-building participatory research; EPODE, Ensemble, Prévenons l'Obésité des Enfants; FFQ, food-frequency questionnaire; FV, fruit and vegetable; FU, follow-up; PA, physical activity; SES, socioeconomic; SSB, sugar-sweetend beverages; Y, year.

<sup>a</sup>Results were presented differently. Following studies presented the pre-post change in intervention: Rhomp and Chomp (unadjusted difference), POP (unadjusted difference), VIASANO (adjusted difference) and SUS (adjusted difference). The rest of the studies presented the difference between intervention and control at follow-up (all adjusted differences): BAEW, APPLE, IYM.

## APPENDIX II: THE SOL PROGRAMME THEORY



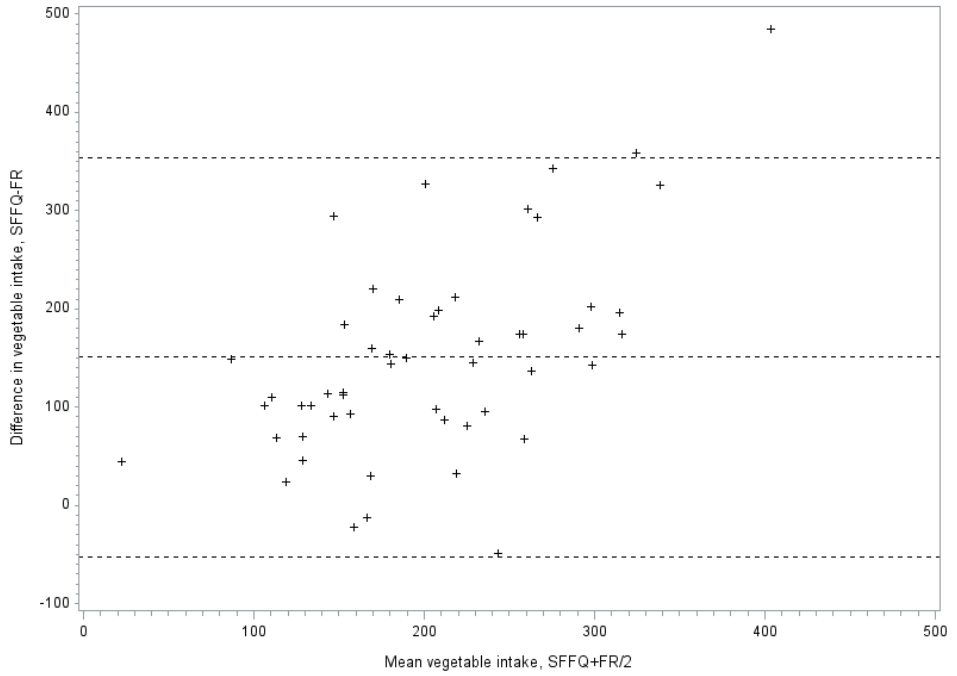
APPENDIX III: OVERVIEW OF THE SOL INTERVENTION THEMES AND ACTIVITIES IN EACH COMMUNITY (ALLINGE, HASLE, NEXØ).



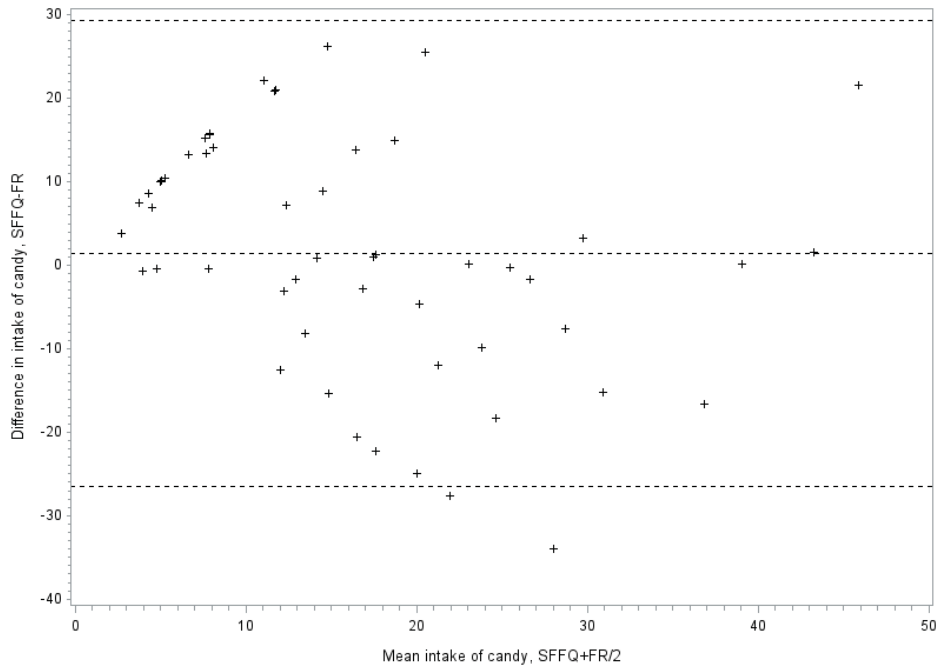
| Themes              | Activities  |
|---------------------|---|
| Kick-off party      | Official outdoor party with physical activity games, health theater and a vegetable soup kitchen.         |
| Taste food          | Taste and cooking workshops in schools and childcare centers.   |
| Nature & play       | Forest trips with professionals (a nature guides and an actor), nature fitness.                           |
| Fish                | Healthy tips and recipes on facebook, cooking workshops, visits to smoke house, harbor orienteering race. |
| Whole grains        | Promotion of whole grains in supermarkets.  |
| Fruit and vegetable | Treasure hunts in supermarkets, lunch box seminars, tastings in supermarket, cooking workshops.           |
| Empowerment         | Future workshop scenarios with school children, theme weeks in schools.                                   |
| Local action        | Local action group meetings.  |
| Healthy Christmas   | Healthy Christmas recipes based on local input shared in supermarkets and on facebook.                    |
| Finalizing parties  | Party in each of the three local communities.   |
| Capacity-building   | Partnership meetings, future scenario workshops with supermarket staff.                                   |

APPENDIX IV: BLAND-ALTMAN PLOTS

**Bland Altman plot**

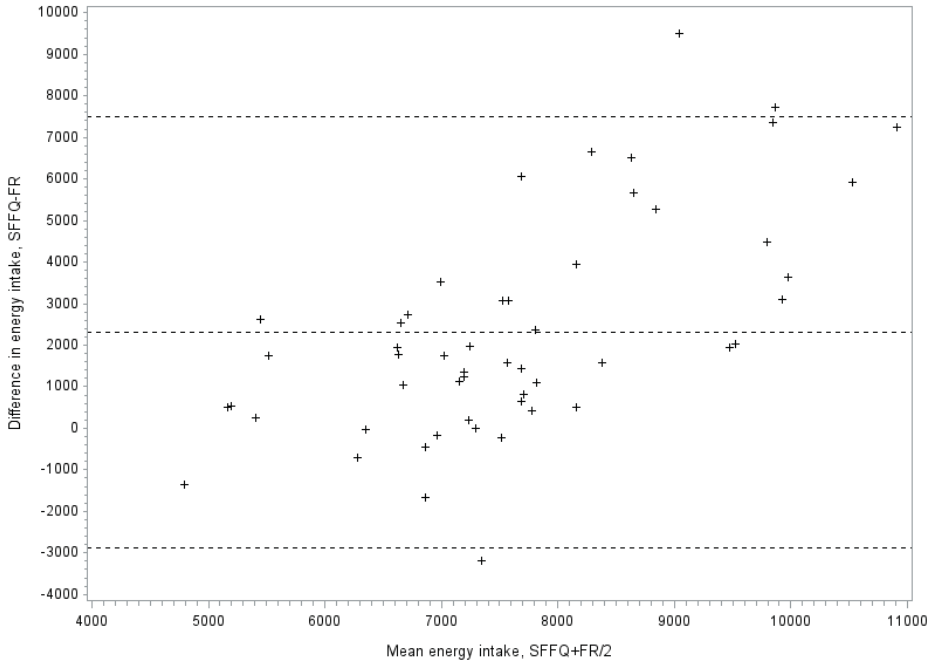


**Bland Altman plot**

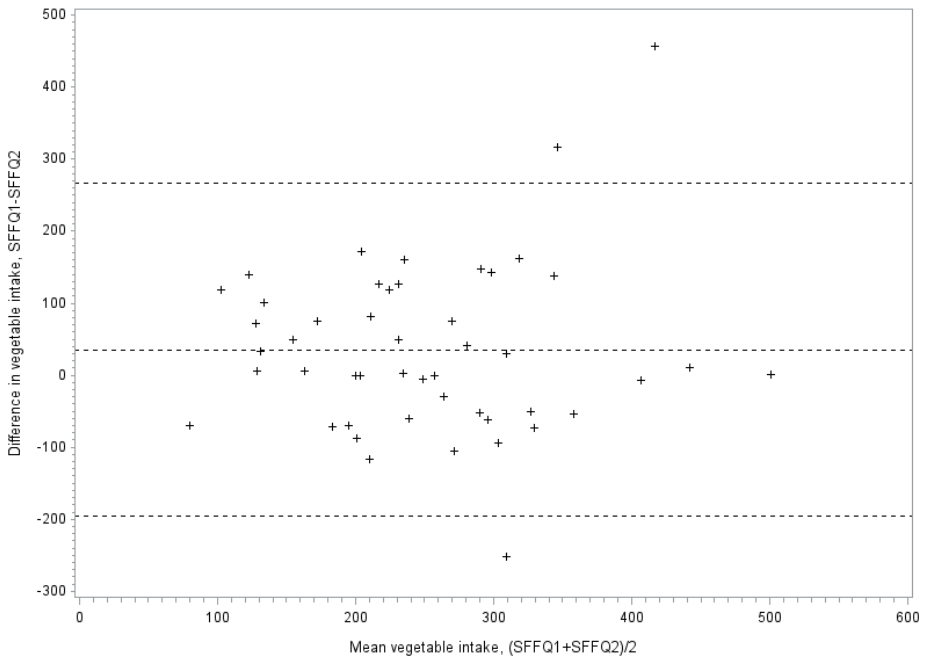


APPENDIX IV: BLAND-ALTMAN PLOTS

**Bland Altman plot**



**Bland Altman plot**



# PAPERS I-III



Paper I:

Buch-Andersen, T; Pérez Cueto, Federico JA; Toft, U (2015):  
*Relative validity and reproducibility of a parent-administered semi-quantitative FFQ  
for assessing food intake in Danish children aged 3-9 years.*  
Public Health Nutrition, 2015 Oct 5:1-11.





# Relative validity and reproducibility of a parent-administered semi-quantitative FFQ for assessing food intake in Danish children aged 3–9 years

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Submitted 23 April 2015; Final revision received 6 August 2015; Accepted 24 August 2015

## Abstract

**Objective:** To assess the relative validity and reproducibility of the semi-quantitative FFQ (SFFQ) applied in the evaluation of a community intervention study, SoL-Bornholm, for estimating food intakes.

**Design:** The reference measure was a 4 d estimated food record. The SFFQ was completed two times separated by a 1-month period in order to test reproducibility.

**Setting:** The Capital Region and the Regional Municipality of Bornholm, Denmark.

**Subjects:** A total of fifty-four children aged 3–9 years were enrolled in the study.

**Results:** In terms of validity, the SFFQ generally overestimated intakes compared with the food records, especially for vegetables. For most intakes, the mean difference increased with increasing intake. Gross misclassification was on average higher for energy and nutrients (17%) than for foods (8%). Spearman correlation coefficients were significant for twelve out of fourteen intakes, ranging from 0.29 to 0.63 for foods and from 0.12 to 0.48 for energy and nutrients. Comparing the repeated SFFQ administrations, the intakes of the first SFFQ were slightly higher than those of the second SFFQ. Gross misclassification was low for most intakes; on average 6% for foods and 8% for energy and nutrients. Intra-class correlations were significant for all intakes, ranging from 0.30 to 0.82 for foods and from 0.46 to 0.81 for energy and nutrients.

**Conclusions:** The results indicate that the SFFQ gives reproducible estimates. The relative validity of the SFFQ was low to moderate for most intakes but comparable to other studies among children.

**Keywords**  
Child nutrition  
Dietary assessment tools  
FFQ  
Reproducibility  
Relative validity

An adequate diet is essential for optimal well-being and development during childhood and for the prevention of disease<sup>(1,2)</sup>. Therefore, accurate assessment of children's dietary intake has become important for monitoring the nutritional status of the population, as well as for conducting interventional and epidemiological research on the link between diet and health among children.

Dietary assessment in young children is particularly challenging, and it is important to develop suitable methods for this age group. Below the age of 8 years, children are not capable of reporting their own dietary intake due to limited cognitive and literacy levels. Therefore, a proxy reporter, typically the parent, needs to be involved, which poses additional challenges<sup>(3,4)</sup>.

The estimated food record (FR) has been recommended for dietary assessment among young children<sup>(5)</sup>. The use of FR is labour intensive, but enables the use of several proxy persons to provide accurate collection of dietary information, for example parents and day-care staff. In large studies the FFQ is the preferred method because administration is easy and costs are low. However, FFQ should be validated in the target population<sup>(6)</sup>. The validity of FFQ is likely to be lower in younger children but the evidence is scarce<sup>(7)</sup>. Only a handful of studies have examined the relative validity of parent-administered FFQ among children below the age of 8 years<sup>(8–16)</sup> and very few have examined food group intakes<sup>(11,13)</sup>. Furthermore, few studies include a reproducibility test<sup>(10,12,13,17)</sup>. Reproducibility studies are difficult to design but are equally important<sup>(6)</sup>.

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As a part of the Danish community intervention study, 'Health and Local Community' (SoL-Bornholm), a questionnaire to assess food intake in 3- to 8-year-old children was developed. Currently, Danish FFQ for adults exist but no (published) Danish FFQ has been developed for young children. This is therefore, to our knowledge, the first Danish FFQ to be validated for this age group.

The purpose of the present study was to assess the relative validity and reproducibility of the semi-quantitative FFQ (SFFQ) for its application in the evaluation of the community intervention study, SoL-Bornholm, in Denmark. The assessment gave priority to food groups relevant to the SoL intervention study (listed below).

## Methods

### *Participants and design*

In September 2012 the community-based health promotion intervention study, SoL-Bornholm, was initiated. The main purpose of the intervention study was to promote healthy eating and physical activity among children. Important success criteria were increased intakes of vegetables, fruits, fish and whole grains, and decreased intakes of soft drinks and candy. In order to assess the food intake among participating children, a parent-administered FFQ was developed for the purpose and tested during the year 2013.

A convenience sample was recruited through postings on school intranets, in day-care centres in the SoL-Bornholm communities and in neighbourhoods in the Capital Region of Denmark. Recruitment from the Capital was necessary since very few families from the intervention setting were able to be recruited in this way. The majority of the final sample originated from the Capital. The sample was, however, comparable to the actual final users with regard to age and food culture. Children aged 3–9 years were included. Before the start of the study, parents were invited to a group meeting where they were given detailed instruction by a trained nutritionist on how to fill out the FR. The instruction used examples of child meals and how to estimate portion sizes. Throughout the study, the parents received reminders by email or text message, and telephone support if necessary. The study was carried out at the Research Centre for Prevention and Health.

The FR and SFFQ were entered by a nutritionist, following standardized procedures. All records and questionnaires were screened for completeness and parents were contacted to provide clarifications in the case of missing data or misunderstandings.

### *Semi-quantitative FFQ*

A parent-administered SFFQ was developed based on an SFFQ previously used and validated in a nationwide survey among children in Norway<sup>(11)</sup>. The SFFQ was

translated and modified to the Danish language. It was also adapted to Danish food culture as well as to the target age group using data from national Danish food intake surveys among children<sup>(18)</sup>.

The nineteen-page questionnaire included twenty-two questions covering 183 food items grouped together according to the Danish meal pattern (Western breakfast, open sandwich for lunch, hot meal for dinner). The recall period was the past 4 weeks, and the frequency alternatives varied from 'never/less than once per month' to 'five or more times a day'. A photographic booklet including sixteen series of colour photographs with four different sizes of portions of meals or food items, ranging from small (A) to large (D), was used by the parents when reporting the amounts of food eaten by the child. The photographic booklet originally included six differently sized portions (A–F) and was developed to assist food reporting among children and adults aged 4–75 years<sup>(19)</sup>. The photographs have been validated among 622 adults and 109 children aged 8–12 years<sup>(19)</sup>. When no photograph was available for a food item, household units were used, e.g. slices, pieces and spoons. The questionnaire consisted of seven sections: (i) introductory questions (height, weight, birth date); (ii) breakfast; (iii) bread (including toppings on bread); (iv) fruits; (v) hot meals (including vegetables); (vi) snacks/sweets; and (vii) beverages. Summary questions about entire food groups were added to the questionnaire to prevent misreporting. A summary question was, for example, 'How often and how many pieces of fruit does your child eat?'

A one-page information letter was mailed to parents together with the questionnaire. This letter contained brief, but detailed information on how to fill out the questionnaire. It also encouraged parents to seek information on the child's intake of foods and beverages when meals were eaten outside the home.

Approximately one month after completion of the SFFQ, the parents were asked to fill out the SFFQ once again in order to test its reproducibility. This interval was chosen to avoid seasonal variation. For convenience, the first administration of the SFFQ is called SFFQ1 and the second administration is referred to as SFFQ2.

### *Estimated food record (reference method)*

The estimated FR was chosen as the reference method. This type of FR is characterized by being less time-consuming than the weighed FR because participants are asked to use household units or photographs instead of weighing all foods and meals. The FR covered four consecutive days, including three weekdays and one day during the weekend (Wednesday to Saturday). The parents were asked to register in detail all foods and beverages consumed by their child using photographs of portion sizes (the same picture booklet as described in the preceding section) or household units. Besides food amounts, the FR contained sections for registering time



and location of meals, the food preparation method, fat percentage and food brand. The FR were filled out by parents shortly after the first administration of the SFFQ.

### Nutrient calculations

Daily individual consumption was calculated from the SFFQ and FR. For the SFFQ, monthly frequencies were divided by 30.4375, and weekly frequencies by 7, to calculate the daily intakes in g/person per d. For the FR, daily intakes were calculated as the mean of the recorded days. Intake in grams was calculated by use of standard weights of food items and portion sizes<sup>(19,20)</sup>. Estimation of the individual daily energy, nutrient and food intakes was calculated using the Danish Food Composition Databank version 7<sup>(21)</sup> and the software program FoodCalc version 1.3<sup>(22)</sup>. Total energy intake was calculated according to the Nordic Nutrition Recommendations<sup>(23)</sup> with fat contributing 37 kJ/g, available carbohydrates and protein contributing 17 kJ/g and dietary fibre contributing 8 kJ/g.

Furthermore, the intakes of specific foods and food groups were calculated. Eight food groups were developed specifically to be used for the evaluation of the SoL-Bornholm intervention study. The grouping of foods into food groups was based on the standards developed by the National Food Institute, Technical University of Denmark<sup>(21)</sup>. These food groups were then modified and supplemented to be more comparable with the Danish dietary guidelines<sup>(24)</sup> and to suit the SoL-Bornholm intervention study. The adaptations were as follows: (i) for the fruit group, removing olives, jams, juices, dried fruit and nuts; (ii) for the vegetable group, removing juices, ketchup, potatoes, soya drinks and mushrooms; (iii) creating the following new food groups relevant for the SoL-Bornholm intervention study: coarse vegetables, canned fish, sweet drinks, candy and whole grains. The vegetable group served as a measure of total vegetable intake, whereas the group named coarse vegetables included only vegetables with high fibre content (above 2 g/100 g) such as cabbage, root vegetables and onions. Potatoes were excluded from the vegetable group because they do not count as a vegetable in the Danish dietary guidelines. Canned fish included all fish sold in cans or similar packaging, and was included because these fish products were a main intervention focus for supermarkets. The whole grains group included rye bread and oats as a marker of whole grain intake. For convenience, this food group is called whole grains in the following sections. Sweet drinks included all non-alcoholic drinks with natural or added sugars (e.g. juice, chocolate milk and lemonade), not including drinks with artificial sweeteners. The candy group included chocolates, liquorice, fruit gums and similar.

A weighting factor was calculated for each of the individual fifty-four children using SFFQ data and the summary questions<sup>(25)</sup> for the following food categories: cold meals (open sandwich); fruit; vegetables; and hot meals. The answers from the summary questions were

divided by the sum of frequencies or amounts from the FFQ, for each food group, as shown below:

$$\frac{\text{Value from summary question}}{\text{Sum of values from individual food items in the SFFQ}}$$

For example, the weighting factor was 0.92 for one of the children's fruit intake. The calculation was based on the calculated intake from the summary question (2 portions of fruit, 6–7 times/week), which was 185.7 g, and the sum of the reported fruit intake from question 15 about intake of different types of fruit, which was 201.55 g. When applying the weighting factor the adjusted fruit intake in grams per day was therefore 10 % smaller.

Previous studies have shown that applying weighting factors often leads to better estimates of nutrient and food intakes<sup>(25,26)</sup>.

### Statistical analyses

All statistical analyses were performed using the SAS statistical software package version 9.4. Descriptive statistics were used to describe baseline characteristics and average intakes of foods, energy and nutrients. Most of the intake data were non-normally distributed both before and after log-transformation, and therefore the mean was presented along with the median and the 5th and 95th percentile.

The Bland and Altman limits of agreement (LOA) method was used to assess agreement (or bias) of the two administrations of the SFFQ and between the two methods<sup>(27)</sup>. This method was used to visually inspect agreement using plots of the mean difference and the 95 % LOA. Mean difference was calculated as the mean of all individual differences between methods (or repeated measures); that is, mean (SFFQ1 – SFFQ2)/*n* or mean (SFFQ – FR)/*n*, where *n* = 2. The 95 % LOA was calculated for each food or nutrient intake as the mean difference  $\pm 1.96$  SD of differences. This measure represents a range of values within which 95 % of all differences between methods are expected to fall. Bland–Altman plots were drawn using the differences between the two measurements plotted against the means of the measurements<sup>(27)</sup>. The middle line of the plot represents the mean difference and the two outer lines represent the 95 % LOA.

A cross-classification analysis was undertaken to calculate the percentage of observations classified into the same or opposite quartile of intake (referred to as gross misclassification in the following)<sup>(28)</sup>. This was done for testing the relative validity as well as reproducibility. The linear association between the two dietary methods and between the first and second administration of the SFFQ was described using Spearman's rank correlation coefficients<sup>(28)</sup>. In addition, intra-class correlation coefficients were calculated to assess reproducibility. For the assessment of the relative validity, correlations were corrected for the day-to-day within-person variation using the

de-attenuation method<sup>(7)</sup>. The corrected correlation,  $r_c$ , was calculated as follows:

$$r_c = r_o \sqrt{[1 + (S_w^2/S_b^2)]/n},$$

where  $r_o$  is the observed correlation,  $S_w^2/S_b^2$  is the ratio of the within- and between-person variances and  $n$  is the number of replicates per person for the given variable. Within-person variation and between-person variation were calculated from replicated FR using the Proc Mixed model in SAS. Additionally, Spearman's rank correlation coefficients were adjusted for energy and person-specific factors. The residual model was used for energy adjustment of correlations between the FR and the first administration of the SFFQ<sup>(29)</sup>. Person-specific factors were defined as the child's age category (pre-school or school) and sex. These covariates were included in a model, and Spearman's partial rank-order correlation coefficients were used for analyses of relative validity and reproducibility.

## Results

Fifty-four children were enrolled in the study. Fifty-four completed SFFQ1 (100%), forty-eight completed SFFQ2 (89%) and fifty-three completed FR (98%) were available. One participant had only three fully recorded days in the FR, but of satisfactory quality, and was therefore included in the analysis. The rest were of satisfactory quality and none were considered to have recorded implausible intakes. None of the children had energy intakes below or above the thresholds suggested for quality check by Willett and Stampfer<sup>(29)</sup>. The characteristics of the children are presented in Table 1.

### Relative validity of the semi-quantitative FFQ

Food, energy and nutrient intakes from the SFFQ and the FR are shown in Table 2. The mean difference between methods varied among intakes, but in general the intakes were overestimated when compared with the reference

(Table 2). Vegetable intakes were particularly overestimated by the SFFQ (151 g for total intake (118%) and 73 g for coarse vegetables (189%)). A few intakes were underestimated, particularly the sugar energy percentage. The lowest degree of over- or underestimation was observed for intake of whole grain foods (-3 g (3%)). When using Bland-Altman plots to examine agreement between methods, it was observed that the mean difference increased with increasing intake for most intakes. For most intakes, the differences were both positive and negative, implying that the participants both under- and over-reported at high intakes. This was, however, not the case for vegetables and energy, where high intakes were mostly related to over-reporting (Fig. 1). When inspecting the 95% LOA (the outer lines in the plot) we observed that the 95% LOA generally were wide, indicating that agreement was better at the group level than at the individual level.

The proportion of children correctly classified into the same quartile ranged from 26% (sweet drinks) to 49% (coarse vegetables; Table 3). Gross misclassification into the opposite quartile was lowest for foods, on average 8%. In general, the cross-classification analyses on energy intake and macronutrient energy percentages revealed slightly lower percentages for classification into the same quartile and higher percentages for gross misclassification (Table 3).

All but two correlations were significant (Table 2). The highest degree of linear association was observed for intakes of whole grains and fish products ( $r=0.58-0.63$ ), there was a less strong association for vegetables and fruit ( $r=0.40-0.46$ ), and the lowest degree of association was observed for sweet drinks and candy ( $r=0.29-0.31$ ). There was a tendency towards weaker correlations for energy and macronutrients and the correlation for energy was especially low ( $r=0.12$ ). The ratio of within- and between-person variance measured from the 4 d FR was between 1.46 and 9.61, and the de-attenuated (corrected) correlation coefficients were therefore substantially higher than the crude correlations (Table 2). Adjustment for energy did not change the correlation coefficients considerably. The most important and largest change was observed for candy (crude value  $r=0.31$ , energy-adjusted value  $r=0.43$ ). When correlations were adjusted for age category or sex, a small change was observed for correlation of energy intake ( $r=0.06$  when adjusted for age category and  $r=0.08$  when adjusted for sex), but otherwise no considerable changes were observed.

### Reproducibility of the semi-quantitative FFQ

Food, energy and macronutrient intakes for the repeated SFFQ are shown in Table 4. Overall, intakes from SFFQ1 were slightly higher than those from SFFQ2 (Table 4). The intake of sweet drinks was especially higher for the first SFFQ (35 g (27%)). Through visual inspection of the Bland-Altman plots, a tendency towards poorer agreement with high intakes was observed. This, however, was

**Table 1** Descriptive characteristics of the children included in the study ( $n=54$ ), Capital Region and the Regional Municipality of Bornholm, Denmark, 2013

| Characteristic                  | $n$    | %     |
|---------------------------------|--------|-------|
| Girls                           | 24     | 44    |
| Boys                            | 30     | 56    |
| Age group                       |        |       |
| Pre-school children (3-6 years) | 26     | 48    |
| School children (6-9 years)     | 28     | 52    |
| Parent reporter, mother         | 46     | 85    |
| Parent reporter, father         | 8      | 15    |
|                                 | Mean   | sd    |
| Weight (kg)*                    | 23.12  | 5.97  |
| Height (cm)*                    | 119.74 | 13.52 |

\*Self-reported by parents.

**Table 2** Relative validity of daily intakes of foods, energy and nutrients estimated by the first administration of the parent-administered semi-quantitative FFQ (SFFQ1) and the average of the 4 d estimated food records (FR), and correlation between SFFQ1 and FR. A total of fifty-three Danish children aged 3–9 years, from the Capital Region and the Regional Municipality of Bornholm, were included in all analyses

|   | SFFQ1 |        |              | FR   |        |            | Mean difference (SFFQ – FR) |     |                     | Correlation between methods |                 |                                 |
|---|-------|--------|--------------|------|--------|------------|-----------------------------|-----|---------------------|-----------------------------|-----------------|---------------------------------|
|   | Mean  | Median | P5, P95      | Mean | Median | P5, P95    | Mean†                       | %   | Spearman's <i>r</i> | 95% CL                      | Variance ratio‡ | Corrected Spearman's <i>r</i> † |
| Vegetables and vegetable products (g/d)   | 278   | 265    | 147, 502     | 128  | 110    | 12, 227    | 151                         | 118 | 0.46***             | 0.22, 0.65                  | 3.17            | 0.62                            |
| Coarse vegetables (g/d)                   | 112   | 99     | 46, 232      | 39   | 30     | 1, 102     | 73                          | 189 | 0.40**              | 0.14, 0.60                  | 4.43            | 0.58                            |
| Fruit and fruit products (g/d)            | 206   | 195    | 6, 384       | 166  | 172    | 4, 329     | 40                          | 24  | 0.45***             | 0.20, 0.64                  | 3.11            | 0.60                            |
| Fish and fish products (g/d)              | 32    | 25     | 1, 92        | 26   | 18     | 0, 80      | 5                           | 18  | 0.63***             | 0.43, 0.77                  | 3.24            | 0.85                            |
| Canned fish (g/d)                         | 12    | 7      | 0, 44        | 14   | 3      | 0, 54      | -2                          | -14 | 0.63***             | 0.42, 0.76                  | 2.72            | 0.82                            |
| Rye bread and oats, 'whole grains' (g/d)§ | 88    | 92     | 30, 145      | 90   | 84     | 31, 173    | -3                          | -3  | 0.58***             | 0.36, 0.73                  | 1.83            | 0.70                            |
| Sweet drinks (g/d)¶                       | 125   | 71     | 10, 457      | 105  | 83     | 0, 255     | 21                          | 20  | 0.29*               | 0.02, 0.52                  | 1.46            | 0.34                            |
| Candy and chocolate (g/d)                 | 17    | 15     | 5, 39        | 16   | 14     | 0, 43      | 1                           | 9   | 0.31*               | 0.05, 0.54                  | 9.61            | 0.57                            |
| Energy (kJ/d)                             | 8783  | 8103   | 5443, 13 694 | 6487 | 6509   | 4642, 8486 | 2296                        | 35  | 0.12                | -0.16, 0.37                 | 4.79            | 0.18                            |
| Dietary fibre (g/d)                       | 26    | 26     | 17, 41       | 20   | 19     | 11, 29     | 7                           | 35  | 0.25                | -0.03, 0.49                 | 3.41            | 0.34                            |
| Protein energy percentage (%¶¶)           | 15    | 15     | 11, 19       | 15   | 16     | 12, 19     | -0.3                        | -2  | 0.30*               | 0.03, 0.53                  | 5.54            | 0.46                            |
| Fat energy percentage (%¶¶)               | 34    | 34     | 25, 46       | 30   | 31     | 24, 37     | 4                           | 13  | 0.48***             | 0.23, 0.66                  | 2.92            | 0.63                            |
| Carbohydrate energy percentage (%¶¶)      | 53    | 53     | 44, 63       | 57   | 58     | 49, 64     | -4                          | -6  | 0.43**              | 0.17, 0.62                  | 3.55            | 0.59                            |
| Sugar energy percentage (%¶¶)             | 5     | 5      | 2, 10        | 7    | 7      | 1, 13      | -2                          | -26 | 0.28*               | 0.01, 0.51                  | 5.69            | 0.44                            |

P5, 5th percentile; P95, 95th percentile; 95% CL, 95% confidence limits.

\**P* < 0.05, \*\**P* < 0.01, \*\*\**P* < 0.001.

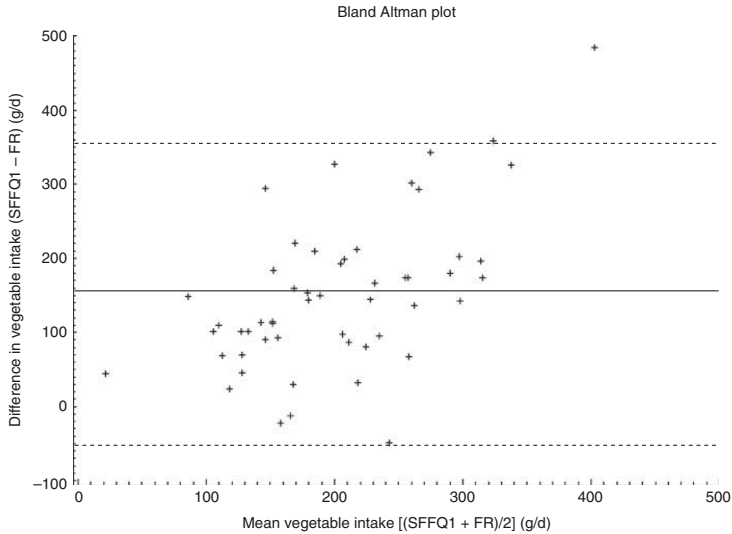
†[(Mean (SFFQ – FR))/(mean (FR))] × 100.

‡Variance ratio is the ratio between within- and between-person variances. Spearman correlation coefficient was adjusted for within-person variance using the de-attenuation method.

§Including rye bread and oats as a marker of whole grain intake.

¶Including all non-alcoholic drinks with natural or added sugars, not including drinks with artificial sweeteners.

¶¶Intakes of macronutrients expressed as a percentage of energy; (macronutrient absolute value × energy conversion factor) × 100.



**Fig. 1** Bland–Altman plot assessing the relative validity of the parent-administered semi-quantitative FFQ (SFFQ) for assessing daily vegetable intake in Danish children aged 3–9 years ( $n$  53), Capital Region and the Regional Municipality of Bornholm, Denmark, 2013. The difference in intake between the first administration of the SFFQ (SFFQ1) and the average of the 4 d estimated food records (FR) is plotted *v.* the mean intake from the two methods; — represents the mean difference and - - - - represent the 95 % limits of agreement corresponding to  $\pm 1.96$  sd

**Table 3** Percentage of participants classified by the first administration of the parent-administered semi-quantitative FFQ (SFFQ1) into the same or opposite quartile of consumption as measured by the average of the 4 d estimated food records (FR) or the second administration of the SFFQ (SFFQ2). A total of fifty-three and forty-eight Danish children aged 3–9 years, from the Capital Region and the Regional Municipality of Bornholm, were included in analyses of SFFQ1 *v.* FR and SFFQ1 *v.* SFFQ2, respectively

|   | SFFQ1 <i>v.</i> FR |                       | SFFQ1 <i>v.</i> SFFQ2 |                       |
|---|--------------------|-----------------------|-----------------------|-----------------------|
|   | Same quartile (%)  | Opposite quartile (%) | Same quartile (%)     | Opposite quartile (%) |
| Vegetables and vegetable products (g/d)   | 43                 | 7                     | 38                    | 8                     |
| Coarse vegetables (g/d)                   | 49                 | 15                    | 40                    | 13                    |
| Fruit and fruit products (g/d)            | 47                 | 11                    | 54                    | 8                     |
| Fish and fish products (g/d)              | 44                 | 0                     | 46                    | 0                     |
| Canned fish (g/d)                         | 41                 | 6                     | 54                    | 8                     |
| Rye bread and oats, 'whole grains' (g/d)† | 36                 | 4                     | 69                    | 0                     |
| Sweet drinks (g/d)‡                       | 26                 | 7                     | 52                    | 4                     |
| Candy and chocolate (g/d)                 | 36                 | 12                    | 33                    | 8                     |
| Energy (kJ/d)                             | 36                 | 26                    | 56                    | 0                     |
| Dietary fibre (g/d)                       | 34                 | 18                    | 42                    | 17                    |
| Protein energy percentage (%)§            | 38                 | 17                    | 50                    | 13                    |
| Fat energy percentage (%)§                | 43                 | 14                    | 58                    | 0                     |
| Carbohydrate energy percentage (%)§       | 42                 | 11                    | 60                    | 8                     |
| Sugar energy percentage (%)§              | 38                 | 18                    | 48                    | 8                     |

†Including rye bread and oats as a marker of whole grain intake.

‡Including all non-alcoholic drinks with natural or added sugars, not including drinks with artificial sweeteners.

§Intakes of macronutrients expressed as a percentage of energy: (macronutrient absolute value  $\times$  energy conversion factor)  $\times$  100.

not the case for vegetables and whole grains. We also observed that the 95 % LOA (the outer lines in the plot) were wide, indicating that agreement was better at the group level than at the individual level.

The cross-classification analysis indicated a low rate of gross misclassification into the opposite quartile for most intakes, on average 6 % for foods and 8 % for energy and

nutrients (Table 3). The proportion of children correctly classified into the same quartile of intake was highest for intakes of whole grains (69 %) and lowest for candy and vegetables (33 % and 38 %, respectively; Table 3).

Intra-class correlation coefficients between the first and second administration of the SFFQ were on average 0.58 for foods and 0.64 for energy and nutrients, and all were





**Table 4** Reproducibility of daily intakes of foods, energy and nutrients estimated by the first and second administration of the parent-administered semi-quantitative FFQ (SFFQ1 and SFFQ2, respectively), and correlation between SFFQ1 and SFFQ2. A total of forty-eight Danish children aged 3–9 years, from the Capital Region and the Regional Municipality of Bornholm, were included in all analyses

|   | SFFQ1 |        |              |      | SFFQ2  |              |       |      | Mean difference (SFFQ1 – SFFQ2) |            |         |            | Correlation between repeated SFFQ |  |  |  |
|---|-------|--------|--------------|------|--------|--------------|-------|------|---------------------------------|------------|---------|------------|-----------------------------------|--|--|--|
|   | Mean  | Median | P5, P95      | Mean | Median | P5, P95      | Mean† | %    | Spearman's r                    | 95% CL     | ICC     | 95% CL     |                                   |  |  |  |
| Vegetables and vegetable products (g/d)   | 268   | 256    | 144, 502     | 233  | 228    | 83, 435      | 35    | 15   | 0.43**                          | 0.17, 0.64 | 0.38**  | 0.12, 0.59 |                                   |  |  |  |
| Coarse vegetables (g/d)                   | 110   | 99     | 46, 232      | 91   | 89     | 23, 177      | 19    | 17   | 0.56***                         | 0.32, 0.72 | 0.44*** | 0.19, 0.64 |                                   |  |  |  |
| Fruit and fruit products (g/d)            | 195   | 192    | 7, 384       | 200  | 192    | 2, 373       | -4    | 2    | 0.55***                         | 0.32, 0.72 | 0.55*** | 0.32, 0.72 |                                   |  |  |  |
| Fish and fish products (g/d)              | 30    | 22     | 1, 92        | 26   | 16     | 5, 79        | 5     | 18   | 0.72***                         | 0.55, 0.83 | 0.81*** | 0.69, 0.89 |                                   |  |  |  |
| Canned fish (g/d)                         | 12    | 5      | 0, 44        | 10   | 4      | 0, 39        | 1     | 7    | 0.66***                         | 0.45, 0.79 | 0.75*** | 0.60, 0.85 |                                   |  |  |  |
| Rye bread and oats, 'whole grains' (g/d)‡ | 83    | 85     | 30, 139      | 79   | 87     | 25, 135      | 1     | 5    | 0.82***                         | 0.73, 0.91 | 0.82*** | 0.70, 0.89 |                                   |  |  |  |
| Sweet drinks (g/d)§                       | 130   | 71     | 10, 457      | 95   | 13     | 2, 297       | 35    | 27   | 0.71***                         | 0.53, 0.83 | 0.60*** | 0.39, 0.75 |                                   |  |  |  |
| Candy and chocolate (g/d)                 | 18    | 15     | 6, 39        | 16   | 13     | 3, 53        | 1     | 8    | 0.30*                           | 0.02, 0.54 | 0.30*   | 0.03, 0.53 |                                   |  |  |  |
| Energy (kJ/d)                             | 8508  | 7990   | 5443, 13 694 | 7749 | 7581   | 4716, 12 146 | 759   | 10   | 0.71***                         | 0.53, 0.82 | 0.66*** | 0.47, 0.79 |                                   |  |  |  |
| Dietary fibre (g/d)                       | 25    | 25     | 17, 37       | 23   | 23     | 14, 34       | 2     | 9    | 0.46***                         | 0.20, 0.66 | 0.46*** | 0.21, 0.65 |                                   |  |  |  |
| Protein energy percentage (%)             | 15    | 15     | 12, 19       | 16   | 15     | 13, 21       | -0.5  | -3   | 0.51***                         | 0.26, 0.70 | 0.53*** | 0.30, 0.70 |                                   |  |  |  |
| Fat energy percentage (%)                 | 34    | 35     | 25, 46       | 34   | 34     | 24, 42       | -0.1  | -0.2 | 0.81***                         | 0.68, 0.89 | 0.81*** | 0.69, 0.89 |                                   |  |  |  |
| Carbohydrate energy percentage (%)        | 54    | 54     | 44, 63       | 53   | 52     | 46, 63       | 0.6   | 1    | 0.74***                         | 0.58, 0.85 | 0.74*** | 0.64, 0.89 |                                   |  |  |  |
| Sugar energy percentage (%)               | 6     | 5      | 2, 10        | 5    | 4      | 2, 9         | 0.7   | 13   | 0.57***                         | 0.34, 0.73 | 0.62*** | 0.41, 0.77 |                                   |  |  |  |

P5, 5th percentile; P95, 95th percentile; 95% CL, 95% confidence limits; ICC, intra-class correlation coefficient.

\* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ .

† $\{[\text{Mean (SFFQ1 – SFFQ2)}] / [\text{mean (SFFQ1)}]\} \times 100$ .

‡Including rye bread and oats as a marker of whole grain intake.

§Including all non-alcoholic drinks with natural or added sugars, not including drinks with artificial sweeteners.

||Intakes of macronutrients expressed as a percentage of energy; (macronutrient absolute value  $\times$  energy conversion factor)  $\times 100$ .

statistically significant (Table 4). Spearman's correlation coefficients were generally similar to the intra-class correlations (Table 4). The food group candy and chocolate deviated from the rest with a markedly lower correlation ( $r=0.30$ ). Correlations for vegetable intakes were also somewhat lower than the majority (intra-class correlation coefficient = 0.38; Spearman correlation coefficient = 0.43). The strongest correlations for food groups were observed for fish and whole grains (intra-class correlation coefficient = 0.81–0.82). When Spearman's correlation coefficients were adjusted for age category or sex, no considerable changes were observed.

**Discussion**

The relative validity of the SFFQ, when compared with a 4 d estimated FR, varied across the different food groups and nutrients (Tables 2 and 3). Most intakes were overestimated, which is a similar finding to the majority of previous studies. Only two of the similar studies identified found an overall underestimation of intakes<sup>(12,13)</sup>, whereas seven observed an overestimation<sup>(8–10,14–16,30)</sup>. Likewise, the validation study performed on the original Norwegian version of the SFFQ reported overestimation of intakes; however, these overestimations were not as large as those observed in the present study<sup>(11)</sup>. A review reported that FFQ overestimated total energy intake by 2–59% when compared with the doubly labelled water method<sup>(31)</sup>. Conversely, dietary assessment using FR is typically related to underestimation of total energy intakes (19–41%)<sup>(31)</sup>. When testing an FFQ using FR as the reference, it is therefore not surprising that we observed an overestimation of most intakes.

The results of the present validation study point towards an overestimation of the child's vegetable intake in particular. This can perhaps be explained by the difficulty parents face when attempting to remember the child's intake of vegetables or when estimating portion sizes. It has previously been observed that there is a low correlation between parental reports of children's fruit and vegetable intake and corresponding serum micronutrients ( $r=0.14–0.29$ )<sup>(32)</sup>. It is also possible that some parents have reported vegetables that were also a part of mixed dishes, causing double reporting.

When assessing validity with the use of cross-classification into quartiles, the results pointed towards highest agreement among food group intakes (Table 3). Coarse vegetables, fruit, candy, energy, dietary fibre and macronutrient energy percentages were related to a high degree of gross misclassification into the opposite quartile (>10%), which were higher than or comparable to other studies using quartiles<sup>(13,14)</sup>. Despite this, the percentages for gross misclassification of vegetables, fish, whole grains and sweet drinks were comparable to (or lower than) a similar study among children<sup>(13)</sup> and other studies performed among adolescents<sup>(33–35)</sup>, all of which used quartile classification.

The use of correlation coefficients to assess validity is under debate but there is a general agreement that correlations above 0.5 are acceptable or good, and that correlations below 0.3–0.4 indicate a low degree of linear association<sup>(6,28)</sup>. In the view of this, the majority of food group intakes can therefore be considered to have an acceptable validity for assessing intakes on a group level and for ranking of children according to food intakes. There are, however, concerns about the measurement of sweet drinks and candy. Few studies have reported results on correlation coefficients of compared food intakes. When compared with the original Norwegian version of the SFFQ, the results of the present study were not considerably different ( $r = 0.26\text{--}0.69$ )<sup>(11)</sup>. The Norwegian study, however, is not directly comparable since the children were 2 years old. One other study, performed in a similar age group, reported correlation coefficients for foods in the range of 0.23 to 0.62, comparable to the present SFFQ<sup>(13)</sup>. Not surprisingly, the correlation coefficients improved after correction for within-person variance. A few other similar studies have reported de-attenuated correlations<sup>(9,13–15)</sup> and among these only one study examined food intakes<sup>(13)</sup>. The latter study observed a large variation in variance ratios (–16.25 to 9.87), but likewise higher correlations after de-attenuation.

The correlation coefficients for energy intake and macronutrient energy percentages were generally similar to or lower than those observed in other studies<sup>(9,12–14,16,17,30)</sup>. All correlations increased after de-attenuation, which is comparable to what is observed in other studies<sup>(9,14,15)</sup>. The correlation for energy intake improved to 0.23 when excluding observations from two children who exceeded the 95 % LOA in the Bland–Altman plot, but the association was still low compared with other studies. The low validity of the energy intake can be explained by a number of different factors. First, dietary assessment in young children is notoriously challenging. As mentioned above, a proxy reporter, typically the parent, needs to be involved, which poses additional challenges. The major challenges include: (i) recall bias; (ii) difficulties in estimating the child's portion size; and (iii) limited supervision of meals when the child is out of the home<sup>(3,4)</sup>. Recall bias is a common problem within retrospective methods and even though parents have been recognized as reliable proxy reporters, remembering the child's diet places high demands on the parent<sup>(4,31)</sup>. Recall bias poses a particular problem when the child spends much of his/her time away from home, which is the standard for most Danish children. A study among 3-year-old children found that the linear association between the FFQ and a food diary decreased markedly for energy intake when the number of meals eaten outside the home increased ( $r = 0.38$  for no meals outside the home to  $r = 0.31$  for four or more meals outside the home)<sup>(16)</sup>. The problem is perhaps minimized when children bring their food from home, which is the case in the present study, but limited supervision of meals will remain a challenge.

Estimating children's portion sizes seems to be a problem across dietary assessment methods<sup>(3,4)</sup> and this could also be a possible explanation for the low validity observed for energy intake. A study indicated that the dietary report is more reliable when both parents participate<sup>(4)</sup>. In the present study, 85 % of the reporters were the mother. According to the additional analyses of person-specific factors, the relative validity of energy intake was affected by age and sex. The sample size was too small to analyse the validity of energy intake in subgroups, but informal tests indicated that the validity was better for children from day-care centres and for boys. If the validity is better in day-care children, this supports the hypothesis that limited supervision of meals is a problem when reporting children's diet. It is likely that schoolchildren consume more meals and drinks out of the home, when visiting friends and family.

Another explanation, unrelated to the reporter, could be the duration of the recording period in the FR. For pragmatic reasons the FR was filled out for 4 d, but optimally a longer recording period would be needed to reflect a reliable intake<sup>(36)</sup>. A recent study, with a large sample size, did observe a small insignificant difference in energy intake between 3 d and 7 d periods<sup>(37)</sup>. The study was conducted in adults, so a longer period would probably be needed for children because of the higher within- to between-subject variation ratio. The problem of high day-to-day variability related to FR can be taken into account by using the de-attenuation method. Finally, a low validity of major food group intakes may have influenced the energy intake. As reported, intakes of sugary foods, sweet drinks and candy had a rather low validity. In addition, it was observed that the reported intake of meat and meat products had a low validity ( $r = 0.21$ ; not reported).

The reproducibility of the SFFQ was tested by comparing two administrations of the SFFQ with a 1-month interval. Mean difference was on average 9 %, indicating a small degree of overestimation by the first SFFQ and a good reproducibility at the group level (Table 2). There was a more moderate agreement at the individual level, as reflected in the wide 95 % LOA. The tendency of overestimation is also reported in other studies, and a previous review stated that the first administration tends to result in greater frequencies of consumption than subsequent administrations<sup>(32)</sup>. This can probably be explained by the learning effect and the increased awareness of eating habits from filling out the FR.

The proportion of children correctly classified into the same quartile was of a similar magnitude to that observed in a reproducibility study in adolescents that also used quartile classification<sup>(35)</sup>. In the present study, gross misclassification into the opposite quartile was below 10 % for most intakes, which is even less than in the adolescent study<sup>(35)</sup>. All correlation coefficients were significant and comparable to those in other reproducibility studies performed among children<sup>(10,12,13)</sup>. Only the intake of





candy was associated with poor correlation. Reproducibility of this food group was not reported by the aforementioned studies among children, but was assessed in adolescents as 'sugar, sweets and snacks' ( $r=0.58$ )<sup>(35)</sup>. Furthermore, it is possible that the Christian holiday, Ascension Day, during the first administration of the SFFQ might have influenced the present results. Two children had a much lower intake of candy and chocolate at the second SFFQ (lower than the 95% LOA), which was possibly caused by increased consumption during the holiday.

It has previously been suggested that the sample size of a validation or reproducibility study should be at least fifty for the LOA method and a minimum of 100 subjects for assessing correlation coefficients<sup>(6)</sup>. The sample size of the present study is therefore a considerable limitation of the study and most likely influences the results causing a higher degree of variation, for example larger SD and 95% LOA. In the cross-classification analysis, gross misclassification of a few children can make a large difference to the percentages. It can therefore be hypothesized that a larger sample size would have led to a higher level of reproducibility and relative validity. A small sample size can also be related to sampling bias, for example when responders are better than non-responders when answering FFQ. An analysis of sampling bias was not within the scope of the study. The sample size of the present study was comparable to that in other studies testing validity or reproducibility of FFQ. Participation in these kinds of study is challenging since it is related to a high subject burden.

In the current study, the estimated FR was chosen as the reference instrument. Unlike the FFQ, the FR method is prospective, does not depend on memory, is open-ended and has direct estimation of portion sizes using household units. Therefore, the measurement errors of FR and FFQ are fairly independent, and we considered the estimated FR to be the best alternative when choosing between different dietary assessment methods<sup>(6)</sup>. The FR method has other limitations however, for example a likely change of dietary habits<sup>(38)</sup>. Under optimal research conditions, inclusion of an objective measure (e.g. a recovery biomarker) in addition to the self-reported intake data (the dietary assessment method) would be ideal. Unlike self-reported data, biomarkers are not prone to reporting bias and the measurement errors are therefore less correlated with the FFQ. The inclusion of expensive biomarkers was unfortunately not possible in the SoL-Bornholm study.

A limitation of the reproducibility study could be a possible memory effect during the completion of SFFQ2 as parents could possibly still remember what they filled in 4 weeks ago<sup>(6)</sup>. It is, however, a challenge to conduct a reproducibility study on FFQ assessing food intakes covering a month, and an optimal approach is unlikely to exist. Having repeated the SFFQ2 a year after and during

the same month would also have been an option, but when conducted in children this may not be the best approach considering the likely increase in energy and nutrient intakes<sup>(23)</sup>. In addition, it would probably have led to lower response rates. Still, reproducibility studies are important and often neglected. A method that lacks reproducibility cannot be valid. When used in the context of a controlled intervention study with repeated measurements, it is of great importance that the study has an acceptable reproducibility in addition to validity<sup>(6,39)</sup>.

The SFFQ tested in the present study had a low level of relative validity for some intakes, which needs to be taken into consideration when analysing results obtained using the SFFQ. The intake of vegetables had a high level of overestimation, intakes of sweet drinks and candy had the lowest correlation among the food groups, and the results for energy intake in particular indicated a low level of validity across statistical methods when compared with other studies. Concerning the reproducibility, an acceptable level was observed for all intakes, but for candy and chocolate. When considering that this food group also obtained a low validity score, the results for this food group must therefore be interpreted with caution when using the questionnaire for testing intervention effects in the SoL-Bornholm study. For all other food group intakes, the study results indicated that the SFFQ is a useful tool when assessing children's food intakes on a group level in the SoL-Bornholm study. The SoL-Bornholm study was designed to test post-intervention differences between the intervention and control group and therefore reproducibility was more important than the ability to measure absolute intakes. The effectiveness analyses should be adjusted for energy intakes, age and sex to reduce potential variance from these variables.

For future use of the SFFQ, it is recommended that the food lists, frequency options and portion sizes are further developed. It is possible that some of the overestimation could have been avoided if the possibility of double reporting was reduced. If the low level of validity for energy intakes was caused by difficulties related to portion size estimation, it is possible that conversion to a non-quantitative FFQ would have increased the validity. This would, however, require that standard portions were developed for this age group in a representative sample.

In summary, the relative validity of the SFFQ was generally highest for foods, but overall low to moderate for most intakes, but comparable to findings of other studies among children. The reproducibility of the SFFQ was high or moderate for almost all intakes across statistical methods. The SFFQ can be used for ranking of children according to food intakes and the authors found that the SFFQ is a useful tool for evaluating the intervention effects of the SoL-Bornholm community intervention study. The use of the SFFQ to evaluate intakes of candy, energy and some of the macronutrient intakes is problematic and these intakes need to be interpreted with caution.

## Acknowledgements

**Acknowledgements:** The authors would like to thank all the families who participated in the study. The authors would also like to thank the Department of Nutrition, University of Oslo, for sharing information on its FFQ. **Financial support:** The study was supported by the Nordea-Fonden. The funder had no role in the design, analysis or writing of this article. **Conflict of interest:** None. **Authorship:** T.B.-A. contributed to conception and design of the study; collecting data, analysis and interpretation of data; drafting and revision of the manuscript; approval of the final version of the manuscript. F.J.A.P.-C. contributed to conception and design of the study; revision of the manuscript; approval of the final version of the manuscript. U.T. contributed to conception and design of the study; interpretation of data; revision of the manuscript; approval of the final version of the manuscript. **Ethics of human subject participation:** The study was conducted according to the guidelines laid down in the Declaration of Helsinki and procedures involving human subjects were approved by an Institutional Review Board, the Ethical Committee of the Capital Region (H-3-2013-036). Written informed consent was obtained from all parents on behalf of their child.

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ISSN (online): 2246-1248  
ISBN (online): 978-87-7112-535-1

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