# Assessment of dietary intake in young populations using new approaches and technologies

**Åsa Svensson**

**Department of Food and Nutrition**
Umeå 2014

Responsible publisher under Swedish law: the Dean of the Social Sciences Faculty

ISBN: 978-91-7601-188-1
Electronic version available at http://umu.diva-portal.org/
Printed by: Print & Media
Umeå, Sweden 2014

# Abstract

**Background** There is a great need for improved dietary assessment methods that give valid intake data and are more user friendly than traditional methods.
**Objectives** The aim of this thesis was to develop, implement, and evaluate dietary assessment methods using new approaches and technologies in young populations, and to investigate variables that are important for reporting accuracy. Another aim was to investigate day-of-the-week effects on assessed energy and sugar intakes among children and adolescents.
**Methods** This thesis is based on data collected as part of four different studies on the implementation of the following dietary assessment methods: the short dietary questionnaire (SDQ), a food record (FR) with either a digital camera or smartphone, and a computer-based 24-hour recall. Young pregnant and non-pregnant women with different weight statuses completed the SDQ. Children with overweight and obesity used digital cameras to complete FRs, and adolescents used the smartphone application FR. Parents of 2–9-year-old European children completed the computer-based 24-hour recall and the results of sugar intake of the children on weekdays and weekends were analysed. The SDQ was evaluated against doubly labelled water (DLW) and a more extensive food frequency questionnaire (FFQ). The two FRs were evaluated against data from a SenseWear Armband (SWA), and the smartphone FR was further compared to a web-based FR.
**Results** The new approaches and technologies used in the dietary assessment methods in this thesis captured between 70% and 79% of the energy intake (EI) of children, adolescents and young women, and the ranking according to EI was generally low with all methods. The negative effect on reporting accuracy with increasing BMI/weight status that has been observed previously was confirmed in our studies. In children and adolescents, a weekend day in the FR emerged as a factor that was positively associated with reporting accuracy. Assessed sugar intake in children and adolescents was high in general and highest on weekends, although EI did not differ between weekdays and weekends.
**Conclusions** FRs using technology should focus on simplifying the recording of consumed foods and amounts to a greater extent, for example, by automatizing these steps as much as possible. The SDQ could be further adapted for testing among other groups than young women, and could be adapted for specific objectives. Factors influencing reporting accuracy need to be taken into consideration and further explored when assessing dietary intake. In order to make it possible to evaluate sugar intake in relation to nutritional recommendations, information about added sugar in foods needs to be incorporated into food composition databases. Further development

and research is needed to obtain dietary assessment methods with improved accuracy and user friendliness.

# Sammanfattning

**Bakgrund** Traditionella kostundersökningsmetoder är krävande och har flera felkällor, vilket ofta leder till att energiintaget (EI) från insamlade kostdata är lägre än individens uppmätta totala energiförbrukning (TEE). Det finns ett stort behov av kostundersökningsmetoder som ger valida resultat och är användarvänliga.

**Syfte** Syftet med avhandlingen var att vidareutveckla kostundersökningsmetoder och att implementera och utvärdera dem bland barn, ungdomar och unga kvinnor. Syftet var också att undersöka faktorer med betydelse för en korrekt rapportering av kostintaget. Vidare var syftet att undersöka skillnader i EI och intag av socker under vardagar och helger bland barn och ungdomar.

**Metod** Avhandlingen baseras på data från fyra olika studier där olika nyutvecklade kostundersökningsmetoder användes. I en studie användes en kort kostenkät (SDQ) på unga gravida och icke-gravida kvinnor med olika viktstatus. Rapporterat EI jämfördes med TEE uppmätt med dubbelmärkt vatten-metoden, och rapporterat intag av näringsämnen och livsmedel jämfördes med en mer omfattande kostenkät (FFQ). I en annan studie samlades kostdata in för 2–9-åringar från åtta europeiska länder med hjälp av en datoriserad 24-timmars recall som besvarades av föräldrarna. Barnens socker- och energiintag jämfördes mellan måndag–torsdag, fredag och helg. I en tredje studie genomförde 8–12-åringar med övervikt eller fetma en kostregistrering med hjälp av digitalkamera vid upprepade tillfällen. I en fjärde studie utvecklades och användes en smartphoneapplikation för kostregistrering bland 15-åringar, som också använde en webb-baserad kostregistrering. Rapporterat EI med kostregistreringarna utvärderades i jämförelse med TEE mätt med SenseWear Armband, och EI och sockerintag under vardagar och helger undersöktes.

**Resultat** SDQ underskattade EI med 30 % bland de icke-gravida kvinnorna och en signifikant högre underskattning skedde bland kvinnorna med övervikt eller fetma. SDQ underskattade EI med 21 % bland de gravida kvinnorna. SDQ kunde dock rangordna EI bland kvinnorna med övervikt eller fetma och gav ett högre estimerat intag av flera näringsämnen och de flesta livsmedel jämfört med FFQ bland de icke-gravida kvinnorna.

De nyutvecklade kostregistreringsmetoderna underskattade EI bland barn med 24 % och bland ungdomar med 29 %. Digitalkamerametoden visade god reproducerbarhet för de olika mättillfällena bland barn. Smartphoneapplikationen kunde uppskatta ungdomars TEE och pojkars fysiska aktivitetsnivå med en fråga om den dagliga fysiska aktiviteten. Underskattning av EI ökade med BMI och var lägre när en helgdag fanns med i kostregistreringen för både barn och ungdomar. Bland barnen

underskattades EI mer bland flickor än pojkar och underskattningen ökade med åldern. Det fanns ingen signifikant skillnad i intagsmängd av näringsämnen och livsmedel när de mättes med smartphoneapplikationen jämfört med den webb-baserade kostregistreringen, och flera näringsämnen och livsmedel var signifikant korrelerade mellan de båda metoderna.

EI hos barn i Europa skilde sig inte åt mellan vardagar och helger, men det totala intaget av mono- och disackarider och/eller livsmedel med hög andel tillsatt socker eller sackaros var generellt högre på helgerna. Sockerintaget på fredagar var ett mellanting mellan intaget under vardagar och helger hos de europeiska barnen.

**Konklusion** De nyutvecklade kostundersökningsmetoderna fångade i genomsnitt mellan 70 % och 79 % av EI bland barn, ungdomar och unga kvinnor, och förmågan att rangordna EI var generellt låg med metoderna. Liksom i tidigare studier underskattades EI i högre grad hos de med övervikt/fetma eller högre BMI i alla grupperna, och bland barn och ungdomar framkom att validiteten ökade med en helgdag i kostregistreringen som en ny påverkande faktor. Barns och ungdomars sockerintag var generellt högt och som högst under helgen.

Det finns ett stort behov av fortsatt forskning för att förbättra kostundersökningsmetoders validitet och användarvänlighet. För kostregistreringsmetoder som använder sig av teknik bör fokus i vidareutvecklingen vara på att göra det enklare för användaren att registrera konsumerade livsmedel och portionsstorlekar, till exempel genom att automatisera dessa steg i så hög grad som möjligt. SDQ kan anpassas och utvärderas även i andra grupper och för olika syften. Faktorer med betydelse för en korrekt rapportering av kostintaget bör tas i beaktande även fortsättningsvis samt undersökas vidare. För att göra det möjligt att utvärdera intaget av socker i jämförelse med näringsrekommendationer bör information om mängden tillsatt socker i livsmedel inkluderas i livsmedelsdatabaser.

# List of papers

I. Svensson Å, Renström F, Bluck L, Lissner L, Franks PW and Larsson C. Dietary intake assessment in women with different weight and pregnancy status using a short questionnaire. *Public Health Nutr*. 2014; 17(9):1939-1948.

II. Svensson Å, Larsson C, Eiben G, Lanfer A, Pala V, Hebestreit A, Huybrechts I, Fernández-Alvira JM, Russo P, Koni AC, De Henauw S, Veidebaum T, Molnár D and Lissner L on behalf of the IDEFICS consortium. European children's sugar intake on weekdays versus weekends: the IDEFICS study. *E J Clin Nutr*. 2014; 68:822-828.

III. Svensson Å, Waling M, Bäcklund C and Larsson C. Overweight and obese children's ability to report energy intake using digital camera food records during a 2-year study. *J Nutr Metab*. 2012; 2012: 247389.

IV. Svensson Å and Larsson C. Evaluation of a smartphone application for dietary intake assessment in adolescents. Submitted manuscript.

The published papers are reprinted with permission from the journals.

# Abbreviations

| | |
|---|---|
| BMI | Body mass index |
| BMI-z | BMI for children calculated based on a reference population |
| BMR | Basal metabolic rate |
| CI | Confidence interval |
| DLW | Doubly labelled water |
| E% | Energy per cent for macronutrients |
| EI | Energy intake |
| FFQ | Food frequency questionnaire |
| FIL | Food intake level |
| FR | Food record |
| IDEFICS | Identification and prevention of Dietary - and lifestyle - induced health EFfects In Children and infantS |
| IOTF | International Obesity Task Force |
| IQR | Interquartile range |
| kJ | Kilojoule = 4.18 kcal |
| MET | Metabolic equivalent of task |
| MJ | Megajoule |
| NNR | Nordic Nutrition Recommendations |
| PAL | Physical activity level |
| PDA | Personal digital assistant |
| SD | Standard deviation |
| SELFH | Studies of the Effect of Lifestyle and Food Habits - overweight children's health |
| SACINA | Self-Administered Children and Infant Nutrition Assessment |
| SDQ | Short Dietary Questionnaire |
| SQL | Structured Query Language |
| SWA | SenseWear Armband |
| TEE | Total energy expenditure |
| WHO | World Health Organization |

# Table of Contents

# Introduction

Foods, drinks, and sometimes dietary supplements are part of the diet, and the types and quantities consumed commonly differ on a daily basis. Therefore, individual diets are difficult to measure. The purpose of dietary assessment is frequently to obtain information about the habitual energy intake (EI) and nutrient intake, by asking individuals to report the foods they consume. However, the reported EI in dietary studies is often lower than the intake needed for energy balance and weight stability (1). Although efforts have been made to improve dietary assessments by developing and validating methods, the methods most often used are still traditional versions of the 24-hour recall, the diet history interview, the food frequency questionnaire (FFQ) and the food record (FR). In recent years, traditional dietary assessment methods have been adapted for use with technology, e.g. computers, personal digital assistants (PDA), and mobile phones (2), which could possibly make dietary assessment more user friendly for study participants and more in tune with their daily lives.

The three dietary assessment methods covered in this thesis are the FFQ, the FR, and the 24-hour recall. Data from a study using a computerized 24-hour recall was used to compare children's sugar intake on weekdays and weekends. High sugar intake has been associated with several conditions such as dental caries, diabetes type 2, and overweight, and the World Health Organization (WHO) recommends that the intake of added sugars should be no more than 10 % of the total energy intake (E%) (3). Knowledge of the sugar intake among children and adolescents could be a basis for the planning of interventions to promote healthy diets in the young. Furthermore, day-of-the-week effects on dietary intake are of concern for researchers aiming to investigate the habitual dietary intakes of individuals.

Other variables of concern for dietary assessment are individual characteristics associated with the accuracy of reported intakes (4). Knowing which individual factors that are associated with misreporting of EI can be helpful when conducting dietary studies in different populations and when interpreting collected dietary data.

The focus of this thesis is on the methodological considerations of using the FFQ and FR with new approaches and technologies, in terms of the validity and reproducibility of the techniques as well as factors that are of importance for the accuracy of reported EI. This thesis also investigates children's sugar intake on different days of the week, using a 24-hour recall.

# Background

This chapter discusses the different dietary assessment methods and their accuracy. It also provides a summary of dietary sugars, including intakes, recommendations, and risks with high intakes.

## Dietary assessment methods

Information about dietary intake is used for many purposes, for example, in studies on the associations between diet and disease, in the development of nutrition recommendations, and in the monitoring of dietary intake and the outcomes of dietary interventions (Figure 1). Increased knowledge about the diet's role in many non-communicable diseases emphasizes the importance of studies into diet and health. However, the development of dietary assessment methods has not kept up with research in other areas. To keep the methodology used in dietary studies in step with other areas of research and society, it is of great importance that the development of improved dietary assessment methods is prioritized.

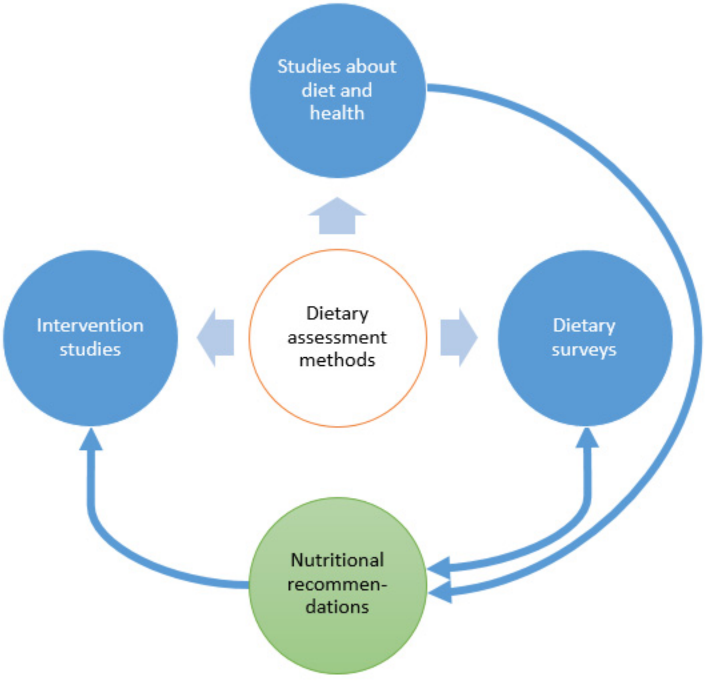


**Figure 1.** Examples of applications of dietary assessment methods.

The most common methods of dietary assessment are the diet history interview, the FFQ, the 24-hour recall, and the FR. The FFQ is a retrospective method that assesses habitual dietary intake over a specified time period, e.g. 3 months, 6 months, or a year. The 24-hour recall and the FR are methods that assess intakes on specific days. To assess individual habitual intake, 24-hour recalls and FRs need to be conducted repeatedly. The choice of dietary assessment methods depends e.g. on the aim of the study, which aspect of the diet that is of interest, and the individual/group under investigation. If the aim is to obtain a group mean intake of a population, one assessment day per participant using an FR or 24-hour recall is sufficient (5). However, the objective is often to assess the habitual and absolute intake of an individual during a specific time period. In those cases, an FFQ, a diet history interview, or repeated FRs or 24-hour recalls might be suitable. In addition, the number of participants and the available resources must be taken into account when selecting the appropriate method. The method of choice should preferably be standardized and validated in the study population prior to use.

### *Food frequency questionnaire*

An FFQ consists of a list of foods, and the respondent is asked to indicate with a checkmark how frequently the foods are consumed. Alternatives range from 'never' to 'more than once per day'. Food items are often grouped by the food category they belong to, but meal-based designs are also used. Some FFQs ask for portion size, for example, by including pictures of a plate with increasing amounts of food or by indicating the size of a serving beside the foods. When using such a semi-quantitative FFQ, it is possible to calculate energy and nutrient intakes and to rank participants according to these intakes.

The FFQ should suit the objectives of the study in terms of the foods/food groups and consumption frequencies included. Included foods should be commonly consumed in the population under study and should contribute to variation in the intake among the participants. If a certain micronutrient is of interest, it is only necessary to include those foods that contain the specific nutrient. FFQs can be short or extensive, and the number of food items have in a review been found to range from 5 to 350 (6). When the purpose is to assess the whole diet and total EI, the FFQ should be extensive enough to give detailed and comprehensive information about the diet. However, an overly extensive FFQ can be burdensome for the participants and possibly lead to careless completion and lower data quality. A short FFQ has the advantage of being easy for the participant to complete, but important information might be missed.

An FFQ is a method suitable for use in large studies because of its cost-effectiveness. It is easy to distribute and can be machine-read to simplify data handling. It is also less burdensome for the participants compared with other methods and usually takes only 15–30 minutes to complete. The main disadvantage is that all foods cannot be included in the FFQ, and it is, therefore, not possible for the participant to report their exact dietary intake. FFQs are not suitable, of course, for use in illiterate participants or young children without proxy reporters. FFQs are the most common dietary assessment method used in epidemiological studies with many participants in which the aim to assess habitual intake and to rank individuals according to intakes (7).

### *24-hour recall*

The 24-hour recall is a method to assess the dietary intake during the previous 24-hours, usually by interviewing the participant. The interview is often performed face-to-face or over the telephone, and the interest is most often in the exact foods and amounts consumed. The respondent is either asked to recall what was eaten the previous day chronologically or a multiple pass method is used (5). To estimate portion size, household measures can be used, or the participant can be provided with food photographs to aid in the estimation of amounts.

The greatest disadvantage with the 24-hour recall is that the respondent might not be able to correctly remember everything that was eaten on the previous day and in what quantities. Another disadvantage is the risk that the participant is affected by the interviewer to give socially desirable answers. When an individual's habitual intake is of interest, several recalls must be conducted, and this puts a higher burden on the respondent compared to using an FFQ. When successful, however, information about all the consumed foods and the exact amounts are obtained. Furthermore, it can be easier for the respondent to recall what was eaten during the previous day than to abstract their intake over several months to respond to an FFQ. The method is also suitable for use in illiterate participants when administered by an interviewer. The 24-hour recall has been used especially in dietary surveys (8).

### *Food record*

An FR aiming to assess the detailed dietary intake can be based on portion estimates or on portion weights. The method is prospective, and the participant records all foods and amounts consumed during the day together with cooking methods, brands, fat content, and other important details. The participant is often provided with a pre-printed form showing the details that should be recorded. When using an estimated FR, amounts and portion sizes are estimated using household measures or pictures of portion sizes. When using a weighed FR, all foods eaten are weighed before consumption. For mixed dishes, it is preferable that all ingredients are recorded separately. Similar to the 24-hour recall, the FR has the ability to give detailed information about the exact foods and amounts consumed. However, because of the high participant burden of recording all consumed foods, there is a risk that the intake will be altered to decrease the burden of recording the data. The assessment of consumed foods will then be correct but will not truly reflect the habitual dietary intake. Furthermore, social desirability can make the participant avoid eating or recording unhealthy foods, or the act of recording could make the participant change their diet simply by making them aware of their intake. An estimated FR is less burdensome for the participant than a weighed FR, but estimated amounts are less precise. An FR is often used for 1–7 days, but some have been used for up to 14 days (9). In the latest national dietary survey in Sweden, a four-day web-based FR was used (10).

***Technology in dietary assessment***

Technological developments have led to new possibilities in dietary assessments. It is now possible to use devices such as computers and mobile phones to assess dietary intake, and this might make it easier for researchers to distribute material related to the assessment and might make the method more user friendly for the participant provided that he or she is familiar with the technology (2). FFQs, 24-hour recalls, and FRs can be conducted with the help of computers, and computer-based 24-hour recalls have been developed and shown to be user friendly among adolescents (11). PDAs and smartphones have been used to conduct FRs in some countries, and these make it possible to send data of consumed foods to the researchers in real time (12, 13). By photographing all food before consumption and plate waste, the researchers are able to see what foods were consumed and in what amounts. For most photographic methods it is still necessary for the participant to note details about the foods that are not visible in the photographs. Methods using automated image analysis of food photographs from smartphones are under development, but have not yet been adapted for use in a Swedish setting (14-16).

The development of new methods of dietary assessment using technology is on-going. An example is the portable device developed by Sun et al. that is worn around the neck and contains a small camera and microphone that objectively records food intake (17). Another example is the algorithm developed by Lacson and Long to automatically identify consumed foods and amounts in a spoken FR (18).

It is important that newly developed methods are available and validated for use in different areas, using different languages and country specific nutrition calculation databases. In Sweden, for example, there are still no published studies that have evaluated dietary assessment methods using smartphones.

## Dietary assessment in different groups

Depending on the group under investigation, different approaches to dietary assessment might be needed. Dietary assessment can be especially challenging in some groups in the general population, for example, in children, adolescents, and young women. Children require different assessment methods than adults. For young children (up to 8 years) proxy respondents should be used, e.g. parents or other care providers who report the child's intake. However, parents usually only have second-hand information about the child's dietary intake at pre-school or at school, and this makes it difficult for them to accurately report the child's intake. For meals consumed at pre-school or school, intake can be reported by the staff or by the child itself, perhaps as early as from age 6 (19). From 8−10 years, children can probably report their intake as reliably as their parents (20), but they might still not have the ability to abstract their dietary intake in the way that is needed when responding to an FFQ or to a diet history interview. Literacy is also an issue when it comes to having children complete an FR.

It has been suggested that adolescents are less accurate reporters than younger children and adults due to irregular eating habits, more meals consumed away from home, and rebellion against authority (20). This creates extra challenges for dietary assessment among adolescents and suggests that dietary assessment methods need to be specially adapted for use in this group. It is also likely that extra efforts are needed to recruit study participants and to keep them from dropping out because adolescents might be less motivated to participate in dietary studies.

Furthermore, whether participants are male or female could be important. Young women are possibly more weight conscious than young men, and this could lead to restrained eating or higher underreporting of dietary intake in this group. If female participants are pregnant, this needs to be taken into account when assessing their diet because they are in a positive energy balance. Dietary intake of other specific groups, e.g. hospital patients or athletes, might also be extra challenging to assess, but such challenges are not the topic of this thesis.

## Accuracy of assessed dietary intake

### *Reference methods to evaluate accuracy*

EI from dietary assessment methods can be validated absolutely in comparison with the doubly labelled water (DLW) method or other measures of total energy expenditure (TEE), or it can be validated relatively by comparing EI with data obtained from a different dietary assessment method. Assessment of a specific food or nutrient can be compared with biomarkers or to the results from another dietary assessment method. The methods used for evaluation of the dietary assessment methods in this thesis include both TEE from different sources and comparisons with other dietary assessment methods.

The rationale behind using TEE as a reference method in validation studies is that EI equals TEE if the individual is in energy balance and there is no change in the body's energy stores. The gold standard method to measure TEE is the DLW method (1). The DLW method is an accurate and reliable method to measure habitual TEE in free-living individuals over the course of 10–14 days. A dose of water loaded with the stable isotopes deuterium and oxygen-18 is given orally to the participant, and urine samples are collected during the following days and analysed using mass-spectrometry. Deuterium is eliminated from the body as water, and oxygen-18 as water and carbon dioxide. The difference between the elimination rates is thus a measure of the carbon dioxide production from which TEE can be calculated using standard equations (21).

Because the DLW method is expensive, other methods to measure TEE are sometimes used. Accelerometers are devices that measure the intensity of physical activity and can—together with age, gender, weight, and height—be used to calculate TEE. The SenseWear Armband (SWA) Pro 2 and Pro 3 are multisensory devices that are worn on the upper arm and measure activity with a 2-axis accelerometer and sensors for heat flux, near-body and skin temperature, and galvanic skin response (BodyMedia, Inc., Pittsburgh, PA, USA). The SWA is placed on the upper right arm over the triceps muscle and registers activity at 1-minute intervals. Because it is not waterproof, the SWA has to be removed before showering or swimming. An advantage with the SWA and other accelerometer-based methods is that physical activity and TEE can be measured for one or several days compared to the DLW method that measures the habitual TEE over a period of around 14 days. A disadvantage with accelerometers is that they are often not able to measure activity while bicycling and swimming.

A much less resource-demanding option to calculate TEE is to use basal metabolic rate (BMR) and physical activity level (PAL). The PAL value is a multiple of BMR reflecting the activity level during one or several days. If the assessed EI is accurate, PAL should equal the food intake level (FIL), which is the multiple of BMR reflecting EI. PAL can be obtained from various sources such as a physical activity questionnaire or diary. The Goldberg cut-off is a method to establish if the assessed EI is compatible with long-term energy balance and survival. It is expressed as a multiple of BMR and is 1.35 at the group level (22). When used on the individual level, and taking the assessment period into account, the cut-off will be lower due to within-subject variations in intakes. The Goldberg method is an option in large studies where other methods for identifying underreporters are lacking.

When validating assessed food and nutrient intake, it is common to use a second dietary assessment method as the reference for relative validity. The reference method should have independent errors, for example, both methods should not rely on the memory of the participant. One of the most common reference methods is the use of FRs over several days (5). However, when developing new versions of traditional assessment methods, it can be of interest to compare the new and traditional method to find out how the changes to the method affects accuracy. Errors in two dietary assessment methods used by the same participant are often dependent because they are related to the individual, and in these cases validation against an objective marker of nutritional status can be useful. Biomarkers exist for several nutrients, and markers of urinary nitrogen (for protein intake), sodium, and potassium are the most sensitive to dietary intakes (5). No biomarker has been available for sugar intake, but the carbon isotope ratio of alanine in red blood cells has recently emerged as a candidate marker that can possibly accurately reflect sugar intake (23). Sucrose and fructose in the urine is another marker for sugar intake that has recently begun to be used in studies (24, 25).

### *Validity in dietary assessment*

A valid dietary assessment method is one that measures what it intends to measure, i.e. it gives accurate results for the aspect of dietary intake under investigation during the specific time period of interest. That is, if the aim is to assess habitual intake, the method should be able to assess that, and not intakes that are true intakes but are altered due to the assessment. Therefore, a valid dietary assessment method must be free from bias (systematic error). There can be several reasons for bias in self-reported dietary intake. This can be due to reporting the incorrect type of food and/or portion size because of difficulties remembering or estimating exactly what was consumed. Omitting unhealthy foods or overreporting healthy foods can be a result of social desirability. Food composition tables or nutrition calculation databases can also be sources of bias. Most often, when the duplicate plate method (the laboratory analysis of a duplicate of the foods consumed) is not an option, a food database is used to calculate EI and nutrient intakes from dietary assessments (26). Because the foods in the database do not have the exact composition of nutrients as the foods consumed, this can lead to bias in the calculated intake data. Studies have shown that assessed dietary intakes often are misreported with underestimation occurring in adults across population groups and with all assessment methods (27). A literature review found that the greatest underestimation among children and adolescents was with FRs that only captured between 11% and 46% of the TEE (28).

Dietary intakes in individuals might vary considerably from day to day (29). Therefore, several days of assessment are needed for each participant when investigating the habitual and absolute intakes. The number of days needed depends on the nutrient under study and the required precision of the assessment (5). Furthermore, intakes often differ systematically by the day of the week, the season, and on holidays, and these differences must be taken into account when assessing dietary intake.

***Reliability in dietary assessment***

Reliability in dietary assessment concerns to what extent the obtained intakes are reproducible and free from random error. The differences in intake when the same method of assessment is used repeatedly should only consist of true variations in dietary intake. Sometimes the natural day-to-day variation is seen as random error because it has, to a large extent, the same effect on the results of dietary assessment as "real" random error (7). Reliability can be increased by increasing the number of assessments. For a method to be valid it is necessary that it is also reliable, but reliability does not guarantee validity. Reproducibility is evaluated by repeated use of the assessment method in the same individuals under the same conditions. Enough time must pass between the assessments so that the participant does not simply repeat the reported intake from the first assessment. However, the time between assessments should not be too long such that the participant might have changed dietary habits, e.g. because of seasonal changes. To minimize the risk for random errors, care must be taken to use standardized procedures and perform quality checks of the assessments.

In children and adolescents who are still growing, EI will be different depending on age. This means that reproducibility of a method in these groups cannot be evaluated by comparing intakes from the first assessment to the next. An alternative approach is to compare the validity between the assessments, i.e. to determine to what extent possible misreporting of intakes are the same over time. This is the approach that was taken in paper III in this thesis.

Statistical methods exist that can be used to correct the intake data used in dietary studies. The statistical procedure used depends on the aim of the study and the dietary data collected. For example, different statistical approaches exist to estimate the habitual dietary intake of a population when one 24-hour recall is used for each participant (30, 31). Such approaches can be more efficient than the repeated assessment of the participants' daily dietary intake.

### *Factors influencing reporting accuracy*

Several individual factors have been associated with the misreporting of dietary intake, and these can be categorized as anthropometric factors (e.g., body mass index (BMI) and weight status), socio-demographic factors (e.g., gender, age, and education level), or psychological factors (e.g., restrained eating and a desire to lose weight) (28). Other health behaviours have also been associated with reporting accuracy (4), and the most consistent finding is a higher degree of underreporting of EI among obese individuals compared with normal-weight individuals (27). An increased underestimation with increased BMI has also been found among overweight and obese children (32). The factors associated with misreporting could possibly differ between children and adults and between males and females.

## Dietary sugars

### *Types of sugars*

Sugars are glycaemic carbohydrates consisting of one or two monomers. The sugars most commonly found in the diet are glucose and fructose (mono-saccharides) and sucrose and lactose (disaccharides). Glucose and fructose occur naturally in fruits and berries, and lactose is found exclusively in dairy products. Sucrose is most often added to foods as a sweetener, but it also occurs in fruits and berries in small amounts. Sometimes glucose and/or fructose syrup is used in confectionary instead of sucrose. Sugar can be categorized and defined in various ways, e.g. as "added" or "free" sugars. Added or refined sugars are sugars added to foods during preparation or by manufacturers (33, 34). Free sugars include the added sugars plus sugars naturally occurring in honey, syrups, and fruit juices (3). The term "extrinsic sugar" is sometimes used for sugars that are free in foods, and the term "intrinsic sugar" is sometimes used for sugars that are naturally occurring in the structure of foods.

***Recommendations***

The WHO recommends no more than 10 E% of added sugars in the diet (3). There is no common recommendation for the European countries (34): however, some European countries have recommendations in line with the WHO recommendation. In the Nordic countries and the UK, it is recommended that intake of added sugars and non-milk extrinsic sugars should be kept below 10 E% (33, 35).

***Intakes in children and adolescents***

The nutrition calculation database from the Swedish National Food Agency lacks information about added sugars, and it is, therefore, difficult to obtain data on sugar intake in Sweden in relation to the recommended intake. In a national survey of children's dietary intake, 18%–22% of energy came from sucrose and monosaccharides, and it was estimated that 13 E%−14 E% was from added sugars (36). In a recent dietary survey in the UK, intake of non-milk intrinsic sugars was 15 E% in 4–10-year-olds and 16 E% in 11–18-year-olds (37). In a study among US adolescents based on national survey data, it was estimated that intake of added sugar was 21 E% (38). Sugar intake in children has been shown to be higher on weekends compared to weekdays. For example, one study showed that sucrose intake in Swedish pre-school children was 11 E% on weekdays and 16 E% on weekends (39). In Danish 4–14-year-old children, intake of sugar-sweetened beverages was higher on weekends compared to weekdays, and this contributed to a higher E% of added sugar on weekends (40). The same difference was not found in a study among overweight US children, where intake of sugar-sweetened beverages was lower on weekends compared to weekdays (41). In Sweden and Denmark, children's intake of sugar on Fridays was also found to be high (40, 42).

***Risks of high intakes***

Several adverse health effects have been associated with a high sugar intake. High sugar consumption will reduce the nutrient density of the diet when foods rich in sugar but low in other nutrients make up a substantial part of the dietary intake (43). There is clear evidence for a link between sugar intake, especially sucrose, and dental caries (44). One study showed a linear relationship between caries and sugar intake from 0-10 E%, and concluded that sugar intake should ideally be limited to no more than 3 E% of the diet (45). High intake of sugar and sugar-sweetened beverages has been identified as a risk factor for overweight and obesity as well as for the development of diabetes type 2 (46-48), although the findings in this regard remain controversial (49). Furthermore, high intake of added sugars is associated with risk factors for cardiovascular disease (38), and childhood obesity is a risk factor for diabetes type 2, hypertension, and coronary heart disease in adulthood (50).

# Aims

The overall aim of this thesis was to develop, implement, and evaluate dietary assessment methods using new approaches and technologies in young populations, as well as to investigate variables that are important for the reporting accuracy. Another aim was to investigate day-of-the-week effects on assessed sugar intake and EI.

The specific aims were:

- To validate the EI assessed with a short dietary questionnaire (SDQ) in pregnant and non-pregnant women with different weight statuses, and to compare the assessed nutrient and food intakes with a more extensive FFQ (Study I).
- To evaluate the validity and reproducibility of a digital camera FR to assess EI in overweight and obese children (Study III).
- To develop, implement, and evaluate a smartphone application to assess EI and TEE in adolescents, and to compare assessed nutrient and food intakes with a web-based FR (Study IV).
- To investigate variables associated with reporting accuracy in children, adolescents, and young women (Studies I, III and IV).
- To compare sugar intake and EI between weekdays (Monday through Thursday), Fridays, and weekends in children and adolescents (Studies II, III and IV).

# Methods and results

This thesis consists of data from four different studies (Table 1). The four studies are described under their own headings together with the methods used in each study and the results of the studies. Development of the dietary assessment method and the data collection for study IV were conducted within the doctoral studies.

**Table 1.** Overview of the papers included in the thesis.

| | Study/Paper I | Study/Paper II | Study/Paper III | Study/Paper IV |
|---|---|---|---|---|
| Name of study | LifeGene pre-pilot | IDEFICS[1] | SELFH[2] | |
| Design | Cross-sectional (baseline 2008–2009) | Cross-sectional (baseline 2007–2008) | Repeated cross-sectional (2007–2009) | Cross-sectional (2013) |
| Geographical area | Västerbotten, Sweden | Survey centres in eight European countries | Västerbotten, Sweden | Västra Götaland, Sweden |
| Participants | Women, 18–35 years old, n = 90 | Children, 2–9 years old, n = 9497 | Children, 8–12 years old, n = 73 | Adolescents, 14–16 years old, n = 81 |
| Dietary assessment method | A food frequency questionnaire "Short Dietary Questionnaire" (SDQ) | Computer-based 24-hour recall completed by parents | Repeated food records with a digital camera | Food record with a smartphone application |
| Reference method | Doubly labelled water<br><br>A more extensive food frequency questionnaire | | SenseWear Armband | SenseWear Armband<br><br>A web-based food record |
| Nutritional focus | Energy intake, macronutrients, Ca, Fe, Se, Zn, food groups | Energy intake, total sugars, foods and drinks rich in added sugar | Energy intake | Energy intake, nutrients and food groups |
| Additional methods used | Weight, height | Weight, height, parental questionnaire | Weight, height | Weight, height, questionnaire |

[1]Identification and prevention of Dietary - and lifestyle - induced health EFfects In Children and infantS. The eight European countries that participated in IDEFICS were Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, and Sweden.
[2]Studies of the Effect of Lifestyle and Food Habits – overweight children's health

## Study I: Validation of the SDQ in women participating in the pre-pilot project for the Swedish LifeGene Study

The pre-pilot project for the Swedish LifeGene Study (51) was conducted in Västerbotten County, in the north-east of Sweden, in 2008–2009. One of the aims of the study was to test measurement instruments that can be used for dietary assessments in pregnant and non-pregnant young women.

### *Methods*

The SDQ was developed with the goal of being short and easy for participants to complete, but still able to capture a majority of the dietary intake and to be used to calculate EI and the intake of calcium, iron, zinc, and selenium. Calcium is important at young ages when bone formation peaks, and iron and selenium intakes have been shown to be lower than recommended in young women participating in a national dietary survey (52). Therefore, food items for the SDQ were selected that had been shown to contribute to a majority of the EI and to the calcium, iron, and selenium intake in the national survey. The selected foods were also shown to capture a majority of the zinc intake. The SDQ asks about the intake during the previous three months and includes 39 foods/food groups/dishes as well as the intake of dietary supplements. The SDQ determines intake as the amounts consumed per day, week, or month, e.g., the number slices of bread consumed per day or week. It also includes questions about the proportions of different types of foods consumed, e.g., what per cent of bread consumption was white, whole meal, or crisp bread. Energy and nutrient contents were aggregated for several representative foods to obtain average values for each of the included items. Portion sizes were obtained by weighing several food items and dishes and from the weight tables provided by the National Food Agency (53). Portion size pictures were included with seven different options for foods such as meat or meat dishes, vegetables, and rice. Energy and nutrient contents were calculated using the nutrition calculation program Dietist XP version 3.1 (Kost och Näringsdata AB, Bromma, Sweden), which uses the Swedish food database (version 2009-05-19). The SDQ is published as supplementary material to Paper I.

Normal-weight and overweight/obese pregnant women born in 1973–1988 were recruited to the LifeGene pre-pilot study with the help of midwives, and normal-weight and overweight/obese non-pregnant women who planned to become pregnant in the future were recruited by advertisements in local media and by word of mouth. Pregnant and non-pregnant women were matched according to age, education level, income level, and region of residence. Exclusion criteria were recent cardiovascular events, recent physically debilitating surgical procedures, unmanaged serious psychiatric disorders, dependency on illicit drugs, or the inability to commit fully to the study protocol.

The LifeGene pre-pilot study aimed to recruit at least 100 women based on sample size calculations, evenly distributed by weight and pregnancy status. Due to difficulties in recruiting obese (BMI ≥30 kg/m$^2$) pregnant women, 35 pregnant women, of whom five were overweight/obese, and 73 non-pregnant women, of whom 35 were overweight/obese, were recruited. Exclusions were made because of non-completion of methods, missing data, or vegetarian diet. Furthermore, three overweight/obese pregnant women were excluded because this group was too small for separate analysis. In total, 65 non-pregnant women, of whom 31 were overweight/obese (BMI ≥25 kg/m$^2$), and 25 pregnant normal-weight (BMI <25 kg/m$^2$) women completed the protocol.

The SDQ was completed at a visit to the Clinical Research Center at Umeå University Hospital. A 66-item FFQ previously used in a large epidemiological study (54) was completed at home after a 10-day DLW measurement period. The FFQ had nine consumption frequencies ranging from 'never' to '4 or more times per day'. Portion size pictures were included for potatoes, rice and pasta, meat and fish, and vegetables. Other portion sizes were natural portion sizes or age- and gender-specific portion sizes obtained from 24-hour recalls in the same general population to which the participants in the present study belonged (53, 55). Energy and nutrient contents were calculated with the computer program StorMATs (Rudans Lättdata, Västerås, Sweden), which used the Swedish food database version 1994 for macronutrients and version 2009 for micronutrients. An 84-item version of the FFQ had been relatively validated against 24-hour recalls in the same general population as the LifeGene pre-pilot study and showed good reproducibility and acceptable validity (56). The FFQ assessed intakes 12 months back (before and during pregnancy), and was, therefore, not used in the analysis of the pregnant women. The SDQ assessed intakes during the previous 3 months (only during pregnancy) and was included in the analysis of the pregnant women. Dietary supplements assessed with the SDQ and FFQ were not comparable and, therefore, were not included in the analysis.

Statistical data analysis was performed in IBM SPSS Statistics version 20 (Armonk, NY, USA), and $P$-values ≤ 0.05 were considered significant. The Bland-Altman method was used to determine the accuracy of the assessed EI compared with the TEE from the DLW measurement. Spearman correlation coefficients were calculated between assessed EI and the TEE from the DLW measurement and for nutrients and food groups between the SDQ and FFQ. Ranking of nutrients and food groups with the SDQ and FFQ were further investigated using cross-classification in quartiles (for the thesis). Differences in EI and TEE and in nutrients and food groups with the SDQ and FFQ were analysed using the Wilcoxon signed-rank test. Analyses were performed for all women together or according to weight and pregnancy status. Differences between the normal-weight and overweight/obese women in terms of the accuracy of assessed EI was analysed with the Mann–Whitney *U*-test.

The study was approved by the Regional Ethical Review Board in Umeå, Sweden.

### *Results*

The characteristics, EI, and TEE of the participants are presented in Table 1, Paper I.

In all non-pregnant women, the median underestimation on the group level with the SDQ (n = 65) was 30% of TEE ($P < 0.001$), and with the FFQ (n = 61) it was 34% of TEE ($P < 0.001$) (Table 1, Paper I).

The median underestimation of EI assessed with the SDQ was 22% of TEE ($P < 0.001$) in normal-weight non-pregnant women and 43% of TEE ($P < 0.001$) in overweight/obese non-pregnant women (Table 1, Paper I). The median underestimation of EI with the FFQ was 29% of TEE ($P < 0.001$) in the normal-weight non-pregnant women and 46% of TEE ($P < 0.001$) in the overweight/obese non-pregnant women. The difference between the groups was statistically significant for both the SDQ ($P = 0.02$) and the FFQ ($P = 0.001$). The correlation between EI and TEE was only significant with the SDQ in the overweight/obese women (Table 1, Paper I).

In the normal-weight pregnant women, the median underestimation of EI with the SDQ was 20.5% of TEE ($P = 0.002$) (Table 1, Paper I). The correlation between EI from the SDQ and TEE was not statistically significant.

The mean differences and the limits of agreement (±1.96 SD) for EI from the questionnaires and TEE categorized by pregnancy and weight status, are presented in Table 2.

Median intakes of protein, carbohydrate, calcium, selenium, and zinc in non-pregnant women were significantly higher when assessed with the SDQ than the FFQ both for crude intakes and intakes/MJ (Table 2, Paper I). Median intakes of fat and iron were significantly higher when assessed with the FFQ than the SDQ. For food groups, the intakes of 15 out of 26 groups were significantly higher when assessed with the SDQ, and 9 were not significantly different between the methods (Table 3, Paper I). The food groups of milk/sour milk/yoghurt with 3% fat and chips and other snacks were significantly higher when assessed with the FFQ. Spearman correlations were statistically significant for all nutrients and foods when comparing the SDQ and FFQ (Table 3). Cross-classification showed that 33%–49% of nutrient intakes and 26%–62% of food group intakes were classified in the same quartile with the SDQ and the FFQ. From 2% to 10% (1–6 individuals) for nutrients and from 0% to 10% for food groups were classified in opposite quartiles (Table 3).

**Table 2.** Results of Bland-Altman analysis of energy intake (EI) as assessed with a short dietary questionnaire (SDQ) and a more extensive food frequency questionnaire (FFQ) compared with total energy expenditure (TEE) measured with the doubly labelled water method.

| | **Bland-Altman method** | |
|---|---|---|
| | **Mean difference, kJ [95% CI[1]]** | **Limits of agreement, kJ** |
| *All non-pregnant women (n = 65)* | | |
| $EI_{SDQ}$ - TEE | -3434 [-4060, -2809] | -8383, 1515 |
| $EI_{FFQ}$ - TEE[2] | -4043 [-4710, -3377] | -9145, 1059 |
| $EI_{SDQ}$ - $EI_{FFQ}$[2] | 487 [-56, 1030] | -4640, 3666 |
| *Non-pregnant, normal-weight women (n = 34)* | | |
| $EI_{SDQ}$ - TEE | -2601 [-3431, -1770] | -7267, 2065 |
| $EI_{FFQ}$ - TEE[2] | -2924 [-3776, -2072] | -7477, 1629 |
| $EI_{SDQ}$ - $EI_{FFQ}$[2] | 165 [-564, 893] | -3728, 4058 |
| *Non-pregnant overweight/obese women (n = 31)* | | |
| $EI_{SDQ}$ - TEE | -4348 [-5225, -3471] | -9032, 336 |
| $EI_{FFQ}$ - TEE[2] | -5200 [-6092, -4308] | -9884, 516 |
| $EI_{SDQ}$ - $EI_{FFQ}$[2] | 820 [-14, 1653] | -3556, 5196 |
| *Pregnant normal-weight women (n = 25)* | | |
| $EI_{SDQ}$ - TEE | -2415 [-3775, -1054] | -8873, 4043 |

[1]Confidence interval from the one-sample *t*-test.

[2]In the analysis of the FFQ, the sample consisted of 31 normal-weight non-pregnant women and 30 overweight/obese non-pregnant women.

**Table 3.** Spearman correlations between nutrients and food groups assessed with a short dietary questionnaire and those assessed with a more extensive food frequency questionnaire in 61 non-pregnant women, and the percentage in the same, adjacent, and opposite quartiles.

| | Spearman correlation [95% CI] | Same quartile % | Adjacent quartile % | Opposite quartile % |
|---|---|---|---|---|
| *Nutrients* | | | | |
| Fat | 0.54 [0.33, 0.70] | 49.2 | 27.9 | 1.6 |
| Protein | 0.46 [0.24, 0.64] | 42.6 | 32.8 | 3.3 |
| Carbohydrates | 0.47 [0.25, 0.65] | 37.7 | 39.3 | 3.3 |
| Calcium | 0.37 [0.13, 0.57] | 39.3 | 42.6 | 9.8 |
| Iron | 0.52 [0.31, 0.68] | 36.1 | 44.3 | 1.6 |
| Selenium | 0.52 [0.31, 0.68] | 42.6 | 39.3 | 3.3 |
| Zinc | 0.41 [0.18, 0.60] | 32.8 | 41.0 | 4.9 |
| *Food groups* | | | | |
| Bread | 0.58 [0.39, 0.73] | 36.1 | 49.2 | 3.3 |
| Butter/margarine on bread, 40% fat[2] | 0.53 [0.32, 0.69] | 55.7 | 31.1 | 13.1 |
| Butter/margarine on bread, 60%–80% fat[2] | 0.69 [0.53, 0.80] | 63.9 | 31.1 | 4.9 |
| Cheese, 17% fat[2] | 0.63 [0.45, 0.76] | 60.7 | 29.5 | 9.8 |
| Cheese, 28% fat | 0.74 [0.60, 0.84] | 57.3 | 34.4 | 3.3 |
| Milk/sour milk/yoghurt, 0.5% fat | 0.70 [0.55, 0.81] | 59.0 | 27.9 | 3.3 |
| Milk/sour milk/yoghurt, 1%–1.5% fat[2] | 0.62 [0.44, 0.75] | 54.1 | 39.3 | 6.6 |
| Milk/sour milk/yoghurt, 3% fat[3] | 0.28 [0.03, 0.50] | – | – | – |
| Boiled potatoes | 0.60 [0.41, 0.74] | 37.7 | 41.0 | 0 |
| Fried potatoes/pommes frites[3] | 0.59 [0.40, 0.73] | – | – | – |
| Vegetables | 0.58 [0.39, 0.73] | 47.5 | 34.4 | 3.3 |
| Fruits and berries | 0.67 [0.50, 0.79] | 54.1 | 29.5 | 1.6 |
| Meat | 0.50 [0.28, 0.67] | 44.3 | 32.8 | 4.9 |
| Fish | 0.53 [0.32, 0.69] | 42.6 | 34.4 | 1.6 |
| Poultry | 0.70 [0.55, 0.81] | 39.3 | 50.8 | 3.3 |
| Pasta | 0.51 [0.30, 0.68] | 47.5 | 29.5 | 9.8 |
| Rice | 0.60 [0.41, 0.74] | 37.7 | 45.9 | 0 |
| Cream/crème fraiche | 0.64 [0.46, 0.77] | 42.6 | 47.4 | 0 |
| Biscuits/cookies/ buns/cake | 0.81 [0.70, 0.88] | 59.0 | 34.4 | 0 |
| Chocolate and sweets | 0.56 [0.36, 0.71] | 26.2 | 59.0 | 1.6 |
| Chips and other snacks[3] | 0.47 [0.25, 0.65] | – | – | – |
| Ice cream | 0.55 [0.35, 0.70] | 49.2 | 39.3 | 0 |
| Juice/syrup/soft drinks | 0.67 [0.50, 0.79] | 62.3 | 19.7 | 4.9 |
| Beer[4] | 0.48 [0.26, 0.65] | 34.4 | 45.9 | 8.2 |
| Wine[3] | 0.72 [0.57, 0.82] | – | – | – |
| Spirits[3] | 0.67 [0.50, 0.79] | – | – | – |

[1]Confidence interval.

[2]Tertiles.

[3]Cut-off points could not be made because of granularity in the data.

[4]n = 58 who reported to consume alcohol.

## Study II: Sugar intake on weekdays versus weekends in children participating in the IDEFICS study

The Identification and prevention of Dietary - and lifestyle - induced health EFfects In Children and infantS (IDEFICS) study was conducted from 2007/2008 (baseline) to 2012 with the aim of describing the effects of environment, diet, and other lifestyle factors on children's health and to develop, implement, and evaluate a community-based primary intervention program to reduce diet and lifestyle-induced disorders with a focus on overweight and obesity (57).

### *Methods*

A computer-based 24-hour recall—the Self-Administered Children and Infant Nutrition Assessment (SACINA)—was developed from the Young Adolescents' Nutrition Assessment on Computer System that had been developed and used in the Healthy Lifestyle in Europe by Nutrition in Adolescence study (58). SACINA assesses food and nutrient intake, EI, portion size, food groups, and the contributions of foods and drinks to EI and nutrient intake during the day of assessment (59). SACINA is structured chronologically around six meal occasions and asks for additional information about the child's day, for example, the time they wake up in the morning and time they spend at pre-school or school. Foods are selected from categories in a hierarchical structure, and foods not included in SACINA can be added. Portion size is reported by selecting from given alternatives suited to the different foods or by entering a known exact amount. Many foods have portion size pictures with increasing amounts to help estimate the consumed amount (Figure 2). By pressing the button 'more' or 'less', a picture with more or less of the food is shown on the screen and the correct portion size can be chosen. Each of the eight countries participating in IDEFICS had their own version of SACINA with foods and portion size pictures common for the respective country. Foods and portion sizes were adapted to suit children, and a beta version of the program was pre-tested in each of the participating countries prior to use in the study and missing foods were added to the list. The final Swedish version of SACINA included 1805 different foods and 165 portion size pictures. The countries used their national food composition tables for calculation of EI and nutrient intakes except Hungary, which used the German food composition table. Intakes were categorized into 110 food groups common for all countries. The food composition tables did not allow for separate calculation of added sugars, so only total sugars (all mono- and disaccharides) were presented in the present study. A second variable representing sugar intake was foods and drinks rich in added sugars. This variable included four sub-groups of foods: cereal-based, dairy-based and sugar-based foods rich in added sugars, and sugar-sweetened drinks.

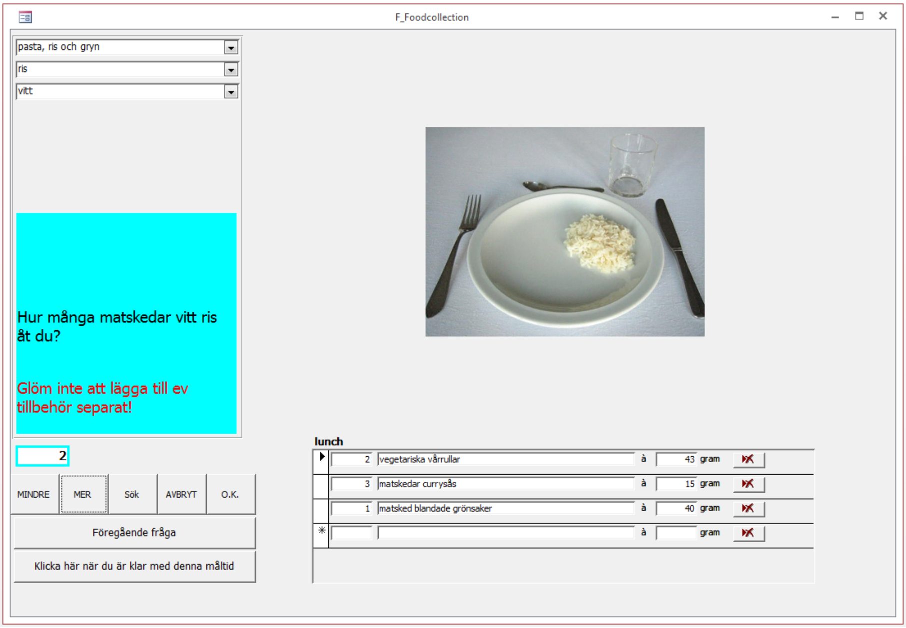


**Figure 2.** Screenshot of the Swedish version of the Self-Administered Children and Infant Nutrition Assessment (SACINA), a computerized 24-hour recall.

Children from Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, and Sweden participated in the IDEFICS study. Survey centres in the participating countries recruited children aged 2–9 years from pre-schools and schools (years 1 and 2) in their respective areas with the aim of including children of varying socioeconomic backgrounds. Thus, the samples were not nationally representative. All children in the selected pre-schools and schools were invited to participate in the study. Of 31,543 invited children, 16,220 participated, and 9497 had at least one day of acceptable 24-hour recall diet data from baseline for inclusion in the present analysis.

During the baseline survey in 2007/2008, 24-hour recalls were completed by proxies (most often parents) of the children at the survey centre or in their homes with the help of a dietician or trained personnel. School meal assessments were conducted for children who ate meals in pre-school or school. This added complications to the data collection in countries such as Sweden where some children in addition to lunch also had breakfast and snacks at pre-school or school. All meals were observed, and foods and drinks were entered into a standardized template by trained staff, teachers, or assistants. Dietary information from the parental and school meal-based parts of SACINA were merged to yield a full-day record. Most children had one day of dietary data, and a subgroup contributed with more than one day of data.

The dietary assessment with SACINA has been validated using adapted Goldberg cut-offs in 6101 of the children participating in the IDEFICS study who had complete information about covariates (60). Results of the validation study showed that 89% of the reports were plausible. Furthermore, several factors were identified that were associated with increased risk of being classified as underestimating EI. Among these factors were increased age and BMI-z of the child, larger household size, belonging to the low-medium income group, male proxy reporter, and the proxy perceiving the child as overweight. Those classified as underestimating EI also had the lowest reported intake of sugary foods.

Data analysis was performed in IBM SPSS Statistics version 20 (Armonk, NY, USA), and $P$-values < 0.05 were considered significant. One 24-hour recall per child was included in the analysis. Because Fridays are structurally similar to both weekdays (during school-time) and weekends (after school), they were analysed separately. The school-based design of IDEFICS did not allow for 24-hour recalls on Fridays and Saturdays without making home visits; therefore, a smaller number of these days were represented in the data. Two different selections of days were made so as to include as many Fridays and Saturdays as possible for children who had more than one recall each. The first selection excluded Fridays and aimed to include as many Saturdays as possible. In this selection, 9340 children were included for comparison of weekdays (Monday−Thursday) and weekends (Saturday−Sunday). In the other selection, as many Fridays as possible were selected and all 9497 children were included for comparison between Fridays and weekdays or between Fridays and weekends. General linear models were performed with the dependent variables of total sugars, foods and drinks rich in added sugar, and EI. The models with the dependent variable EI were adjusted for age, gender, and country, and the models with the dependent variables total sugars and foods and drinks rich in added sugar were additionally adjusted for EI. Models were tested for interactions by country and age group. The age groups were divided into pre-school children aged 2–5 years and school children aged 6−9 years. Not all countries were analysed separately due to a lack of dietary data for Fridays or weekends. A Bonferroni correction was applied in the models comparing Fridays with weekdays or weekends to take into account the multiple testing.

Ethical approval was obtained from each country’s responsible authority.

### *Results*

The characteristics of the children along with their EIs and sugar intakes are presented in Table 1, Paper II. The intake of total sugars was 97 ±48 grams/day, or 26 ±10 E%. The intake of total sugars ranged from 77 grams/day (19 E%) in Estonia to 114 grams/day (30 E%) in Germany. The intake of foods and drinks rich in added sugar was 308 ±295 grams/day. The intake of foods and drinks rich in added sugar ranged from 99 grams/day in Cyprus to 430 grams/day in Germany.

In the weekday (Monday–Thursday) vs. weekend analysis (n = 9340), the adjusted intake of total sugars was 92 grams/day on weekdays and 99 grams/day on weekends ($P < 0.001$) (Figure 2A, Paper II). For foods and drinks rich in added sugars, the intake was 261 grams/day on weekdays and 307 grams/day on weekends ($P < 0.001$) (Figure 2B, Paper II). In the Friday analysis (n = 9497), the intake of total sugars was 96 grams/day, and the intake of foods and drinks rich in added sugar was 271 grams/day. The intake of total sugars on Fridays was similar to that on weekends and was significantly different from the intake on weekdays ($P = 0.009$) (Figure 3A, Paper II). The intake of foods and drinks rich in added sugar on Fridays was similar to that on weekdays and significantly lower compared to the intake on weekends ($P = 0.02$) (Figure 3B, Paper II). The EI was 6389 ±2105 kJ/day and did not differ when comparing weekdays to weekends (results not shown). The results varied by country and age group of the child (pre-school or school). The weekend effect on the intake of total sugars and foods and drinks rich in added sugar (n = 9340) was more pronounced in the pre-school children compared to the school children (Figures 2A and B, Paper II). Children in Belgium had a lower intake of total sugars on weekends (only Sundays) compared to weekdays ($P = 0.05$). Children in Spain had a higher EI on weekends (only Sundays) compared to weekdays ($P = 0.009$). Unadjusted intakes of total sugars, sub-groups of foods and drinks rich in added sugar, and EI on weekdays and weekends are displayed by country in Table 4.

**Table 4.** Crude intakes of energy, total sugars, and different groups of foods and drinks rich in added sugar per day in children from eight European countries participating in the IDEFICS study. The intakes are separated into weekdays (Monday through Thursday) and weekends (Saturday to Sunday). Intake of sugars could not be derived for the children in Cyprus because such data were not in the country's nutrition database.

| | Belgium | | Cyprus | | Estonia | | Germany | | Hungary | | Italy | | Spain | | Sweden | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Weekday n = 320 | Weekend n = 53 | Weekday n = 1020 | Weekend n = 129 | Weekday n = 718 | Weekend n = 10 | Weekday n = 1322 | Weekend n = 407 | Weekday n = 760 | Weekend n = 776 | Weekday n = 1473 | Weekend n = 503 | Weekday n = 465 | Weekend n = 159 | Weekday n = 900 | Weekend n = 325 |
| | *Mean (SD)* | | | | | | | | | | | | | | | |
| Energy, kJ/day | 5745 (1774) | 6061 (1943) | 5520 (1836) | 5191 (1631) | 7077 (2251) | 6186 (1291) | 6240 (2253) | 6242 (2125) | 6011 (2114) | 6090 (1987) | 7196 (2099) | 7173 (2375) | 6598 (1841) | 7211 (2207) | 6442 (1843) | 6109 (1887) |
| Energy, kcal/day | 1369 (423) | 1446 (464) | 1319 (439) | 1240 (390) | 1690 (538) | 1478 (308) | 1491 (538) | 1492 (508) | 1435 (505) | 1453 (474) | 1720 (502) | 1714 (568) | 1576 (440) | 1722 (527) | 1541 (434) | 1461 (451) |
| Sugars, g/day | 95 (45) | 90 (33) | – | – | 77 (36) | 82 (41) | 111 (56) | 112 (57) | 96 (50) | 111 (53) | 86 (38) | 93 (42) | 90 (30) | 97 (39) | 83 (34) | 89 (37) |
| | *Median (interquartile range)* | | | | | | | | | | | | | | | |
| Sugar-rich products, cereal-based, g/day | 30 (12–51) | 54 (13–105) | 14 (0–50) | 30 (0–58) | 25 (0–74) | 0 (0–94) | 6 (0–35) | 20 (0–60) | 5 (0–44) | 20 (0–60) | 35 (16–70) | 40 (20–100) | 31 (15–70) | 60 (23–107) | 0 (0–8) | 6 (0–60) |
| Sugar-rich products, dairy-based, g/day | 0 (0–200) | 0 (0–200) | 0 (0–65) | 0 (0–75) | 100 (0–204) | 0 (0–11) | 111 (0–225) | 70 (0–200) | 65 (0–200) | 115 (0–200) | 0 (0–0) | 0 (0–0) | 100 (0–200) | 110 (0–200) | 197 (0–350) | 35 (0–150) |
| Sugar-rich products, other, g/day | 16 (0–36) | 0 (0–29) | 0 (0–17) | 0 (0–20) | 18 (0–43) | 6 (0–24) | 20 (0–42) | 24 (0–52) | 6 (0–26) | 12 (0–33) | 10 (0–24) | 10 (0–24) | 15 (5–30) | 16 (10–40) | 0 (0–28) | 15 (0–53) |
| Sugar-rich drinks, g/day | 0 (0–15) | 0 (0–200) | 0 (0–0) | 0 (0–0) | 0 (0–0) | 0 (0–0) | 106 (0–350) | 150 (0–400) | 0 (0–265) | 200 (0–400) | 0 (0–50) | 0 (0–200) | 0 (0–0) | 0 (0–0) | 0 (0–0) | 0 (0–200) |
| All sugar-rich foods and drinks, g/day | 187 (59–335) | 265 (110–380) | 50 (15–143) | 74 (30–150) | 221 (97–373) | 47 (8–227) | 341 (150–601) | 363 (180–604) | 320 (150–545) | 419 (208–670) | 91 (44–220) | 167 (70–340) | 169 (100–265) | 250 (135–335) | 267 (107–446) | 235 (91–403) |

## Study III: Evaluation of a digital camera food record in children participating in the SELFH study

Studies of the Effect of Lifestyle and Food Habits – overweight children's health (SELFH) was a two-year randomized controlled intervention study commencing in 2006 in the city of Umeå, Sweden (61). The study focused on food and lifestyle habits and aimed to prevent negative health effects in overweight and obese children.

### *Methods*

The children participating in this study were 8–12 years old. Because children of this age often eat away from home, e.g. at school or at friends' homes, it was decided that the estimated FR used in the study would be conducted with the help of a digital camera so that the children would not have to carry a paper and pencil with them throughout the day. The photographs of the foods consumed during the day were used to complete an estimated paper and pencil FR in the evening. Photographs were taken of all consumed foods as well as any leftovers, and a measuring tape was placed beside the food to facilitate portion size estimation (Figure 3). The children were also provided with a booklet containing pictures of common foods with different portion sizes and known weights (62). The paper and pencil FR was a food diary with fields for all required information such as the time of the meal, the type of food, and other important information such as cooking method, brand name, fat content, etc. The parents helped the children fill in the food diary in the evening with help of the photographs, booklet, and standard household measures.

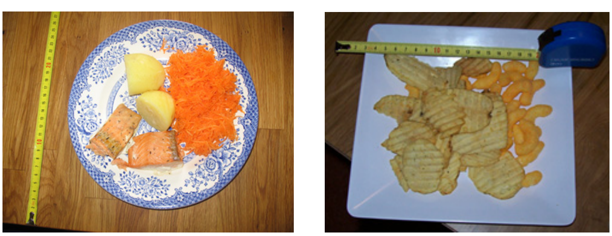

**Figure 3.** Examples of food photographs taken by participants in the SELFH study to aid in recording of dietary intake in the evening. Participants were asked to place a measuring tape beside the dish to facilitate the estimation of portion size.

A total of 105 eligible overweight and obese children were included in the SELFH study and randomized to either the intervention or control group. The same measurements were made in both groups regarding anthropometrics, dietary intake and physical activity. The children in the intervention group also participated in 15 group sessions and used a web-based platform aimed at improving their dietary habits and increasing their physical activity. Overweight and obesity were defined according to the International Obesity Task Force (IOTF) as an adult BMI of ≥25 kg/m$^2$ for overweight and ≥30 kg/m$^2$ for obesity (63). Twelve children dropped out before baseline measurements, and this left 93 children in the study. FR and SWA data from 73 children were used at inclusion. Of these, 57 children remained after 1 year and 54 remained after 2 years of the study. Girls and boys were equally represented in the sample. FR and TEE data were available for 73 children at the first assessment occasion and for 27 children at the seventh assessment occasion.

Children were recruited by sending letters to all families with children born in 1995−1998 and living in the municipalities of Umeå, Nordmaling, Vännäs, Robertsfors, and Bjurholm in Västerbotten County in northern Sweden. Inclusion criteria were being born in 1995−1998, living near the city of Umeå, having access to the Internet, and having no attention deficit disorder or diseases that affected the metabolic variables.

FRs were completed on seven occasions that were evenly distributed over the 2-year study period. Six occasions were 2-day records, and after 1 year a 4-day record was conducted. The FRs covered all seasons and included both weekdays and weekends. FRs with only one meal recorded per day were excluded as were FRs on days when the child had a stomach illness. On the same days as the FR, the children wore an SWA to measure TEE. The computer software InnerView Professional version 5.1 (BodyMedia, Inc., Pittsburgh, PA, USA) was used to estimate TEE from the SWA data together with the child's gender, age, weight, and height. A cut-off of 19 hours/day was used for the SWA data. The children's weight and height were measured by a research nurse at Umeå University Hospital. BMI and BMI-z were calculated based on three different reference populations (64-66), and BMR was calculated according to Dietz et al. (67).

The data were analysed using IBM SPSS Statistics version 19, and *P*-values ≤ 0.05 were considered significant. Seven children with no FR data on the first assessment occasion had data on the second occasion, and these were moved and regarded as the first assessment occasion so that the first assessment occasion was complete for all 73 children. The following assessment for these seven children were also moved, and the time between assessments remained unchanged. Spearman correlation was calculated for EI and TEE, and the difference between EI and TEE was analysed using the one-sample *t*-test. The accuracy of the assessed EI was illustrated with a Bland-Altman plot. A mixed model procedure was performed to investigate the reproducibility of the FR between the assessment occasions and the variables (gender, age, and BMI-z) that affected the reporting accuracy. The models were adjusted for the study group (intervention group or control group) and to account for weekend days in the FR, and the BMI-z from WHO reference values was used in the model (66). Reproducibility was defined as repeated validity in the growing children. The dependent variable was [(EI - TEE) / TEE] because the Bland-Altman plot showed that the reporting accuracy was dependent on the average energy values. A Bonferroni correction was applied to take into account the multiple testing. For the thesis, mixed model analysis was also performed for the dependent variables of total mono- and disaccharides, sucrose, and EI to investigate differences when a weekend day was included in the FR on all assessment occasions. Models for total mono- and disaccharides and sucrose were adjusted for study group, gender, age, and EI.

Ethical approval was obtained from the Regional Ethical Review Board in Umeå, Sweden.

***Results***

The characteristics of the children at inclusion and after 1 and 2 years of participation are presented in Table 1, Paper III.

Reporting accuracy is displayed in Figure 1, Paper III. At the first assessment occasion, children underestimated EI by 24% compared with TEE ($P < 0.001$) (Table 2, Paper III). The correlation between EI and TEE was borderline significant ($P = 0.051$) on the first assessment occasion. The photographic FR method was reproducible, i.e. no significant differences in reporting accuracy were found between the seven assessment occasions.

The difference between EI and BMR on the first assessment occasion is shown in Figure 4. In total, seven boys and nine girls had an assessed EI that was less than the calculated BMR. The mean assessed EI was 1513 kJ above the calculated BMR.

Mixed model analysis including all seven assessment occasions showed that EI relative to TEE was less underestimated in boys ($P = 0.03$) and in FRs that comprised a weekend day ($P = 0.05$) (Table 3, Paper III). Underestimation relative to TEE increased with BMI ($P < 0.001$) and age ($P = 0.004$). There was no effect of gender or having a weekend day in the FR when TEE was not adjusted for.

The median intake of total mono- and disaccharides was 120 ±62 grams/day, or 24 ±8 E%, at the first assessment occasion. The intake of sucrose was 50 ±40 grams/day, or 10 ±8 E%. For all seven assessment occasions taken together, the intake of sucrose was significantly higher when a weekend day was included in the FR ($P$ = 0.002), but no difference was found for total mono- and disaccharides or EI (results not shown). Descriptive statistics of the proportion of children with low, medium, and high E% intake of sucrose and total sugars in the FR with and without a weekend day included are presented in Table 5. Cut-offs were chosen after examining the data.

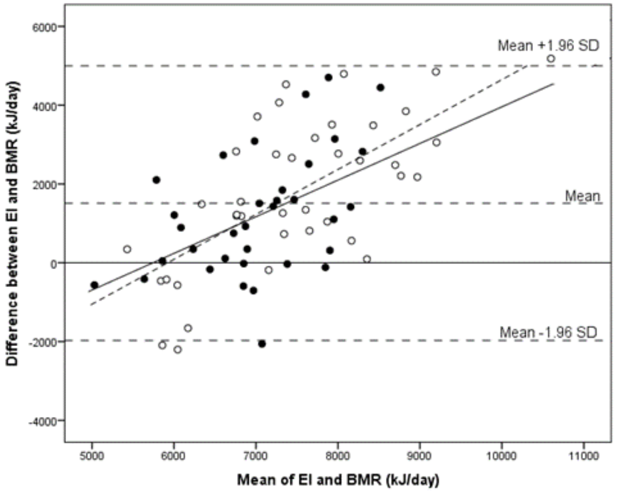


**Figure 4.** Difference between energy intake (EI) from digital camera food records and basal metabolic rate (BMR) plotted against the mean of the two variables in overweight and obese children (n = 73). Girls are displayed as ● and a solid regression line and boys are shown as ○ and a dashed regression line.

**Table 5.** Intake of total sugars (all mono- and disaccharides) and sucrose in children with and without a weekend day included in the food record.

| | **No weekend day in the food record** | **Weekend day in the food record** |
|---|---|---|
| | n (%) | n (%) |
| Total sugars, <20 E% | 13 (36) | 5 (13) |
| Total sugars, 20–29 E% | 19 (53) | 21 (57) |
| Total sugars, ≥30 E% | 4 (11) | 11 (30) |
| Total | 36 (100) | 37 (100) |
| | | |
| Sucrose, <10 E% | 22 (61) | 11 (30) |
| Sucrose, 10–15 E% | 13 (36) | 11 (30) |
| Sucrose, ≥16 E% | 1 (3) | 15 (40) |
| Total | 36 (100) | 37 (100) |

## Study IV: Development, implementation and evaluation of a smartphone application for dietary assessment in adolescents

The implementation and evaluation of a smartphone dietary assessment application was conducted among adolescents in Västra Götaland, Sweden, in 2013. The study aimed to investigate the accuracy and user friendliness of the smartphone application to assess dietary intake.

### *Methods*

The smartphone application was developed with the aim of providing a user-friendly alternative for adolescents to complete an FR. The method was developed by the author and main supervisor in collaboration with an engineering student in 2011/2012.

The users of the smartphone application register an account by entering their name, date of birth, gender, weight, height, e-mail address, telephone number, parents' highest completed education level, country of origin of the user and their parents, any special diet, a user name, and a password of one's own choice. Female users are asked whether they are pregnant or breastfeeding. The entered information can later be changed in the smartphone application. The entering of personal information in the application could in some instances replace the collection of background data through questionnaires or other data collection methods.

The smartphone FR assesses EI, the intake of nutrients and foods, portion sizes, and food groups. The information recorded in the FR consists of all foods and drinks consumed during the specific day. Dietary intake is recorded after a meal together with information about the date, time, and type of meal (breakfast, lunch, dinner, or snack). In the application, foods are selected from a database and can be free-text searched or chosen from hierarchical categories of food groups or types of dishes. The different search functions are provided to make it easier for the user to find the consumed food. Portion size is entered for each entered food item by selecting from suitable units, e.g. tablespoon or piece. Several food items have portion size pictures with increasing amounts and known weights to make it easier to estimate the consumed amounts.

At the end of the registration day, users enter the following information about their day that could aid in the interpretation of the recorded dietary data:

- Intake of dietary supplements
- Physical activity level

- How much of the dietary intake was recorded
- Whether dietary intake and physical activity were representative or if they ate more or less or were more or less physically active than usual
- Whether they had tried to gain or lose weight
- Whether they had felt stressed or anxious during the day

When all of the information has been entered, it is saved and sent to a central server where the data are stored and the EI and nutrient intakes are calculated. Users can view their recorded foods in an archive in the smartphone application, and they can add or delete foods and change amounts. They can also view and change the information about their day that was entered in the evening.

Through the archive, users can view feedback about their dietary intake (Figure 5). Feedback is presented in the form of pie charts, staple diagrams, and absolute intake numbers for EI, macronutrients, fruits and vegetables, dietary fibre, calcium, iron, vitamin C, vitamin D, and folic acid in relation to recommended intakes (33). They can also view information about their BMI and TEE from recorded physical activity level. The PAL values used in the smartphone application were adapted from Torun (68), and were different for girls and boys. BMR was calculated according to Henry (69). The feedback is provided to the user as an incentive to register their dietary intake and enter the information in the evening in the smartphone application, and can be viewed immediately after sending the data to the server.


**Figure 5.** Screenshots showing (A) the main page of the smartphone application, and (B) an example of the feedback for one assessment day.

Optional features have been developed to make the smartphone application more user friendly. One of these features is to receive reminders to record the dietary intake in the form of status bar notifications at a time interval of the user's choice. Another feature is the ability to take photographs. The user can photograph meals with the smartphone camera from the application, and the photographs can be stored and viewed later as a memory aid if dietary intake cannot be recorded at the time of consumption. The photographs can also be compared with portion size pictures to aid in the estimation of consumed amounts.

The smartphone application method includes the application, a web-server for downloading the application and for communicating with a Structured Query Language (SQL) server, and an SQL server for performing the calculations and storing the data (Figure 6). Tables of foods, food groups, dishes, energy and nutrient contents, and pictures and other alternatives for portion size estimation that had been used in a Swedish dietary survey were obtained from the National Food Agency. This ensure that the most complete and updated Swedish food composition table is used and that the results are comparable to those from the national dietary survey (10). The food composition database version 2010-05-05 includes over 1900 foods and dishes and was updated with recipes for common dishes prior to the national survey. Data recorded by users are stored on the SQL server and viewed using the FileMaker Pro 12 version 3 software package (FileMaker, Inc., Santa Clara, CA).

The application was developed for Android, mainly for practical reasons. Choosing between the two leading operating systems of Android and iOS, Android was chosen because it allows for the installation of applications from websites not approved by the company. Not having to share the application on Google play or App Store was an advantage in the study where only data from adolescents recruited to the study would be collected. Another possibility was to register the participants' telephone numbers to let them download the application without going through App Store. However, this was not considered a feasible option for the smartphone application evaluation study because the participants' should be able to download the application at the time that they were recruited to the study.

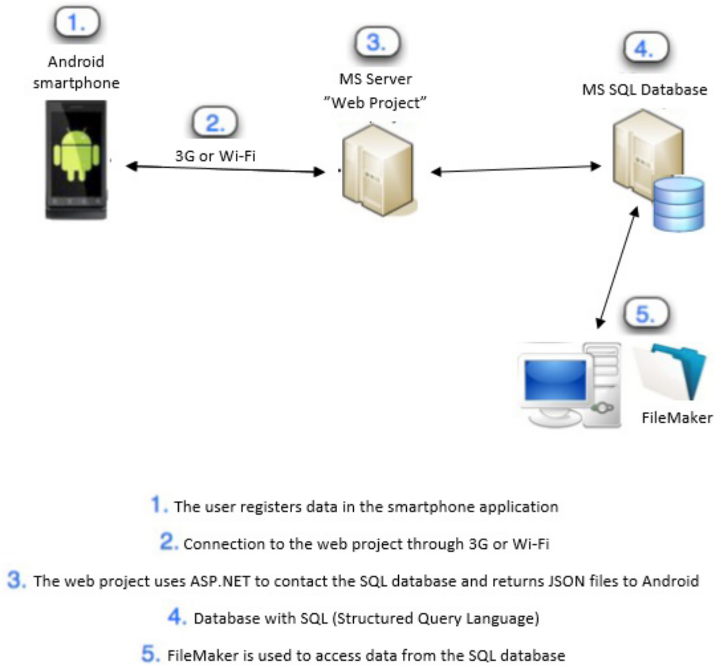


**Figure 6.** The transfer of information when using the smartphone application method.

A pilot test was conducted prior to the main evaluation study in order to test the methods and to practice the presentation and procedures of the study. Adolescents were recruited from one year 9 class outside Gothenburg in November 2012, and six adolescents—five girls and one boy—participated. The participants went through the same procedures as in the main study, and a group interview was conducted to find out what the participants thought of the study and of the user friendliness of the smartphone application. Some changes were made after the pilot test, including adaptions to the smartphone application.

For the main study, adolescents living in the city of Gothenburg—in the southwest part of Sweden—and in neighbouring municipalities were recruited to an evaluation study of the smartphone application method in 2013. Recruitment was from students in year 9 continuously throughout the year. Head teachers of 136 schools were contacted and asked to provide contact information for teachers who could be asked to assign class time for a presentation of the study and for recruitment of participants. Teachers were contacted with information about the aim and procedures of the study. In total, teachers in 12 schools and 28 school classes agreed to the presentation and recruitment to the study. Of the 12 schools, 5 were independent schools. The 12 schools were representative of the municipalities at large regarding the proportions of adolescents with foreign background (the adolescent and/or both parents having been born outside Sweden) and of having at least one parent with higher education beyond upper secondary school (70).

The author and an assistant visited the classes and presented the study. After the presentations, the study participants were measured for weight and height and filled in a questionnaire. They were provided with the application on their own smartphone or on a borrowed phone that came with a charger and a data traffic subscription. They were also provided with an SWA to wear on the same days that they completed the FR along with written instructions about the study and how to use the FR. The SWA was used as the reference method to be able to evaluate the EI from the smartphone application against the objectively measured TEE. Adolescents participating during the spring term were also provided with a portion size booklet, a notebook, login details and information on how to use a web-based FR method. The web-based method was the same as the one developed by the National Food Agency and used in the Swedish national dietary survey (10), which made it possible to evaluate the intake of nutrients and foods recorded in the smartphone application FR. Participants were asked to complete the smartphone application method on three consecutive days while wearing the SWA. Adolescents participating during the spring term also used the web-based FR on three days the week before or after using the smartphone application FR, while wearing the SWA. The days of the week were the same for both FRs and were decided beforehand and scheduled to cover weekdays as well as weekends. However, it was found that recording dietary intake with two different methods for a total of six days was too burdensome for the participants. Therefore, the web-based method was only used during the spring term.

The questionnaire used in the study included the following instruments and questions: the full Three Factor Eating Questionnaire (revised 18-item) (71), the Figure Rating Scale (72), five selected items from the brief Fear of Negative Evaluation Scale (73), seven selected items from the Marlow and Crown Social Desirability Scale (74), fifteen selected items measuring conscientiousness from the International Personality Item Pool (75), one question each about the frequency of breakfast consumption, the frequency of eating in the school canteen, whether participants thought what they eat is important, and whether they perceived the study to be comprehensible, manageable, and meaningful. The instruments and questions were selected because they have been found to influence reporting accuracy in previous research (4, 76) or were thought to possibly influence reporting accuracy.

According to sample size analysis [$N = 2 \times (2.8 \times SD/Difference)^2$], 50 girls and 64 boys were needed to find an 837 kJ (200 kcal) difference between EI from the smartphone application FR and TEE from the SWA at an alpha of 0.05 and a power of 80%. The SD was obtained from a previous study of 15-year-old girls and boys in Gothenburg (77). In total, 85 girls and 63 boys were recruited to the smartphone application evaluation study. Of these, 50 girls and 31 boys provided data for EI and TEE that could be used in the analysis. The initial plan was to collect data to evaluate the smartphone application during the course of one school term. However, because of a low participation rate and a low rate of completion of the methods, it was decided to continue the data collection for another term to obtain a higher number of adolescents who had completed the methods. Many participants had iPhones and, therefore, needed to borrow an Android smartphone, which was provided to those participating in the study. Of the 81 participants included in the main analysis, 72 borrowed a smartphone and 9 used their own.

Data analysis was performed in IBM SPSS Statistics version 21, and *P*-values ≤ 0.01 were considered significant due to the high number of statistical tests. A cut-off of 19 hours was used for SWA data, and FRs with EI at or above 500 kcal were included in the analysis. The 81 participants with data for both EI and TEE had records for a total of 222 days. Of these, 66 had complete questionnaire data. The 15 participants without complete questionnaire data had one or a few items missing each that were imputed. The results did not differ between the 66 participants with complete questionnaire data and the 81 participants including the 15 with imputed data. In total, 61 had data on sugar intake for comparison between weekdays (Monday−Thursday) with Fridays and/or weekends. Of the participants that answered the questions in the evening, 69 also had TEE data from the SWA. Fifteen participants used both the smartphone FR and the web-based method to record their dietary intake.

Differences in characteristics, EI, and TEE based on gender and weight status were analysed using the Mann–Whitney *U*-test. The Wilcoxon signed-rank sum test was used to analyse differences between EI and $TEE_{SWA}$, between $TEE_{app}$ and $TEE_{SWA}$, and between EI, nutrients, and food groups assessed with the two FR methods. Spearman correlations were calculated for EI and $TEE_{SWA}$, $TEE_{app}$ and $TEE_{SWA}$, and for EI, nutrients, and food groups from the two FR methods. The Bland-Altman method was used to determine the level of agreement between the two methods. The data are displayed for all participants and by gender and weight status (thinness/normal-weight, overweight/obese) (78). Thinness was combined with normal-weight and overweight was combined with obesity due to the small numbers of participants with thinness or obesity. Questionnaire variables, gender, BMI-z (78), school, parental education level (highest of both parents categorized as low, medium, or high), the origin of the participant and their parents (participant and/or their parents born in or outside Sweden), and the inclusion of a weekend day in the FR were tested one by one and stepwise in linear regression models for their association with [(EI - $TEE_{SWA}$) / $TEE_{SWA}$]. Indices were created for the questionnaire instruments. The responses to the Figure Rating Scale were categorized as no discrepancy between current and ideal body size, preferring to be smaller, or preferring to be larger. The variable of frequency of having breakfast was categorized as seven times/week or fewer than seven times/week, and school canteen attendance was categorized as five times/week or fewer than five times/week. Variables regarding whether the study participants thought what they were eating was important and whether they found the study comprehensible, manageable, and meaningful were categorized as yes or somewhat/no. For the thesis, differences in sugar intake (total mono- and disaccharides in grams/day and as E% and sucrose in grams/day and as E%) between the days of week were analysed with the Wilcoxon signed-rank sum test for weekdays (Monday–Thursday) vs. weekends, weekdays vs. Fridays, and Fridays vs. weekends.

Ethical approval was obtained from the Regional Ethical Review Board in Umeå, Sweden.

### *Results*

The characteristics of the participants, the questionnaire responses, and the EI and TEE are presented in Tables 1, 2, and 3, respectively, in Paper IV. The proportion of adolescents included in the analysis with at least one parent with college/university education was 49% (Table 1, Paper IV), which is less than the 63% who had at least one parent with higher education than upper secondary school among all adolescents in the municipalities. The proportion of adolescents born outside Sweden and/or with both parents born outside Sweden was 19% among those included in the analysis compared with 15% among all adolescents in the municipalities. EI was underestimated by 29% compared to the TEE calculated from the SWA data ($P < 0.001$) (Table 3, Paper IV). There was no significant correlation between EI and TEE.

The mean differences and limits of agreement (±1.96 SD) between the EI assessed with the smartphone application and the web-based method and between the TEE from the SWA and the smartphone application by gender and weight status are presented in Table 6.

Differences between EI and BMR are shown in Figure 7. In total, 13 boys and 16 girls had an assessed EI that was less than the calculated BMR. The mean assessed EI was 666 kJ above the calculated BMR.

Inclusion of a weekend day in the FR increased the reporting accuracy of EI relative to TEE ($P = 0.007$). The reporting accuracy relative to TEE decreased with increased BMI-z ($P = 0.003$) (Table 4, Paper IV).

TEE was overestimated with the smartphone application compared to the SWA ($P < 0.001$), but not in boys. Correlations between TEE from the smartphone application and the SWA were significant overall in both girls and boys ($P < 0.001$) (Table 3, Paper IV). The correlation could be explained by the participants' weight, which to a great extent influences an individual's energy expenditure. However, when comparing PAL assessed with the smartphone application, which is not influenced by body weight, with TEE and with the average metabolic equivalent of task (METs) from the SWA, significant correlations still existed. Subgroup analysis showed that the correlation between PAL and average METs was significant only among boys (0.54, $P= 0.003$).

EI and the intakes of nutrients and food groups assessed with the smartphone application and the web-based method are presented in Tables 8 and 9, respectively. EI, nutrients, and food groups were not significantly different between the methods, and monosaccharides, iron and vitamin E were significantly correlated. Two of the 34 food groups were significantly correlated: nuts and savory snacks, and sugar, syrup, honey and artificial sweeteners.

The median intake of total mono- and disaccharides was 83 ±63 grams/day, or 21 E% (n = 81). For sucrose, the median intake was 36 ±53 grams/day, or 8 E%. Of the 37 participants with data for both weekdays and weekends, the intake of sucrose was 9 E% on weekdays compared to 13 E% on weekends ($P = 0.02$). There was no significant difference between weekdays and weekends for total mono- and disaccharides. No significant differences in intakes of sucrose or total mono- and disaccharides were found between weekdays and Fridays (n = 23) or between Fridays and weekends (n = 27). EI did not differ between weekdays, Fridays and weekends (results not shown). Descriptive statistics of the proportion of the 81 adolescents with low, medium, and high E% for total sugars and sucrose on different days of the week are presented in Table 7. Cut-offs were chosen after examining the data.

**Table 6.** Results of Bland-Altman analyses of energy intake assessed with a smartphone application ($EI_{app}$) and total energy expenditure measured with a SenseWear Armband ($TEE_{SWA}$), and of total energy expenditure assessed with a smartphone application ($TEE_{app}$) and $TEE_{SWA}$, and of $EI_{app}$ and energy intake assessed with a web-based method ($EI_{web}$).

| | Bland-Altman method | |
|---|---|---|
| | **Mean difference, kJ [95% CI[1]]** | **Limits of agreement, kJ** |
| *All (n = 81)* | | |
| $EI_{app}$ - $TEE_{SWA}$ | -2588 [-3231, -1945] | -8611, 3114 |
| $TEE_{app}$ - $TEE_{SWA}$[3] | 1439 [1099, 1779] | -1332, 4210 |
| $EI_{app}$ - $EI_{web}$[2] | -399 [-1361, 563] | -3804, 3005 |
| *Girls (n = 50)* | | |
| $EI_{app}$ - $TEE_{SWA}$ | -2447 [-3044, -1851] | -6561, 1667 |
| $TEE_{app}$ - $TEE_{SWA}$[3] | 2045 [1723, 2367] | 48, 4042 |
| *Boys (n = 31)* | | |
| $EI_{app}$ - $TEE_{SWA}$ | -2814 [-4248, -1380] | -10478, 4850 |
| $TEE_{app}$ - $TEE_{SWA}$[3] | 552 [-13, 1117] | -2304, 3408 |
| *Thinness/normal-weight (n = 69)* | | |
| $EI_{app}$ - $TEE_{SWA}$ | -2282 [-2949, -1615] | -7724, 3160 |
| $TEE_{app}$ - $TEE_{SWA}$[3] | 1499 [1169, 1829] | -939, 3937 |
| *Overweight/obese (n = 12)* | | |
| $EI_{app}$ - $TEE_{SWA}$ | -4343 [-6346, -2340] | -10523, 1837 |
| $TEE_{app}$ - $TEE_{SWA}$[3] | 1155 [-175, 2484] | -2947, 5257 |

[1]Confidence interval from the one-sample *t*-test.

[2]n = 15.

[3]n in the analysis of $TEE_{app}$ and $TEE_{SWA}$: All, n = 69; girls, n = 41; boys, n = 28; thinness/normal-weight, n = 57; overweight/obese, n = 12.

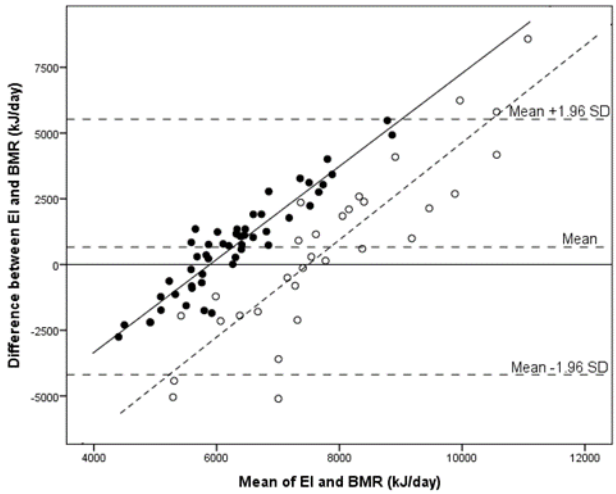


**Figure 7.** Difference between energy intake (EI) from the smartphone application food record and basal metabolic rate (BMR) against the mean of the two variables in adolescents (n = 81). Girls are displayed as ● and a solid regression line, and boys are shown as ○ and a dashed regression line.

**Table 7.** Intake of total sugars (all mono- and disaccharides) and sucrose in adolescents on different days of the week.

| | Monday–Thursday | Friday | Weekend |
|---|---|---|---|
| | n (%) | n (%) | n (%) |
| Total sugars, <20 E% | 25 (42) | 22 (55) | 26 (47) |
| Total sugars, 20–29 E% | 31 (52) | 10 (25) | 17 (31) |
| Total sugars, ≥30 E% | 4 (6) | 8 (20) | 12 (22) |
| Total | 60 (100) | 40 (100) | 55 (100) |
| | | | |
| Sucrose, <10 E% | 40 (67) | 20 (50) | 23 (42) |
| Sucrose, 10–15 E% | 12 (20) | 12 (30) | 16 (29) |
| Sucrose, ≥16 E% | 8 (13) | 8 (20) | 16 (29) |
| Total | 60 (100) | 40 (100) | 55 (100) |

**Table 8.** Energy intake (EI) and nutrients assessed with a smartphone application and web-based method (n = 15). The data are presented as the median and interquartile range (IQR) and their associated correlation coefficients.

| | Smartphone application | | Web-based method | | | |
|---|---|---|---|---|---|---|
| | Median | IQR | Median | IQR | *P*-value[1] | Spearman's rho (*P*-value) |
| Energy, kcal | 1436 | 973 | 1649 | 616 | 0.36 | 0.53 (0.04) |
| Energy, kJ | 6011 | 4072 | 6899 | 2579 | 0.36 | 0.53 (0.04) |
| *Nutrients* | | | | | | |
| Fat, g | 63 | 32 | 55 | 29 | 0.65 | 0.54 (0.04) |
| Protein, g | 58 | 23 | 61 | 38 | 0.05 | 0.29 (0.30) |
| Carbohydrates, g | 154 | 131 | 204.1 | 68.6 | 0.21 | 0.47 (0.08) |
| *Fibre* | 11 | 8 | 14.0 | 6.6 | 0.11 | 0.60 (0.02) |
| *Mono-saccharides* | 28 | 20 | 24.7 | 17.6 | 0.43 | 0.67 (0.007) |
| *Disaccharides* | 49 | 75 | 56.2 | 37.8 | 0.82 | 0.41 (0.13) |
| *Sucrose* | 27 | 57 | 33.7 | 34.1 | 0.87 | 0.27 (0.33) |
| Vitamin A, RE[2] | 580 | 460 | 442 | 299 | 0.19 | 0.55 (0.04) |
| Vitamin C, mg | 66 | 42 | 68 | 74 | 0.78 | -0.35 (0.21) |
| Vitamin D, µg | 3 | 4 | 4 | 3 | 0.23 | 0.31 (0.25) |
| Vitamin E, mg | 6 | 5 | 8 | 5 | 0.06 | 0.75 (0.001) |
| Vitamin $B_6$, mg | 1 | 1 | 1 | 2 | 0.53 | 0.44 (0.10) |
| Vitamin $B_{12}$, µg | 3 | 2 | 3 | 3 | 0.43 | 0.41 (0.13) |
| Folate, µg | 153 | 74 | 177 | 82 | 0.46 | 0.59 (0.02) |
| Niacin, NE[3] | 22 | 10 | 26 | 28 | 0.10 | 0.34 (0.22) |
| Thiamine, mg | 0.5 | 1.0 | 0.8 | 1.2 | 0.97 | 0.35 (0.21) |
| Riboflavin, mg | 1.1 | 0.9 | 0.7 | 1.2 | 0.82 | 0.17 (0.55) |
| Calcium, mg | 585 | 392 | 691 | 337 | 0.39 | 0.45 (0.10) |
| Iron, mg | 7 | 4 | 7 | 1 | 1.00 | 0.66 (0.008) |
| Magnesium, mg | 177 | 112 | 234 | 78 | 0.11 | 0.32 (0.25) |
| Phosphorus, mg | 945 | 612 | 985 | 359 | 0.11 | 0.34 (0.22) |
| Potassium, mg | 1873 | 959 | 2084 | 1134 | 0.69 | 0.33 (0.23) |
| Selenium, µg | 27 | 15 | 29 | 20 | 0.08 | 0.46 (0.08) |
| Sodium, mg | 2636 | 1427 | 2450 | 1123 | 0.78 | 0.22 (0.44) |
| Zinc, mg | 8 | 4 | 8 | 4 | 0.82 | 0.38 (0.16) |

[1]*P*-value derived from the Wilcoxon signed-rank test for the difference in intakes between the two methods.
[2]Retinol equivalents.
[3]Niacin equivalents.

**Table 9.** Food groups assessed with a smartphone application and web-based method (n = 15). The data are presented as the median and interquartile range (IQR) and their associated correlation coefficients.

| | Smartphone application | | Web-based method | | | |
|---|---|---|---|---|---|---|
| | **Median** | **IQR** | **Median** | **IQR** | ***P*-value[1]** | **Spearman's rho (*P*-value)** |
| Vegetables, pulses, and roots | 47 | 205 | 47 | 84 | 0.82 | 0.38 (0.16) |
| Fruits and berries | 49 | 99 | 33 | 58 | 0.12 | 0.50 (0.06) |
| Potatoes | 37 | 63 | 88 | 118 | 0.17 | -0.23 (0.40) |
| Bread | 66 | 57 | 69 | 29 | 0.53 | 0.41 (0.13) |
| Rice and grains | 0.7 | 35 | 0 | 12 | 0.26 | -0.18 (0.52) |
| Pasta | 0 | 28 | 42 | 87 | 0.03 | -0.13 (0.65) |
| Porridge and gruel | 0 | 0 | 0 | 0 | 1.0 | -0.11 (0.71) |
| Breakfast cereals | 8 | 15 | 2 | 9 | 0.29 | 0.53 (0.04) |
| Meat | 42 | 46 | 57 | 50 | 0.88 | 0.36 (0.18) |
| Poultry | 0 | 30 | 15 | 65 | 0.28 | -0.47 (0.07) |
| Sausages | 7 | 26 | 0 | 17 | 0.21 | -0.21 (0.44) |
| Fish and shellfish | 0 | 25 | 17 | 30 | 0.56 | 0.26 (0.35) |
| Eggs | 3 | 5 | 0.8 | 10 | 0.86 | -0.11 (0.70) |
| Milk, fermented milk, and yoghurt | 250 | 286 | 275 | 290 | 0.65 | 0.55 (0.03) |
| Cream and sour cream | 0 | 18 | 0 | 0 | 0.16 | 0.12 (0.68) |
| Cheese | 14 | 26 | 9 | 25 | 0.78 | 0.49 (0.06) |
| Spreads, butter, and oil | 16 | 15 | 8 | 15 | 0.28 | 0.26 (0.34) |
| Coffee | 0 | 0 | 0 | 0 | 0.66 | -0.07 (0.80) |
| Tea | 0 | 0 | 0 | 7 | 0.34 | 0.21 (0.46) |
| Juice | 133 | 200 | 0 | 100 | 0.01 | 0.48 (0.07) |
| Soft drinks, sport drinks, and energy drinks | 67 | 333 | 125 | 233 | 0.84 | 0.64 (0.01) |
| Beer, wine, and spirits | 0 | 0 | 0 | 0 | 0.66 | 0.63 (0.01) |
| Jam, marmalade, and apple sauce | 0 | 13 | 0 | 32 | 0.95 | 0.27 (0.33) |
| Nuts and savoury snacks | 0 | 6 | 0 | 2 | 0.46 | 0.65 (0.008) |
| Ice cream | 0 | 0 | 0 | 8 | 0.79 | 0.20 (0.47) |
| Candy | 7 | 39 | 8 | 45 | 0.92 | 0.39 (0.15) |
| Buns, biscuits, and cakes | 0 | 37 | 7 | 25 | 0.88 | 0.28 (0.32) |
| Sweet soups and desserts | 0 | 0 | 0 | 0 | 1.0 | 0.42 (0.12) |
| Sugar, syrup, honey, and artificial sweeteners | 0 | 0 | 0 | 0.4 | 0.47 | 0.86 (<0.001) |
| Pizza, pie, and pierogi | 0 | 100 | 0 | 65 | 0.60 | 0.48 (0.07) |
| Pancakes, waffles, and crepes | 0 | 50 | 0 | 42 | 0.97 | -0.23 (0.42) |
| Soup | 0 | 0 | 0 | 0 | 0.11 | –[3] |
| Sauces | 19 | 67 | 34 | 100 | 0.58 | 0.37 (0.18) |
| Nutritional supplements[2] | 0 | 0 | 0 | 0 | 0.32 | –[3] |

[1]*P*-value derived from the Wilcoxon signed-rank test for the difference in intakes between the two methods.
[2]Includes protein drinks and bars, recovery drinks, and meal replacement products but not vitamin and mineral supplements.
[3]The intake with one method was zero for all participants.

# Discussion

## Main findings

This thesis aimed to evaluate the accuracy of dietary assessment methods using new approaches and technologies, among children, adolescents, and young women, and to investigate factors that might influence reporting accuracy. Another aim was to investigate children and adolescents' sugar intake on weekdays and weekends. The SDQ was not valid for assessing EI, but it did capture equal or higher amounts of EI and nutrient and food intakes in young pregnant and non-pregnant women of different weight status compared with a more extensive questionnaire that is used in epidemiologic studies. FRs aided by digital cameras and smartphones showed similar accuracy as traditional FRs in children and adolescents. Sugar intake was high in children and adolescents, and higher on weekends compared to weekdays, although EI did not differ between weekdays and weekends. In accordance with previous research, a higher underestimation of EI with higher BMI or in overweight/obese compared to normal-weight participants was also found in the present studies among children, adolescents, and young non-pregnant women. Furthermore, children and adolescents reported a more accurate EI on weekends compared with weekdays, although the EI was still underestimated on weekends, and this is a finding that warrants further investigation.

## Implications for dietary assessment in women

Misreporting of EI in dietary assessments is common in both men and women. Whether women underestimate their dietary intake to a higher extent than men has been investigated in several studies that show differing results, but taken together the evidence points to no general difference according to gender (79-82). However, women have been shown to underestimate EI when using an FFQ when compared with the DLW method, e.g. by 34%–38% in the USA (81), by 24% in Brazil (83), and by 22% in Germany (84). In another study comparing EI assessed with an FFQ with TEE measured with the DLW method in Norwegian women, the 10% underestimation was not statistically significant (85). Results of the LifeGene pre-pilot study showed that EI assessed with the SDQ was underestimated by 22% in non-pregnant normal-weight women and by 43% in non-pregnant overweight and obese women. The higher degree of underestimation of EI among overweight compared to normal-weight participants is in line with results of previous studies evaluating an FFQ (86, 87).

The magnitude of misreporting among women has been shown to be greater when using an FFQ compared with repeated 24-hour recalls in studies using

DLW as the reference method (83, 88). However, one study showed higher EI assessed with an FFQ compared with repeated 24-hour recalls in women and men analysed together (89). Furthermore, an FFQ was shown to give higher estimates of EI when relatively validated compared with FRs, e.g. the EI assessed with the FFQ was 1.16 times the EI assessed with an FR in adult men and women in Greece (90), 1.17 times the EI assessed with an FR in Australian men and women (91), and 1.42 times the EI assessed with an FR in Finnish women (92). Similar to the diet history interview, an FFQ requires a retrospective abstraction of the dietary intake. This can be more difficult than responding to a 24-hour recall or keeping an FR, although the 24-hour recall also relies on memory and the FRs have other disadvantages such as being burdensome. This, and the fact that all foods cannot be included, makes FFQs less useful for assessing the precise individual intake.

FFQs are often used in epidemiological studies in cases where ranking individuals according to intake is the goal. In the LifeGene pre-pilot study, the SDQ was able to rank the overweight/obese women according to EI, but not the normal-weight women. The more extensive FFQ was unable to rank either the normal-weight or overweight/obese women according to EI. In a study with DLW as the reference method, an FFQ could rank participants according to EI (84), but in another DLW study the FFQ was not able to rank participants' EI (85). These results show that dietary data from FFQs must be used with caution and must be validated before use in epidemiologic research.

In this thesis, the amounts of nutrients and foods assessed with the SDQ were often higher than those obtained using the 66-item FFQ. Intakes of nutrients and foods were significantly correlated between the SDQ and the FFQ, and between 26% and 64% of the women were classified in the same quartile for nutrients and foods with the two methods. Because no reference method with uncorrelated errors was used, it was not possible to evaluate the ranking ability or the ability of the SDQ and FFQ to assess the precise intakes of nutrients and foods.

The SDQ was designed with the aim of being short and easy to complete. It has previously been shown that longer FFQs have higher correlations for nutrients than shorter FFQs (93, 94), and this is to be expected because FFQs with more items will be more likely to capture a majority of an individual's dietary intake than an FFQ including only the most commonly consumed foods. However, using a very long FFQ can result in overestimation of intakes (95) or careless completion of the FFQ. Because it is impossible to include every food item, there must be a trade-off between the number of items and the burden on the respondent. By careful design, an

FFQ can be improved in terms of response rate and quality of data without being too extensive (96). In the LifeGene pre-pilot study, the SDQ generally gave higher estimates of EI, nutrients, and foods compared with the 66-item FFQ. This was in line with a study showing that a longer FFQ did not result in a more accurate estimation of EI (81). Intakes of snacks and high-fat milk products were lower when assessed with the SDQ compared with the FFQ but were not significantly correlated between the methods. This indicates that the SDQ could be improved regarding these food groups. Future validation studies of the SDQ should include nutrient biomarkers or a reference dietary assessment method with independent errors for relative comparisons in order to evaluate its ability to assess nutrient and food intake.

Health, reproduction, and pregnancy outcomes in women of reproductive age who intend to have children are dependent on a well-balanced diet. Dietary assessment methods that can be used in this group and among pregnant women are, therefore, important. The FFQs used among pregnant women have been relatively validated against other dietary assessment methods such as FRs and 24-hour recalls (97-100). Studies using objective measures of TEE for comparison with assessed EI are less common (101), and the DLW method has to our knowledge not been used previously for validation in this group. In the LifeGene pre-pilot study, EI assessed with the SDQ was underestimated by 21% in the pregnant normal-weight women and was not able to rank them according to EI. The median assessed EI in relation to TEE was similar in the pregnant and non-pregnant normal-weight women. However, the median assessed EI was 384 kJ higher in pregnant compared with non-pregnant women, and the median TEE was 832 kJ higher. The extra energy required in the second trimester of pregnancy has been estimated to be 1200 kJ/day (99), thus the SDQ was not able to detect the entire difference in energy requirements, only a portion of it.

The SDQ did not capture enough of the EI in young women and did not have a good enough ranking ability to be considered a valid method to assess the habitual dietary intake of the individuals, but in the non-pregnant women it was not less valid than a more extensive and traditionally designed FFQ previously used in epidemiologic research (54). The design of the SDQ and its ability to capture a majority of the EI in young women makes it useful as a rapid screening tool when the aim is to assess most of the dietary intake but an exact measure of the individual's total dietary intake is not necessary. A potential application is in field studies where a paper-based and quick method is preferred. For this objective, the SDQ can be further developed and adapted to suit the study aim and population of interest. For example, the design of the SDQ can be a starting point and foods and portion sizes can be adapted to the study population and more food groups can be added. Increasing the number of items in the SDQ can help to clarify if its design (with open questions about amounts) is superior to an FFQ with a traditional design that often includes more items.

Low ranking ability is a serious problem with the use of FFQs among young women in epidemiological studies. Studies have claimed that the evaluated FFQs are valid based on comparisons with other dietary assessment methods (90), but because errors are often correlated between methods this might not be the case. Validation with biomarkers have shown that the intakes of some nutrients as assessed with FFQs are sufficiently correlated, but others are not (102, 103). Future studies need to choose dietary assessment methods that have been shown to be valid specifically for the nutrient or nutrients of interest. In some cases it might be necessary to use several different methods to determine the intake and the degree of error in the assessment. The method of triads is sometimes used to obtain more accurate results than those obtained from using only one or two methods (104, 105). Steele suggests combining assessment methods on several levels, such as including household food purchases for dietary assessment on the individual level, to obtain more comprehensive and thereby more accurate data. Even though many FFQs have several shortcomings, FFQs might still have advantages compared with other non-objective assessment methods in addition to their ease of distribution. For example, it has been shown that an FFQ was able to detect some of the extra energy required in obese compared to normal-weight women but the 24-hour recall was not (88). Perhaps overweight and/or weight-conscious women are less prone at underreporting intakes with FFQs because reporting habitual intakes is different from accounting for what was consumed during a specific day.

## Implications for dietary assessment in children and adolescents

The evaluation of the digital camera FR among 8–12-year-old overweight/obese children participating in the SELFH study showed that the accuracy of the reported EI was reproducible over the 2-year study period but was underestimated by 24% on the first assessment occasion compared with TEE calculated from the SWA data. The study evaluating the smartphone application among adolescents showed that EI was underestimated by 29% compared with TEE from the SWA. In both studies, the underestimation of EI increased with TEE, and it increased with BMI-z when TEE was taken into account. Furthermore, both studies showed that having a weekend day in the FR was associated with less underestimation of EI, although underestimation still occured. When taking TEE into account in the SELFH study, girls underestimated EI more than boys and the underestimation increased with age. Gender did not affect reporting accuracy among the adolescents participating in the smartphone application evaluation study, nor did any of the investigated variables that previously have been found to influence reporting accuracy, e.g. skipping breakfast, less frequent school canteen attendance, or a wish to weigh less (76). A daily question about the physical activity during the day in the smartphone application overestimated TEE among girls but not among boys. Furthermore, the daily physical activity question was able to rank participants according to TEE and to rank the boys according to PAL. A sub-sample of the adolescents who additionally used a web-based method reported similar EI, similar amounts of most nutrients, and similar amounts of foods with the two methods. In addition, monosaccharides, vitamin E, iron and two food groups were significantly correlated when assessed with the two methods.

Previous research among children and adolescents showed underestimation of EI assessed with FRs of between 12% and 21% in normal-weight children (106-109), and between 25% and 41% in overweight and obese children (106, 107, 110). The cited studies used "traditional" pencil and paper FRs and DLW as the reference method. A review concluded that underestimation of EI among children and adolescents is higher when using FRs compared with other dietary assessment methods (28). Maintaining an FR can be burdensome for the participant, and this can lead to both under-eating in order to avoid recording and can lead to some consumed foods not being recorded. School-aged children and adolescents might find it extra tiresome to record food intake because they often consume meals away from home. Furthermore, adolescents might have more irregular eating patterns than children and adults and might be less interested in participating in dietary studies. Children from 8 years of age are most often able to record their dietary intake themselves, but assistance from parents might make it easier for them to complete an FR. Among adolescents, parents might be less in control and not as able to influence whether the adolescent completes the dietary assessment. FRs using technology does not differ from pencil and paper FRs in the inherent steps in the method (i.e. remembering and taking the time to record the food, finding out what type of food was consumed, and estimating the consumed amounts). Therefore, there might be no reason to believe that digital camera or smartphone application FRs give more valid data compared with traditional FRs. However, using technology might make the recording more interesting for children and adolescents and thereby improve adherence to studies and to the recording of dietary intake. Developing new versions of traditional methods is a way to keep dietary assessment methods up to date and make the methods more in tune with the daily lives of young people. Up to now, no dietary assessment methods using smartphone applications have been validated when it comes to the ability to assess the habitual dietary intake among children and adolescents. However, methods using technology to keep FRs have been, or are being, developed. For example, smartphone applications for dietary assessment that uses automatic image analysis of food pictures in order to make it easier to keep an FR are being developed in the USA (14-16). The use of this type of technology might be a way to avoid the burden of manually recording foods and portion sizes and thus to improve the quality of the collected dietary data and to enhance study participation. However, some challenges regarding the identification of foods and food contents as well as correct portion size estimation still need to be solved. In the UK, a smartphone application developed to support weight loss estimated the dietary intake reasonably well compared with 24-hour recalls in adults (13). In Japan, an FR used with a PDA was developed and evaluated in adults and showed underestimation of the dietary intake (12).

Similar to what has been found for adults, overweight and obese children and adolescents tend to underestimate EI to a higher extent than their normal-weight counterparts (27). Children in the SELFH study using the digital camera FR had a lower underestimation of EI compared with the adolescents using the smartphone application FR, and this was despite the fact that all of the children in the SELFH study were overweight/obese, while the majority of the adolescents using the smartphone application FR were normal-weight. The higher underestimation among adolescents could possibly be explained by them being older than the children in the SELFH study. Underestimation increased with age in the 8–12-year-old children, and such an increase in this age group has been shown previously (20, 28). No such difference was detected in the adolescents, who were all of approximately the same age (around 15 years). In the analysis of dietary data, TEE should be controlled for because it can have an effect on reporting accuracy (108). Gender influenced reporting accuracy in the SELFH study after taking TEE into account, but there was no difference in reporting accuracy for girls and boys using the smartphone application FR. Previous research has shown no consistent difference in the underestimation of EI between girls and boys (28, 76). In the study evaluating the smartphone application FR, a questionnaire was included with questions about individual factors that have previously been shown to affect reporting accuracy among children and/or adults. None of the included variables had a significant effect on reporting accuracy. The strongest factor influencing reporting accuracy apart from BMI was having a weekend day in the FR. This was also an important factor in the SELFH study. A reason for the higher reporting accuracy on weekends could be the fact that children and adolescents are less busy with other activities on weekends compared with school days and that this allows them more time to focus on the FR. Another possible reason could be that they consume more meals at home on weekends and, therefore, have more knowledge about how the foods were prepared and can more easily report their dietary intake.

The digital camera FR used in the SELFH study was reproducible, which is defined here as having similar validity over the assessment occasions. This definition of reproducibility was used because it can be assumed that food intake would change over a 2-year study period and that the EI of the children would increase as they grow older.

The smartphone application FR assessed as much of the adolescents' EI, nutrient intake, and food intake as the web-based FR method. However, the sample completing both methods was very small (n = 15), and the ability of the smartphone application to assess nutrient and food intake should preferably be evaluated against repeated 24-hour recalls or biomarkers.

It was possible to rank adolescents' TEE using one question about physical activity during the day when compared with TEE from the SWA. The same result was obtained when comparing TEE from the SWA with the participants' weight instead of TEE from the daily question about physical activity in the smartphone application. Furthermore, the smartphone application was able to rank PAL among the boys. It has previously been shown that two questions could accurately measure PAL in adult women over a 2-week period compared with DLW (111, 112). Another DLW study on six women and three men showed that it was possible to measure PAL and TEE by using two questions about physical activity during the last three months (113). By using one or two questions about the daily physical activity, it might be possible to relatively validate EI from dietary assessment methods against estimated TEE without extra equipment, e.g. accelerometers, although using weight or BMR seems to work equally well. In the smartphone application, PAL values for girls should be adjusted because TEE was overestimated on the group level.

Dietary assessment methods for use among children and adolescents need to be further developed. A review has shown that diet history interviews are the most accurate method for assessing dietary intake among adolescents (114), and this is probably because this is a less demanding method than the FR. However, when the aim is to assess the detailed dietary intake, an FR that makes it simple for participants to record food intake and consumed amounts should be available. Illner et al. conclude in a review study that the problem of misreporting in dietary assessments will not be solved by technology so long as the underlying methodology remains the same (2). Results from the present thesis support this assumption. To improve reports of dietary intake with FRs among children and adolescents, the method used needs to be fundamentally different from traditional methods. Automated image analysis of food photographs with smartphones might be a way to go. Steele identified mobile applications and improved computer visualization techniques to analyse food images as two of the most promising research directions in the field of dietary assessment (115). Even if this method is developed participants will still need to remember to photograph the consumed foods. Furthermore, they might need to learn to use a back-up method in case of technical problems (16). Participant-specific misreporting due to individual factors will also still be an issue. As seen among young women, factors influencing reporting accuracy need to be taken into account in dietary studies among children and adolescents and need to be further investigated. New and innovative dietary assessment methods should be evaluated compared with DLW and biomarkers of nutrient intake. Study participants should be trained in using the method before the study, and the use of incentives might increase participation rates.

Suggestions to improve and further develop the smartphone application include:

- Further development of alternatives included in the food database to make it easier to search and find consumed foods.
    - Some food groups, e.g. bread and cheese, need fewer alternatives to choose between.
    - Some foods should be added, e.g. foods not belonging to a traditional Swedish diet.
    - More recipes should be included for commonly consumed dishes, e.g. tacos, which are burdensome to record one ingredient at a time.
    - The search function should be improved, e.g. by making more commonly consumed foods appear at the top of the list.
- Portion size estimation should be further improved, e.g. by enabling sending photographs of consumed foods to the researcher who can then estimate and double-check the recorded amounts.
- r study</IDText><Disps for automated analysis of food photographs, this should be incorporated in the smartphone application.
- PAL values were set too high for girls and should be adjusted.
- If the smartphone application is to be used in intervention studies, the feedback function should be improved or omitted for this purpose.

- The design of the smartphone application should be made more attractive for adolescents.
- The smartphone application should be developed for other operating systems such as iOS.

## Sugar intake in children and adolescents

Intake of sugar in the IDEFICS, SELFH and smartphone application studies was assessed as total sugar intake (all mono- and disaccharides), sucrose intake, and/or foods and drinks rich in added sugar. Among the 2–9-year-old children in the IDEFICS study, the assessed intake of total sugars was 97 grams/day in the year 2007/2008. The assessed intake of total sugars among the 8–12-year-old overweight and obese children in the SELFH study was higher in 2006 compared with the adolescents in the smartphone application study in 2013 at 120 grams/day vs. 83 grams/day, respectively. Differences in sugar intake between the studies could be a result of differences in EI due to differences in age, weight status, or misreporting. Expressed as E%, the intake of total sugars was 26 E% in the IDEFICS study (22 E% among the Swedish IDEFICS children), 24 E% in the SELFH study, and 21 E% in the smartphone application evaluation study.

Because the nutrition calculation databases used did not have information about added sugar content in foods, it was not possible to evaluate the intakes in comparison with the maximum level of intake recommended by the WHO (3) and the NNR (33). The intake of sucrose can be assumed to be more similar to the intake of added sugar (although underestimated) than the intake of total sugars. In the SELFH study and the smartphone application evaluation study, intakes of sucrose (including naturally occurring sucrose) were 10 E% and 8 E%, respectively, i.e. the amount of sucrose reached or almost reached the maximal intake level of no more than 10 E% added sugars. The assessed intake was less than that of 4-year-olds and children in years 2 and 5 who participated in a Swedish national dietary survey and whose intakes of sucrose were 12 E% to 14 E% (36). In the IDEFICS study, where data for sucrose intake were not available for all participating countries, the analysis was performed for intake of foods and drinks rich in added sugar in grams; however, these data cannot be compared with WHO recommendations or the NNR.

In the IDEFICS study, intakes of total sugars and foods and drinks rich in added sugar were higher on weekends compared with weekdays. Friday intakes were a mix between intakes on weekdays and weekends. The intake of total sugars on Fridays was more similar to that on weekends, and the intake of foods and drinks rich in added sugar was more similar to the intake on weekdays. The results differed by country. In the Swedish IDEFICS sample, the intake of total sugars on Fridays and weekends was higher compared with Mondays–Thursdays, but there was no difference in the intake of foods and drinks rich in added sugar. The explanation for this is that the Swedish children consumed more sweets and sugar-sweetened beverages on weekends, and these have a higher density of sugar compared with sweetened dairy products that were consumed more on weekdays. In the SELFH and the smartphone application studies, the intake of sucrose was higher on weekends compared with weekdays, but there was no difference for the intake of total sugars. EI did not differ between weekdays and weekends in any of the studies, and this suggests that the higher sugar intake on weekends was at the expense of the intake of starch, fat, and protein.

National surveys of children's dietary intakes tend to show sugar intakes exceeding recommendations (36, 37, 116). A review of dietary surveys among children in European countries published in 2004 found the highest intakes of sucrose (18 E%) among children in Austria and Finland (117). The review also found that intakes of total sugars and sucrose were lowest in Southern European countries and that the intake declines with age. Previous studies of Swedish pre-school children residing in Stockholm (39) and Gothenburg (42) have shown high sucrose intakes. In the study conducted in Stockholm, intake was 16 E% on weekends (39). Higher sugar intake on weekends has also been found among 3-year-old Finnish children (118) and on Fridays and weekends among Norwegian children aged 4 years and Norwegian children in years 4 and 8 (119). A study among Danish children aged 4–14 years that included data on added sugar was able to show that the intake was higher on Fridays and weekends compared with Mondays−Thursdays and that Friday and weekend intakes exceeded recommendations (40). In contrast, the intake of sucrose among children in New Zealand aged 5–14 years was higher on school-days compared with non-school-days (120). Similarly, intake of non-milk extrinsic sugar was not higher on weekends compared with weekdays among children aged 5–17 years in Scotland (121). Cultural differences in dietary habits could explain these differing results. The studies conducted in Scandinavian countries all show higher intakes of sugar on weekends compared with weekdays.

The implications that day-of-the-week effects can have on the assessment of dietary intakes are well known, and the results of the present studies of sugar intake strengthen the knowledge that habitual dietary intake ought to be assessed on both weekdays and weekends. Furthermore, when assessing sugar intake, Fridays should be included as a separate category because they are a mix between weekdays and weekends when it comes to sugar intake.

Sugar intake in children has remained high for many years. Interventions could target families in order to reduce sugar intake on weekends when it has been shown to be extra high. Parents have a great impact on children and have the most opportunities to set good examples and provide healthy alternatives to their children, and this is especially the case on weekends when most families spend more time together.

## Methodological considerations

All validation studies of dietary assessment methods are limited by the fact that, unless direct observations are made, there is no reference method that measures the exact dietary intake (26). However, the method that is chosen as the reference should be the best available to detect errors in the method that is being validated. The purpose of this thesis has mainly been to evaluate dietary assessment methods against measures of TEE. In the LifeGene pre-pilot study, DLW was used as the reference method for all participants, which is a great strength of the study. DLW is regarded as the "gold standard" method and can objectively measure TEE over a period of approximately two weeks.

In the SELFH and smartphone application evaluation studies, the SWA was used to objectively measure TEE. An individual's EI does not necessarily equal TEE each day and often varies over several days even for an individual in energy balance. This problem can be overcome by assessing diet over many days. However, a too long of a measurement period can become burdensome for the participant and can cause less accurate recording of the dietary intake. In the SELFH study, EI and TEE were assessed for two days on all occasions except one in which the assessment was conducted for four days. In the smartphone application evaluation study, EI and TEE were assessed for one to six days, although some participants voluntarily recorded their diet and wore the SWA for more than the requested three days. On average, the diet was recorded for 2.7 (0.9) days and the SWA was worn for 2.7 (1.2) days. The SWA is not as accurate as the DLW method for measuring TEE, and validation studies of the SWA against DLW have shown varying results. The SWA has often been shown to be accurate on the group level but with wide limits of agreement (122). Thus, the SWA might not be valid for measuring TEE on the individual level. A related issue is that children and adolescents are in positive energy balance due to growth. It was assumed that this would not be an issue in the studies because diet was assessed for only a few days with the FR and the extra energy required during this short time period was negligible.

In papers I and IV, misreporting of EI was correlated between the SDQ and the FFQ and between $EI_{app}$ and $EI_{web}$, respectively. To avoid this correlated error structure when using two dietary assessment methods, EI should preferably have been relatively validated using methods with uncorrelated errors, e.g. FRs for the FFQ and 24-hour recalls for the FR (5). Individual factors might, however, make participants misreport to the same extent regardless of dietary assessment method, and this could account for some of the correlated error. Furthermore, the SDQ cannot be assumed to have assessed the exact nutrients and foods as the more extensive FFQ, and the smartphone application FR cannot be assumed to have assessed the exact nutrients and foods as the web-based FR, because the assessments covered different time periods.

In the comparison of the SDQ with the FFQ, several differences inherent in the methods might have caused the different results. For example, the questionnaires included a different number of food items, they did not use the same reference foods in the nutrition calculation program, and different databases were used to calculate EI and nutrient content. Furthermore, portion sizes were not obtained in the same ways. A questionnaire should be adapted for use in the population under investigation; therefore, different portion sizes and consumption frequencies can be seen as part of the questionnaire designs and not as methodological limitations, although the results will be affected by these differences.

The comparison of nutrients and food groups between the smartphone application FR and the web-based FR was limited by the small sample (n = 15) completing both methods. However, the comparison was strengthened by both methods using the same food database and portion size alternatives.

Correlations are often used to compare methods in validation studies. This approach has been criticized because a high correlation does not necessarily mean that there is good agreement between methods (123). A plot of the difference between methods with 95% limits of agreement against the mean of the methods shows the group mean difference between the methods as well as the variability around the mean. In this thesis, Bland-Altman plots were used to illustrate the agreement between methods, and correlations were used as complements to assess the ranking ability of the methods. Correlations of assessed EI and objectively measured TEE were generally non-significant for the methods evaluated in this thesis. An explanation for the low correlations between EI and TEE in papers III and IV could be that the SWA used as reference method was not able to measure TEE at the individual level. It would have been desirable to use the DLW method to measure TEE so as to be better able to evaluate the ranking ability of the FR according to EI. However, the LifeGene pre-pilot study used the DLW method to measure TEE of all participants, and no significant correlation between EI and TEE was found except for the SDQ in the non-pregnant overweight/obese women.

BMI influenced reporting accuracy in the three studies validating dietary assessment methods, and this is consistent with previous research (27). Gender and age were found to influence reporting accuracy among overweight and obese children, and underestimation of EI increased with TEE. Therefore, TEE should be accounted for when investigating possible differences in the accuracy of reported EI between girls and boys, between normal-weight and overweight, and between different age groups. Otherwise, differences in TEE could mask differences by gender, weight status, or age because boys often have higher TEE compared with girls, overweight often have higher TEE compared with normal-weight, and TEE increases with age. Furthermore, it was found that reporting accuracy was higher with a weekend day in the FR. Because the mean of reported EI and measured TEE was calculated for all assessment days of an individual, it was not possible to separate and compare weekends with weekdays. Doing so might possibly have shown an even more pronounced difference in reporting accuracy.

In children and adolescents who are growing, BMI is not a suitable measure. Instead, BMI-z (also referred to as the BMI SD score or iso-BMI) is used. BMI-z is calculated based on data from a reference population. It can be used to classify children according to weight status based on SD scores or percentiles that correspond to an adult BMI of 25 $kg/m^2$ for overweight and 30 $kg/m^2$ for obesity. In the SELFH study, data from three different child reference populations (one Swedish (65), one American (64) and one mixed American/international (66)) were used to calculate BMI-z, and data from the IOTF, which is based on international reference child populations, was used to classify children according to weight status (63). Data from the IOTF were used to classify participants according to weight status in the IDEFICS and smartphone application evaluation studies, and the data were used to calculate BMI-z (78) in the smartphone application evaluation study. For Swedish children, data from a Swedish or an international reference population can be assumed to be more suitable than an American reference population, and the international reference can be assumed to be the most suitable for the European sample of children in the IDEFICS study.

Most children participating in the IDEFICS study had one day each of dietary intake assessed with 24-hour recalls. Therefore, one day per child was selected for the analysis of sugar intake on weekdays versus weekends. One assessed day is not enough to be representative of the habitual sugar intake on the individual level, although on the group level it was enough to detect a difference between weekdays and weekends in the large sample of children. Furthermore, reporting bias is possible when parents, as in the IDEFICS study, are used as proxy-reporters of the child's dietary intake. Sugary foods could be selectively underreported due to a wish to report a socially desirable diet for the child. A study of misreporting with 24-hour recalls in the IDEFICS study showed that 89% were classified as plausible reports when compared with adapted Goldberg cut-off values (60).

Results of the studies in the present thesis might not be generalizable to the general population of children, adolescents, and young women. In the SELFH and LifeGene pre-pilot studies, participants were recruited, for example, by advertising, and this resulted in selected samples of motivated participants. Furthermore, overweight and obese individuals, who have shown to be more prone to underestimating compared with normal-weight individuals, were specifically recruited to these two studies and this most probably affected the results. In the IDEFICS and smartphone application evaluation studies, on the other hand, recruitment of participants was conducted through pre-schools and schools. The children participating in IDEFICS Sweden were shown to differ from reference children matched according to age and gender and living in the same municipality (124). Participating children were less likely to live in families with low education and income, single parenthood, or a foreign background. Furthermore, the children in the IDEFICS study were not nationally representative. In the smartphone application evaluation study, 49% of the participants included in the analysis reported college or university as the highest education level completed by their parents, and 19% reported a foreign background. This was not much different from the average proportions for adolescents in the municipalities that the sample was drawn from. The average proportion of adolescents with parents who had higher education than upper secondary school was 63% in the municipalities, and 15% had foreign background according to data from the 2013/2014 school year (70). The averages for the included schools were 63% and 18%, respectively. This indicates that the adolescents included in analysis and the schools that the study recruited from were representative for Gothenburg and neighbouring municipalities with regard to the educational level of parents and the proportion of adolescents who had foreign backgrounds.

A limitation to the analysis of sugar intake is that the assessed intakes could not be compared with the recommendation of less than 10 E% added sugar in the diet. Added sugar is not included in nutrition calculation databases, and the analysis was performed, therefore, for the total intake of mono- and disaccharides. The Swedish nutrition calculation database from the National Food Agency also has information about the sucrose level in foods (added and naturally occurring sucrose combined). Therefore, sucrose intake was analysed in the SELFH and smartphone application evaluation studies. In the IDEFICS study, data from all eight participating countries were harmonized to be comparable. Because many countries did not have sucrose in the nutrition calculation database, this information was excluded for the Swedish IDEFICS sample. Instead, the intake of foods and drinks rich in added sugar based on food groups common for all countries was used in the analysis. To avoid this problem in future studies, added sugars should be included in food composition databases. Furthermore, to evaluate the accuracy of assessed sugar intake, new biomarkers might be useful (23, 25).

A limitation to the smartphone application evaluation study was that the application was only developed for use with Android smartphones. When recruiting study participants it was discovered that most of the adolescents owned an iPhone. Therefore, they borrowed an Android smartphone to be able to participate in the study. This made it more difficult for them to use the application compared to if they had been able to use their own smartphones, which they were used to handling. They also had to bring an extra smartphone with them during the day or they left it at home and recorded their dietary intake in the evenings. This could have affected the recording and validity of the obtained dietary data.

# Conclusions

Despite being short, the SDQ captures as much of EI and nutrient intake as a more extensive and commonly used FFQ. The SDQ can be used to assess dietary intakes of young women when there is a need for a short instrument that still captures a majority of the EI. The SDQ should be evaluated regarding its ability to assess nutrient and food intake compared with preferably objective methods, and in other groups such as children, men, and the elderly. The design of the SDQ can be adapted to suit different populations and study objectives.

FRs completed with the aid of digital cameras and smartphones did not show increased accuracy compared with traditional FRs among children and adolescents. Innovative methods are needed that place minimal burden on the participants, and this is especially important when assessing the dietary intakes of children and adolescents. The goal should be completely objective methods, and smartphone applications with automated image analysis of food photographs that are currently in development might be a step toward this goal.

Known factors associated with the misreporting of dietary intake in the population under study should be considered when performing dietary assessments, and new factors that might be of importance should be investigated. The present thesis confirmed results from previous studies showing that weight status, BMI, TEE, age, and gender can influence the reporting accuracy of EI. Furthermore, including a weekend day in the FR as compared to only including weekdays was found to influence reporting accuracy among children and adolescents, and the reasons for this should be investigated.

The intake of sugar among children differs not only between weekdays and weekends but also on Fridays. When assessing children's sugar intake using estimated FRs or 24-hour recalls, a weekday (Monday–Thursday), Friday, and weekend day should be included. To be able to evaluate children's sugar intake in relation to nutritional recommendations, it must be possible to assess the intake of added sugars. Added sugars should, therefore, be included in food composition tables. Alternatively, recommendations can additionally be given for total mono- and disaccharides or sucrose, which are possible to assess. Biomarkers for sugar might be used to evaluate the accuracy of subjectively reported sugar intake.

Efforts should be made to reduce sugar intake in children and adolescents, on both weekdays and weekends. Parents might have a significant impact on the child's dietary intake during weekends, and they can use this opportunity to be good role models and to provide healthy foods. They might also have the opportunity to provide healthy breakfasts during school days. Society should help parents set limits and make it easier for them to provide healthy foods for their children. They might need support to make healthy purchases, and this could include structural changes that make healthy alternatives more available and desirable. Children also need support from parents and others adults to make healthy food choices.

# Acknowledgements

Many people have contributed to this thesis in different ways. I would like to thank all of you who supported me throughout the process and to give special thanks to:

**Christel Larsson**, my main supervisor, for believing in my abilities when I was accepted to the doctoral studies and for keeping me on track and supporting me during these four years. Thank you for always being engaged in my studies and so very generous with your time and knowledge.

**Lauren Lissner**, my co-supervisor, for providing me with a workplace at "Epi" during my first year as a doctoral student, for involving me in the IDEFICS study, and for great advice on how to improve the content and language of the thesis.

I would like to thank all the adolescents participating in the smartphone application evaluation study for their curiosity and patience when completing the methods. I would also like to thank the teachers who welcomed me to their classes to recruit study participants and who helped me motivate them.

Thanks to my co-authors in the SELFH study, **Maria Waling** and **Catharina Bäcklund**, for doing a great job with SELFH and for valuable advice on our paper.

To all the co-authors in the LifeGene pre-pilot study, thank you for providing me with great data and advice on our paper.

I would also like to thank all co-authors in the IDEFICS study, especially **Gabriele Eiben** for answering my IDEFICS-related questions and **Anne Lanfer** for nice chats outside work.

Thanks to *everyone* at the Department of Food and Nutrition, and Sport Science, the base for my studies, for providing me with a supportive environment and regular coffee breaks. Special thanks to everyone participating in the doctoral student seminars and to **Agneta Sjöberg** for discussing my work at the pre-mid seminar.

Thanks also to my colleagues at Public Health Epidemiology "Epi" for our discussions and chats at research seminars and other occasions. A special thanks to **Kirsten Mehlig** for statistical counselling and to **Maria Magnusson** for an orientation into the world of qualitative research.

Thanks to my colleagues at the Department of Food and Nutrition, Umeå University. I have felt like one of you even though you have almost never seen me at work... Thank you **Petra Rydén** for being discussant at my mid seminar.

I would like to thank my past and present fellow doctoral students at the three above-mentioned departments. Special thanks to **Lotta** for our lunches and fikas, **Linn** and **Jenny** for being such good organizers, and **Stina** for input on my papers at the pre-mid seminar.

Thanks to my colleagues at other departments (Clinical Nutrition at University of Gothenburg, Linköping University, and Karolinska Institutet among others) whom I have had the pleasure of meeting during these years and who have helped me in my progress. Thank you **Katarina Bälter** and **Marie Löf** for discussing my work at mid and final seminars, and thanks to **Frode Slinde** and **Hilde Brekke** for lending me extra SenseWear Armbands to use in my study.

**Anna Karin Lindroos** at the National Food Agency, thank you for letting me use your database tables and portion size alternatives for the smartphone application method and your "web-based method" for comparison. Thanks also for discussing the smartphone application method and study. **Marianne Arnemo**, thank you for helping me use the web-based method.

**Mats Högdal** and **Fredrik Bäck**, thank you for your work on the smartphone application project.

Thank you **Moa Hallmyr Lewis**, **Agneta Mattiasson** and **Christopher Holmberg** for help and good company when making school visits in the smartphone application evaluation study. I could not have done it alone.

Last but not least, thanks to my family (**Mamma, Pappa, Elin, Mormor** and **Malte**) and friends.

# References

1. Shoeller DA. Validation of habitual energy intake. Public Health Nutr. 2002;5(6A):883-8.

2. Illner AK, Freisling H, Boeing H, Huybrechts I, Crispim S, Slimani N. Review and evaluation of innovative technologies for measuring diet in nutritional epidemiology. Int J Epidemiol. 2012;41(4):1187-203.

3. Nishida C, Uauy R, Kumanyika S, Shetty P. The joint WHO/FAO expert consultation on diet, nutrition and the prevention of chronic diseases: process, product and policy implications. Public Health Nutr. 2004;7(1A):245-50.

4. Maurer J, Taren DL, Teixeira PJ, Thomson CA, Lohman TG, Going SB, et al. The psychosocial and behavioral characteristics related to energy misreporting. Nutr Rev. 2006;64(2 Pt 1):53-66.

5. Gibson RS. Principles of Nutritional Assessment. 2nd ed. New York: Oxford University Press; 2005.

6. Cade JE, Burley VJ, Warm DL, Thompson RL, Margetts BM. Food-frequency questionnaires: a review of their design, validation and utilisation. Nutr Res Rev. 2004;17(1):5-22.

7. Willett W. Nutritional Epidemiology. 3d ed. New York: Oxford University Press; 2013.

8. Briefel RR. Assessment of the US diet in national nutrition surveys: national collaborative efforts and NHANES. Am J Clin Nutr. 1994;59(Suppl. 1):164-7.

9. Lambe J, Kearney J, Leclercq C, Zunft HF, De Henauw S, Lamberg-Allardt CJ, et al. The influence of survey duration on estimates of food intakes and its relevance for public health nutrition and food safety issues. Eur J Clin Nutr. 2000;54(2):166-73.

10. Amcoff E, Edberg A, Enghardt Barbieri H, Lindroos AK, Nälsén C, Pearson M, et al. Riksmaten - vuxna 2010-11. Livsmedels- och näringsintag bland vuxna i Sverige. [In Swedish]. Uppsala: Livsmedelsverket, 2012.

11. Foster E, Hawkins A, Delve J, Adamson AJ. Reducing the cost of dietary assessment: self-completed recall and analysis of nutrition for use with children (SCRAN24). J Hum Nutr Diet. 2014;27(Suppl. 1):26-35.

12. Kikunaga S, Tin T, Ishibashi G, Wang D-H, Kira S. The application of a handheld personal digital assistant with camera and mobile phone card (Wellnavi) to the general population in a dietary survey. J Nutr Sci Vitaminol. 2007;53:109-16.

13. Carter MC, Burley VJ, Nykjaer C, Cade JE. 'My Meal Mate' (MMM): validation of the diet measures captured on a smartphone application to facilitate weight loss. Br J Nutr. 2013;109(3):539-46.

14. Weiss R, Stumbo PJ, Divakaran A. Automatic food documentation and volume computation using digital imaging and electronic transmission. J Am Diet Assoc. 2010;110(1):42-4.

15. Schap TE, Zhu F, Delp EJ, Boushey CJ. Merging dietary assessment with the adolescent lifestyle. J Hum Nutr Diet. 2014;27(Suppl. 1):82-8.

16. Martin CK, Nicklas T, Gunturk B, Correa JB, Allen HR, Champagne C. Measuring food intake with digital photography. J Hum Nutr Diet. 2014;27(Suppl. 1):72-81.

17. Sun M, Fernstrom JD, Jia W, Hackworth SA, Yao N, Li Y, et al. A wearable electronic system for objective dietary assessment. J Am Diet Assoc. 2010;110(1):45-7.

18. Lacson R, Long W. Natural language processing of spoken diet records (SDRs). AMIA Annu Symp Proc. 2006:454-8.

19. Hunsberger M, Pena P, Lissner L, Grafström L, Vanaelst B, Börnhorst C, et al. Validity of self-reported lunch recalls in Swedish school children aged 6-8 years. Nutr J. 2013;12:129.

20. Livingstone MBE, Robson PJ, Wallace JMW. Issues in dietary intake assessment of children and adolescents. Br J Nutr. 2004;92(Suppl. 2):213-22.

21. Weir JB. New methods for calculating metabolic rate with special reference to protein metabolism. 1949. Nutrition. 1990;6(3):213-21.

22. Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA, et al. Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. Eur J Clin Nutr. 1991;45(12):569-81.

23. Choy K, Nash SH, Kristal AR, Hopkins S, Boyer BB, O'Brien DM. The carbon isotope ratio of alanine in red blood cells is a new candidate biomarker of sugar-sweetened beverage intake. J Nutr. 2013;143(6):878-84.

24. Tasevska N, Runswick SA, McTaggart A, Bingham SA. Urinary sucrose and fructose as biomarkers for sugar consumption. Cancer Epidemiol Biomarkers Prev. 2005;14(5):1287-94.

25. Tasevska N, Midthune D, Tinker LF, Potischman N, Lampe JW, Neuhouser ML, et al. Use of a urinary sugars biomarker to assess measurement error in self-reported sugars intake in the Nutrition and Physical Activity Assessment Study (NPAAS). Cancer Epidemiol Biomarkers Prev. 2014;23(12):2874-83.

26. Rutishauser IH. Dietary intake measurements. Public Health Nutr. 2005;8(7A):1100-7.

27. Hill RJ, Davies PS. The validity of self-reported energy intake as determined using the doubly labelled water technique. Br J Nutr. 2001;85(4):415-30.

28. Forrestal SG. Energy intake misreporting among children and adolescents: a literature review. Matern Child Nutr. 2011;7(2):112-27.

29. Champagne CM, Han H, Bajpeyi S, Rood J, Johnson WD, Lammi-Keefe CJ, et al. Day-to-day variation in food intake and energy expenditure in healthy women: the Dietitian II Study. J Acad Nutr Diet. 2013;113(11):1532-8.

30. Dodd KW, Guenther PM, Freedman LS, Subar AF, Kipnis V, Midthune D, et al. Statistical methods for estimating usual

intake of nutrients and foods: a review of the theory. J Am Diet Assoc. 2006;106(10):1640-50.

31. Tooze JA, Kipnis V, Buckman DW, Carroll RJ, Freedman LS, Guenther PM, et al. A mixed-effects model approach for estimating the distribution of usual intake of nutrients: the NCI method. Stat Med. 2010;29(27):2857-68.

32. Waling MU, Larsson CL. Energy intake of Swedish overweight and obese children is underestimated using a diet history interview. J Nutr. 2009;139(3):522-7.

33. Nordic Council of Ministers. Nordic Nutrition Recommendations 2004. Integrating nutrition and physical activity. 4th ed. Copenhagen: Nord; 2004.

34. European Food Safety Authority (EFSA). Scientific Opinion on Dietary Reference Values for carbohydrates and dietary fibre. EFSA Journal. 2010;8(3).

35. Salmon J. Excerpts from Dietary Reference Values for Food Energy and Nutrients for the United Kingdom: introduction to the Guide and Summary Tables. Nutr Rev. 1992;50(3):90-3.

36. Enghardt Barbieri H, Pearson M, Becker W. Riksmaten - barn 2003. Livsmedels- och näringsintag bland barn i Sverige. [In Swedish]. Uppsala: Livsmedelsverket, 2006.

37. National Diet and Nutrition Survey Results from years 1, 2, 3 and 4 (combined) of the rolling programme (2008/2009 - 2011/2012). London: Public Health England, 2014.

38. Welsh JA, Sharma A, Cunningham SA, Vos MB. Consumption of added sugars and indicators of cardiovascular disease risk among US adolescents. Circulation. 2011;123(3):249-57.

39. Sepp H, Lennernäs M, Pettersson R, Abrahamsson L. Children's nutrient intake at preschool and at home. Acta Paediatr. 2001;90(5):483-91.

40. Rothausen BW, Matthiessen J, Hoppe C, Brockhoff PB, Andersen LF, Tetens I. Differences in Danish children's diet quality on weekdays v. weekend days. Public Health Nutr. 2012;15(9):1653-60.

41. Hart CN, Raynor HA, Osterholt KM, Jelalian E, Wing RR. Eating and activity habits of overweight children on weekdays and weekends. Int J Pediatr Obes. 2011;6(5-6):467-72.

42. Garemo M, Lenner RA, Strandvik B. Swedish pre-school children eat too much junk food and sucrose. Acta Paediatr. 2007;96(2):266-72.

43. Alexy U, Sichert-Hellert W, Kersting M. Associations between intake of added sugars and intakes of nutrients and food groups in the diets of German children and adolescents. Br J Nutr. 2003;90(2):441-7.

44. Tinanoff N, Palmer CA. Dietary determinants of dental caries and dietary recommendations for preschool children. J Public Health Dent. 2000;60(3):197-206.

45. Sheiham A, James WP. A reappraisal of the quantitative relationship between sugar intake and dental caries: the need for new criteria for developing goals for sugar intake. BMC Public Health. 2014;14:863.

46. Clabaugh K, Neuberger GB. Research evidence for reducing sugar sweetened beverages in children. Issues Compr Pediatr Nurs. 2011;34(3):119-30.

47. Hu FB. Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases. Obes Rev. 2013;14(8):606-19.

48. Malik VS, Pan A, Willett WC, Hu FB. Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis. Am J Clin Nutr. 2013;98(4):1084-102.

49. Kaiser KA, Shikany JM, Keating KD, Allison DB. Will reducing sugar-sweetened beverage consumption reduce obesity? Evidence supporting conjecture is strong, but evidence when testing effect is weak. Obes Rev. 2013;14(8):620-33.

50. Park MH, Falconer C, Viner RM, Kinra S. The impact of childhood obesity on morbidity and mortality in adulthood: a systematic review. Obes Rev. 2012;13(11):985-1000.

51. Almqvist C, Adami HO, Franks PW, Groop L, Ingelsson E, Kere J, et al. LifeGene – a large prospective population-based study of global relevance. Eur J Epidemiol. 2011;26(1):67-77.

52. Becker W, Pearson M. Riksmaten 1997-98. Kostvanor och näringsintag i Sverige. Metod- och resultatanalys. [In Swedish]. Uppsala: Livsmedelsverket, 2002.

53. Livsmedelsverket. Vikttabell. [In Swedish]. Uppsala: Livsmedelsverket; 1999.

54. Winkvist A, Hörnell A, Hallmans G, Lindahl B, Weinehall L, Johansson I. More distinct food intake patterns among women than men in northern Sweden: a population-based survey. Nutr J. 2009;8:12.

55. Johansson G, Wikman A, Ahrén AM, Hallmans G, Johansson I. Underreporting of energy intake in repeated 24-hour recalls related to gender, age, weight status, day of interview, educational level, reported food intake, smoking habits and area of living. Public Health Nutr. 2001;4(4):919-27.

56. Johansson I, Hallmans G, Wikman A, Biessy C, Riboli E, Kaaks R. Validation and calibration of food-frequency questionnaire measurements in the Northern Sweden Health and Disease cohort. Public Health Nutr. 2002;5(3):487-96.

57. Ahrens W, Bammann K, Siani A, Buchecker K, De Henauw S, Iacoviello L, et al. The IDEFICS cohort: design, characteristics and participation in the baseline survey. Int J Obes (Lond). 2011;35(Suppl. 1):3-15.

58. Vereecken CA, Covents M, Matthys C, Maes L. Young adolescents' nutrition assessment on computer (YANA-C). Eur J Clin Nutr. 2005;59(5):658-67.

59. Hebestreit A, Reinecke A, Huybrechts I. Computer based 24-hour dietary recall: the SACINA program. In: Bamman K, Ahrens W, editors. Measurement tools for a health survey on nutrition, physical activity and lifestyle in children: the European IDEFICS study. New York: Springer; 2013.

60. Börnhorst C, Huybrechts I, Ahrens W, Eiben G, Michels N, Pala V, et al. Prevalence and determinants of misreporting among European children in proxy-reported 24 h dietary recalls. Br J Nutr. 2012;109(7):1257-65.

61. Waling MU. Dietary and metabolic effects of a 2-year lifestyle intervention on overweight and obese children. Umeå: Umeå University; 2011.

62. Håglin L, Hagman U, Nilsson M. Evaluation of the meal model "Matmallen": a means of estimating consumed amounts of food. Scand J Nutr. 1995;39:79-83.

63. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 2000;320(7244):1240-3.

64. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R, et al. CDC growth charts: United States. Adv Data. 2000(314):1-27.

65. He Q, Albertsson-Wikland K, Karlberg J. Population-based body mass index reference values from Göteborg, sweden: birth to 18 years of age. Acta Paediatr. 2000;89(5):582-92.

66. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ. 2007;85(9):660-7.

67. Dietz WH, Bandini LG, Schoeller DA. Estimates of metabolic rate in obese and nonobese adolescents. J Pediatr. 1991;118(1):146-9.

68. Torun B. Energy requirements of children and adolescents. Public Health Nutr. 2005;8(7A):968-93.

69. Henry CJ. Basal metabolic rate studies in humans: measurement and development of new equations. Public Health Nutr. 2005;8(7A):1133-52.

70. http://siris.skolverket.se/siris/ris.elever_gr.rapport [In Swedish]. Stockholm: Skolverket; 2014 [cited 2014 October 20].

71. Karlsson J, Persson LO, Sjöström L, Sullivan M. Psychometric properties and factor structure of the Three-Factor Eating Questionnaire (TFEQ) in obese men and women. Results

from the Swedish Obese Subjects (SOS) study. Int J Obes Relat Metab Disord. 2000;24(12):1715-25.

72. Stunkard AJ, Sørensen T, Shulsinger F. Use of the Danish Adoption Register for the study of obesity and thinness. Research publications - Association for Research in Nervous and Mental Disease. 1983;60:115-20.

73. Leary MR. A brief version of the Fear of Negative Evaluation Scale. Pers Soc Psychol B. 1983;9:371-6.

74. Crowne DP, Marlow D. A new scale of social desirability independent of psychopathology. J Consult Psych. 1960;24(4):349-54.

75. Goldberg L, Johnson J, Eber H, Hogan R, Ashton M, Cloninger C, et al. The International Personality Item Pool and the future of public-domain personality measures. J Res Pers. 2006;40:84-96.

76. Lioret S, Touvier M, Balin M, Huybrechts I, Dubuisson C, Dufour A, et al. Characteristics of energy under-reporting in children and adolescents. Br J Nutr. 2011;105(11):1671-80.

77. Sjöberg A, Slinde F, Arvidsson D, Ellegård L, Gramatkovski E, Hallberg L, et al. Energy intake in Swedish adolescents: Validation of diet history with doubly labelled water. Eur J Clin Nutr. 2003;57:1643-52.

78. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes. 2012;7(4):284-94.

79. Westerterp KR, Goris AHC. Validity of the assessment of dietary intake: Problems of misreporting. Curr Opin Clin Nutr Metab Care. 2002;5:489-93.

80. Livingstone MBE, Black AE. Markers of the validity of reported energy intake. J Nutr. 2003;133(Suppl. 3):895-920.

81. Subar AF, Kipnis V, Troiano RP, Midthune D, Schoeller DA, Bingham S, et al. Using intake biomarkers to evaluate the extent of dietary misreporting in a large sample of adults: the OPEN study. Am J Epidemiol. 2003;158(1):1-13.

82. Freedman LS, Commins JM, Moler JE, Arab L, Baer DJ, Kipnis V, et al. Pooled results from 5 validation studies of dietary self-report instruments using recovery biomarkers for energy and protein intake. Am J Epidemiol. 2014;180(2):172-88.

83. Scagliusi FB, Ferriolli E, Pfrimer K, Laureano C, Cunha CS, Gualano B, et al. Underreporting of energy intake in Brazilian women varies according to dietary assessment: a cross-sectional study using doubly labeled water. J Am Diet Assoc. 2008;108(12):2031-40.

84. Kroke A, Klipstein-Grobusch K, Voss S, Möseneder J, Thielecke F, Noack R, et al. Validation of a self-administered food-frequency questionnaire administered in the European Prospective Investigation into Cancer and Nutrition (EPIC) Study: comparison of energy, protein, and macronutrient intakes estimated with the doubly labeled water, urinary nitrogen, and repeated 24-h dietary recall methods. Am J Clin Nutr. 1999;70(4):439-47.

85. Andersen LF, Tomten H, Haggarty P, Løvø A, Hustvedt BE. Validation of energy intake estimated from a food frequency questionnaire: a doubly labelled water study. Eur J Clin Nutr. 2003;57(2):279-84.

86. Lutomski JE, van den Broeck J, Harrington J, Shiely F, Perry IJ. Sociodemographic, lifestyle, mental health and dietary factors associated with direction of misreporting of energy intake. Public Health Nutr. 2011;14(3):532-41.

87. Yannakoulia M, Panagiotakos DB, Pitsavos C, Bathrellou E, Chrysohoou C, Skoumas Y, et al. Low energy reporting related to lifestyle, clinical, and psychosocial factors in a randomly selected population sample of Greek adults: the ATTICA Study. J Am Coll Nutr. 2007;26(4):327-33.

88. Lissner L, Troiano RP, Midthune D, Heitmann BL, Kipnis V, Subar AF, et al. OPEN about obesity: recovery biomarkers, dietary reporting errors and BMI. Int J Obes (Lond). 2007;31(6):956-61.

89. Liu L, Wang PP, Roebothan B, Ryan A, Tucker CS, Colbourne J, et al. Assessing the validity of a self-administered food-frequency questionnaire (FFQ) in the adult population of Newfoundland and Labrador, Canada. Nutr J. 2013;12:49.

90. Bountziouka V, Bathrellou E, Giotopoulou A, Katsagoni C, Bonou M, Vallianou N, et al. Development, repeatability and validity regarding energy and macronutrient intake of a semi-quantitative food frequency questionnaire: methodological considerations. Nutr Metab Cardiovasc Dis. 2012;22(8):659-67.

91. Barrett JS, Gibson PR. Development and validation of a comprehensive semi-quantitative food frequency questionnaire that includes FODMAP intake and glycemic index. J Am Diet Assoc. 2010;110(10):1469-76.

92. Paalanen L, Männistö S, Virtanen MJ, Knekt P, Räsänen L, Montonen J, et al. Validity of a food frequency questionnaire varied by age and body mass index. J Clin Epidemiol. 2006;59(9):994-1001.

93. Block G, Hartman AM, Naughton D. A reduced dietary questionnaire: development and validation. Epidemiology. 1990;1(1):58-64.

94. Molag ML, de Vries JH, Ocké MC, Dagnelie PC, van den Brandt PA, Jansen MC, et al. Design characteristics of food frequency questionnaires in relation to their validity. Am J Epidemiol. 2007;166(12):1468-78.

95. Krebs-Smith SM, Heimendinger J, Subar AF, Patterson BH, Pivonka E. Estimating fruit and vegetable intake using food frequency questionnaires: a comparison of instruments. Am J Clin Nutr. 1994;59:283.

96. Subar AF, Ziegler RG, Thompson FE, Johnson CC, Weissfeld JL, Reding D, et al. Is shorter always better? Relative importance of questionnaire length and cognitive ease on response rates and data quality for two dietary questionnaires. Am J Epidemiol. 2001;153(4):404-9.

97. Baer HJ, Blum RE, Rockett HR, Leppert J, Gardner JD, Suitor CW, et al. Use of a food frequency questionnaire in American Indian and Caucasian pregnant women: a validation study. BMC Public Health. 2005;5:135.

98. Barbieri P, Nishimura RY, Crivellenti LC, Sartorelli DS. Relative validation of a quantitative FFQ for use in Brazilian pregnant women. Public Health Nutr. 2013;16(8):1419-26.

99. Butte NF, King JC. Energy requirements during pregnancy and lactation. Public Health Nutr. 2005;8(7A):1010-27.

100. Mouratidou T, Ford FA, Fraser RB. Reproducibility and validity of a food frequency questionnaire in assessing dietary intakes of low-income Caucasian postpartum women living in Sheffield, United Kingdom. Matern Child Nutr. 2011;7(2):128-39.

101. Brantsaeter AL, Haugen M, Alexander J, Meltzer HM. Validity of a new food frequency questionnaire for pregnant women in the Norwegian Mother and Child Cohort Study (MoBa). Matern Child Nutr. 2008;4(1):28-43.

102. Sauvageot N, Alkerwi A, Albert A, Guillaume M. Use of food frequency questionnaire to assess relationships between dietary habits and cardiovascular risk factors in NESCAV study: validation with biomarkers. Nutr J. 2013;12(1):143.

103. Serra-Majem L, Pfrimer K, Doreste-Alonso J, Ribas-Barba L, Sánchez-Villegas A, Ortiz-Andrellucchi A, et al. Dietary assessment methods for intakes of iron, calcium, selenium, zinc and iodine. Br J Nutr. 2009;102(Suppl. 1):38-55.

104. Carlsen MH, Karlsen A, Lillegaard IT, Gran JM, Drevon CA, Blomhoff R, et al. Relative validity of fruit and vegetable intake estimated from an FFQ, using carotenoid and flavonoid biomarkers and the method of triads. Br J Nutr. 2011;105(10):1530-8.

105. Combet E, Lean M. Validation of a short food frequency questionnaire specific for iodine in UK females of childbearing age. J Hum Nutr Diet. 2014;27(6):599-605.

106. Bandini LG, Schoeller DA, Cyr HN, Dietz WH. Validity of reported energy intake in obese and nonobese adolescents. Am J Clin Nutr. 1990;52(3):421-5.

107. Champagne CM, Baker NB, DeLany JP, Harsha DW, Bray GA. Assessment of energy intake underreporting by doubly labeled water and observations on reported nutrient intakes in children. J Am Diet Assoc. 1998;98(4):426-33.

108. Bandini LG, Cyr H, Must A, Dietz WH. Validity of reported energy intake in preadolescent girls. Am J Clin Nutr. 1997;65(Suppl. 4):1138-41.

109. Bratteby L-E, Sandhagen B, Fan H, Enghardt H, Samuelson G. Total energy expenditure and physical activity as assessed by the doubly labeled water method in Swedish adolescents in whom energy intake was underestimated by 7-d diet records. Am J Clin Nutr. 1998;67(5):905-11.

110. Singh R, Martin BR, Hickey Y, Teegarden D, Campbell WW, Craig BA, et al. Comparison of self-reported, measured, metabolizable energy intake with total energy expenditure in overweight teens. Am J Clin Nutr. 2009;89(6):1744-50.

111. Bexelius C, Löf M, Sandin S, Trolle Lagerros Y, Forsum E, Litton JE. Measures of physical activity using cell phones: validation using criterion methods. J Med Internet Res. 2010;12(1):e2.

112. Bexelius C, Sandin S, Trolle Lagerros Y, Litton JE, Löf M. Estimation of physical activity levels using cell phone questionnaires: a comparison with accelerometry for evaluation of between-subject and within-subject variations. J Med Internet Res. 2011;13(3):e70.

113. Johansson G, Westerterp KR. Assessment of the physical activity level with two questions: validation with doubly labeled water. Int J Obes (Lond). 2008;32(6):1031-3.

114. Burrows TL, Martin RJ, Collins CE. A systematic review of the validity of dietary assessment methods in children when compared with the method of doubly labeled water. J Am Diet Assoc. 2010;110:1501-10.

115. Steele R. An Overview of the State of the Art of Automated Capture of Dietary Intake Information. Crit Rev Food Sci Nutr. 2014. (E-publication ahead of print version).

116. 2007 Australian National Children's Nutrition and Physical Activity Survey. Main Findings. 2007.

117. Lambert J, Agostoni C, Elmadfa I, Hulshof K, Krause E, Livingstone B, et al. Dietary intake and nutritional status of children and adolescents in Europe. Br J Nutr. 2004;92(Suppl. 2):147-211.

118. Lehtisalo J, Erkkola M, Tapanainen H, Kronberg-Kippilä C, Veijola R, Knip M, et al. Food consumption and nutrient

intake in day care and at home in 3-year-old Finnish children. Public Health Nutr. 2010;13(6A):957-64.

119. Frost Andersen L, Överby N, Lillegaard IT. Er det forskjell på hva barn spiser på hverdager og i helgen? [In Norwegian]. Barn. 2003(2-3):89-98.

120. Rockell JE, Parnell WR, Wilson NC, Skidmore PM, Regan A. Nutrients and foods consumed by New Zealand children on schooldays and non-schooldays. Public Health Nutr. 2011;14(2):203-8.

121. Macdiarmid J, Loe J, Craig LC, Masson LF, Holmes B, McNeill G. Meal and snacking patterns of school-aged children in Scotland. Eur J Clin Nutr. 2009;63(11):1297-304.

122. Van Remoortel H, Giavedoni S, Raste Y, Burtin C, Louvaris Z, Gimeno-Santos E, et al. Validity of activity monitors in health and chronic disease: a systematic review. Int J Behav Nutr Phys Act. 2012;9:84.

123. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet. 1986;1(8476):307-10.

124. Regber S, Novak M, Eiben G, Lissner L, Hense S, Sandström TZ, et al. Assessment of selection bias in a health survey of children and families – the IDEFICS Sweden-study. BMC Public Health. 2013;13(1):418.