Universidade de Lisboa
Faculdade de Medicina de Lisboa

Food consumption in school-age children – a new web-based recall for dietary assessment in Portugal

Maria Ana Silva Carvalho Cohen Kadosh

Orientadores: Prof. Doutor José Manuel Domingos Pereira Miguel
Prof.ª Doutora Ana Isabel Gomes Rito

Tese especialmente elaborada para obtenção do grau de Doutor em Doenças Metabólicas e Comportamento Alimentar, ramo Ciências e Tecnologias da Saúde, especialidade Nutrição.

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Doctoral Programme in Metabolic Disorders and Eating Behaviour

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2016

A impressão desta tese foi aprovada pelo Conselho Científico da Faculdade de Medicina de Lisboa em reunião de 20 de Outubro de 2015.

To my Mother

LIBERDADE, Fernando Pessoa

Ai que prazer
Não cumprir um dever,
Ter um livro para ler
E não o fazer!
Ler é maçada,
Estudar é nada.
O sol doira
Sem literatura.
O rio corre, bem ou mal,
Sem edição original.
E a brisa, essa,
De tão naturalmente matinal,
Como tem tempo não tem pressa...

Livros são papéis pintados com tinta.
Estudar é uma coisa em que está indistinta
A distinção entre nada e coisa nenhuma.

Quanto é melhor, quanto há bruma,
Esperar por D. Sebastião,
Quer venha ou não!

Grande é a poesia, a bondade e as danças...
Mas o melhor do mundo são as crianças,
Flores, música, o luar, e o sol, que peca
Só quando, em vez de criar, seca.

O mais do que isto
É Jesus Cristo,
Que não sabia nada de finanças
Nem consta que tivesse biblioteca...

This PhD thesis is based on the following three papers (Paper 1-3), referred to the text by their numbers and reproduced as appendices (Paper 1 and Paper 2):

Paper 1 (Appendix I)

Development of a new computer program to assess dietary intake in Portuguese school-age children: a qualitative approach.

Maria Ana Carvalho, Osvaldo Santos, Ana Rito, Emma Foster, Helen J Moore, José Pereira Miguel

Acta Pediátrica Portuguesa 2014; 45: 116-123.

Paper 2 (Appendix II)

Validation of the Portuguese self-administered computerised 24-hour Dietary Recall (PAC24) among second-, third- and fourth-grade children.

Maria Ana Carvalho, Tom Baranowski, Emma Foster, Osvaldo Santos, Bruno Cardoso, Ana Rito, José Pereira Miguel

Journal of Human Nutrition and Dietetics 2014; doi: 10.1111/jhn.12280. [Epub ahead of print]

Paper 3

The Portuguese self-administered computerised 24-hour dietary recall (PCA24): a web application for dietary assessment in children.

Maria Ana Carvalho, Emma Foster, Bruno Cardoso, Osvaldo Santos, Ana Rito, José Pereira Miguel

(Submitted)

Preface

"There can be no keener revelation of a society's soul than the way in which it treats its children", Nelson Mandela

Since I was young, I dreamed of working with and for children. I spent the best part of my childhood studying, reading and playing as a doctor, a teacher and a mother. I always knew what made me happy and I have been working ever since to achieve my goals.

I started my undergraduate degree in Dietetics and Nutrition in 2004. In 2007, I did a nutrition training at the National Directorate of Public Health of Angola where I collaborated on two different projects: 1) Management of childhood malnutrition and 2) Baby Friendly Hospital Initiative, both of UNICEF. This experience strengthened my will to study, work and research in the field of childhood nutrition in order to be able to contribute, in some way, to the improvement of children's quality of life.

In 2008, I enrolled in the Doctoral Programme in Metabolic Disorders and Eating Behaviour at the Faculty of Medicine, University of Lisbon. At the same time, I started to work on some community projects whose main purpose was to tackle childhood obesity, namely the Childhood Obesity Surveillance Initiative-Portugal (COSI-Portugal), Project Obesity Zero (POZ) and MUN-SI Project. I had the great honour and opportunity to work in one of the most prestigious nutrition teams in Portugal who encouraged the development of my PhD.

One of the most difficult and challenging parts of these projects was related to the assessment of dietary intake in children. The measurement of energy and nutrients is challenging because of many unique respondent and observer considerations. Furthermore, accurate dietary assessment is critical for monitoring the nutritional status of children and for measuring the impact of dietary interventions.

This thesis describes the development, validation and pilot study of a new web-based recall for dietary assessment in Portuguese school-age children: the Portuguese self-administered computerised 24-hour Dietary Recall (PAC24). The present thesis has six

chapters. Chapter 1 presents a literature review about childhood nutrition and health, food consumption, the assessment of dietary intake and the application of new technologies in nutritional epidemiology. Chapter 2 describes the methodology used in the development of this work. Chapters 3, 4 and 5 present the development, validation and pilot study of PAC24, respectively. Finally, Chapter 6 discusses the development of PAC24, reviews its strengths and limitations and attempts to anticipate the direction of future research.

It is my hope that the readers and experts in this area find this thesis useful for their practices. Moreover, I am confident that PAC24 will start to be used to monitor the dietary intake of Portuguese school-age children and that this will provide the basis for epidemiological studies on the links between nutrition and health, which in turn will contribute to the improvement of public health policies and the design of national health programmes.

Maria Ana Silva Carvalho

Lisbon, Portugal.

September 2015

Acknowledgements

First and foremost, I would like to thank Prof.ª Doutora Isabel do Carmo who believed in my work from the beginning and allowed me to enrol in this PhD. Thank you to my supervisor, Prof. Doutor José Pereira Miguel for encouraging me to develop a critical work and for all the challenges and invitations given, particularly for allowing me to be part of the organizing committee of the *I Simpósio sobre Alimentação e Nutrição dos 0 aos 18*. Thanks to Prof.ª Doutora Ana Rito for her guidance, friendship and for all the opportunities that allowed me to acquire both knowledge and experience.

I would also like to thank Mestre Osvaldo Santos for all the scientific support given throughout the development and validation of PAC24; Engenheiro Bruno Cardoso for his tireless dedication and technical support in the development of PAC24; Dr. Emma Foster for having me in Newcastle University for an internship and for teaching me and sharing the basis in computerised dietary recalls that were essential to the development of PAC24; Dr. Tom Baranowski for sharing his scientific knowledge about web dietary assessment programs for children and also for his participation in PAC24 validation.

Thank you to my best friend for giving me faith, hope and strength every day. Special thanks to Ana Lúcia, Beatriz, Carlos, Grigas, Leonor, Mariana and Rita, you made this journey so much easier.

To my family, in particular to my mother, Luísa, my sister, Catarina, and my brother, João. Thank you for your support and for your unconditional love. You are truly the best family in the world!

And last (but not least) to my husband, Lourenço. Thank you for your love. Thank you for being the one and only to make me believe and laugh in the most difficult moments. Without you, this thesis wouldn't have been possible.

Resumo

A avaliação do consumo alimentar infantil é crucial para monitorizar o estado nutricional das crianças, explorar a relação entre a alimentação e o estado de saúde das populações em idade pediátrica, bem como identificar padrões e comportamentos alimentares nesta faixa etária. Esta avaliação levanta questões metodológicas referentes à validade e fiabilidade dos dados obtidos. O questionário às últimas 24-horas (Q24-h) representa um dos métodos, de avaliação do consumo alimentar, mais exatos para estimar o valor energético e nutricional em crianças e adolescentes. Contudo, o Q24-h é dispendioso e financeiramente inviável para estudos epidemiológicos em larga-escala. A utilização da tecnologia está a ser realizada em vários países do mundo, com o intuito de automatizar o Q24-h, tornando-o menos oneroso e de mais fácil e rápida utilização. O objetivo deste estudo é desenvolver, validar e ensaiar um novo questionário *online* para avaliar o consumo alimentar em crianças Portuguesas em idade escolar: o *Portuguese self-administered computerised 24-hour Dietary Recall* (PAC24).

O PAC24 é uma adaptação *online* do Q24-h desenhado para ser autoadministrado em crianças Portuguesas do segundo, terceiro ou quarto ano do 1º ciclo do ensino básico (7-10 anos de idade). As crianças são inicialmente inquiridas sobre o consumo de alimentos e bebidas realizado no dia anterior. A pesquisa de alimentos é feita através da inserção livre de texto em campos próprios, com um sistema de reconhecimento automático de erros ortográficos. Para a maioria dos alimentos, a quantidade consumida pela criança é estimada através da seleção da imagem da porção alimentar, servida e deixada no prato, representada em sete imagens digitais correspondentes a sete porções diferentes. A informação sobre a hora, o local, bem como a utilização de televisão e computador é atribuída para cada uma das refeições. O código e o peso (g ou mL) de cada alimento selecionado é atribuído para cada item alimentar. A base de dados disponível contém 380 alimentos. A informação sobre os alimentos e o respetivo valor energético e nutricional está ligada a uma base de dados que contém essencialmente informação da Tabela da Composição dos Alimentos consumidos em Portugal.

O desenvolvimento do PAC24 foi baseado numa revisão da literatura, em 21 sessões de *Focus Groups* (FG) conduzidas em sete escolas do 1º ciclo do ensino básico, localizadas nas sete regiões de Portugal, e a partir do contributo de investigadores, nacionais e internacionais, com experiência reconhecida em metodologias de avaliação do consumo alimentar infantil. O primeiro protótipo do PAC24 foi testado e o seu conteúdo validado

por um painel de peritos. A exatidão do PAC24 foi estudada através da sua comparação com a observação do almoço escolar consumido pelas crianças (‘*gold standard*’) de duas escolas básicas da região de Lisboa e Vale do Tejo (LVT). Foi conduzido um estudo piloto para testar a exequibilidade do PAC24 no que respeita aos procedimentos, métodos e processamento dos dados. O estudo piloto foi conduzido numa escola básica na região de LVT em dois dias não consecutivos com 15 dias de intervalo. O consumo alimentar, em particular a ingestão energética e nutricional (proteína, gordura total, hidratos de carbono, fibra, cálcio, sódio e potássio) foi estudado. O teste de Wilcoxon foi utilizado para comparar o consumo alimentar entre o primeiro e o segundo momento de avaliação. O valor de $p<0.05$ foi considerado estatisticamente significativo.

Participaram 204 crianças nas sessões de FG, tendo sido identificados 3959 itens alimentares. A forma como as crianças reportaram o consumo alimentar do dia anterior foi demonstrada: a maioria das crianças reportou o consumo de alimentos de forma cronológica, organizado pelas três refeições principais; os *snacks* e alguns alimentos, como os doces, foram apenas reportados após questões específicas; nem todas as crianças reportaram o consumo alimentar de forma bem sucedida. Por último, foram identificados diferentes significados e formas de denominar os alimentos com especificidade regional. Estes resultados foram tidos em conta no desenvolvimento do PAC24. No teste de usabilidade (n=12), verificou-se que o PAC24 é um questionário atrativo para as crianças em idade escolar e consequentemente capaz de captar a atenção das crianças aquando o seu preenchimento. Foram ainda verificados alguns problemas técnicos que foram simplificados e modificados previamente ao estudo de validação. A comparação do PAC24 com a observação do almoço escolar (n=41 crianças) resultou, ao nível dos alimentos, em 67.0% de *matches* (alimentos/bebidas reportados no PAC24 e na observação do almoço escolar), 11.5% de *intrusions* (alimentos/bebidas reportados no PAC24 mas não na observação do almoço escolar) e 21.5% de *omissions* (alimentos/bebidas reportados na observação do almoço escolar mas não no PAC24). A utilização do PAC24 levou à subestimação do peso dos alimentos, em média, em 32%. Os resultados provenientes do estudo piloto demonstraram que as crianças (n=48) demoraram em média 27 minutos para completar o PAC24. A ingestão média de energia foi de 1799 kcal e a de proteína, gordura total e hidratos de carbono (em termos percentuais do valor energético total) foi de 17.2%, 29.0% e 47.8%, respetivamente. Não foram encontradas diferenças estatisticamente significativas entre o consumo alimentar no primeiro e segundo momento de avaliação ($p>0.05$).

Em suma, o PAC24 é custo-efetivo, intuitivo e atrativo para as crianças Portuguesas em idade escolar. O PAC24 pode ser utilizado para estimar, de forma válida, o consumo alimentar em grupo, em particular a ingestão energética e nutricional. Esta informação é crucial para o desenho e a implementação de estudos epidemiológicos que visem o estudo da relação entre a alimentação e a saúde das crianças, bem como de políticas de saúde ao nível nacional.

Palavras Chave: crianças, avaliação do consumo alimentar, questionário às últimas 24 horas, tecnologia, validade.

Abstract

Accurate dietary assessment is critical for monitoring the nutritional status of children, examining associations between diet and health, and identifying dietary intake patterns and eating behaviours. The study of diets of children poses methodological problems relating to the accuracy of assessment. The 24-hour Dietary Recall (24-h DR) is among the most accurate methods to estimate total energy and nutrient intakes in school-age children. Traditional 24-h DR is expensive and impractical for large-scale studies. The application of technology to automate the more accurate 24-h DR is being conducted in multiple countries across the world, making them less expensive and easier to use. The objective of this study is to develop, validate and test a new web-based recall for dietary assessment in Portuguese school-age children: the Portuguese self-administered computerised 24-h DR (PAC24).

The PAC24 is a self-administered web-based 24-h DR based on multiple pass method directed to second-, third- or fourth-grade Portuguese children (7-10 years old). In PAC24, children are first questioned about food and drink consumption on the previous day. Food entry is done via free text search, supported by a spell check application. For the majority of foods, amount consumed is estimated by selecting the closest portion size, served and leftover, if any, among seven different digital images. Data about time, place, television watching and computer use are assigned to each eating occasion. The food composition code and weight (g or mL) of selected items are automatically allocated and stored. A database of 380 food items is available. Food, energy and nutrient information is linked to a database that contains essentially information about Portuguese food composition table.

The development of PAC24 was based on literature review, 21 focus groups (FG) developed in seven primary schools of the seven main regions of Portugal and input from national and international researchers with experience in computer-dietary assessment among children. A prototype of PAC24 was tested and its content was validated through an expert meeting. Accuracy was determined by comparison of PAC24 with lunch observations (‘gold standard’) in two schools in Lisbon and Tagus Valley (LTV) region. A pilot study was conducted to check the feasibility of PAC24 with respect to procedures, methods and data processing in one primary school in LTV region on two non-consecutive days with 15 days apart. The food consumption, particularly total energy and nutrient (protein, total fat, carbohydrate, fibre, calcium,

sodium, potassium) intakes were studied. Wilcoxon signed-rank tests were used to compare the food consumption between the first and second measurement occasion. A p-value <0.05 level was considered as statistically significant.

Two hundred and four children participated in the FG, where 3959 food items were identified. The main ways in which children report their previous day's food consumption were revealed: they generally reported foods chronologically organized by the three main meals; snacks and some foods like sweets were only reported after specific prompts; not all children were able to report foods successfully. Finally, different meanings and labelling of some specific food items were identified and taken into account in the development of PAC24. In the usability test (n=12), it was shown that PAC24 is engaging for school-age children and therefore captures and maintains their attention while completing the questionnaire. This study also identified some technical problems that were simplified and modified before the validation study. Comparison of PAC24 against observations (n=41 children) at the food level resulted in 67.0% for matches (foods/drinks reported in PAC24 and by observers), 11.5% for intrusions (foods/drinks reported in PAC24 but not by the observers) and 21.5% for omissions (foods/drinks reported by the observers but not in PAC24). Use of the PAC24 led to underestimates of the weight of food on average by 32% of the actual intake. Children took on average 27 minutes to complete PAC24 on pilot study (n=48 children). Mean energy intake per day was 1799 kcal. Mean protein, carbohydrate and total fat intakes (as a percentage of energy intake) were 17.2%, 47.8% and 29.0%, respectively. Significant differences were not observed on food consumption between the first and second measurement occasion (p>0.05).

In summary, PAC24 is a cost-effective, intuitive and an engaging method for Portuguese school-age children. The PAC24 could be used to estimate dietary intake on a group level, accurately. This method will provide useful information for epidemiological studies on the links between diet and health and contribute to the improvement of public health policies at national level.

Keywords: accuracy, children, dietary assessment, technology, 24-h dietary recall.

List of Abbreviations

AMPM	Automated Multiple-Pass Method
ASA24-Kids	Automated Self Administered 24^{TM}-Kids
BMI	Body Mass Index
CAAFE	Food Intake and Physical Activity of School Children
DH	Diet History
DLW	Doubly Labeled Water
DRIs	Dietary Reference Intakes
EFCOVAL	European Food Consumption Validation Project
EFSA	European Food Safety Authority
EGFCD	Expert Group on Food Consumption Data
EI	Energy Intake
EU	European Union
FAO	Food and Agriculture Organization
FFQ	Food Frequency Questionnaire
FG	Focus Groups
FIRSSt	Food Intake Recording Software System
FR	Food Record
FVJ	Fruit, Vegetable and Juice
HBS	Household Budget Surveys
ICC	Intra Class Correlation
IOM	Institute Of Medicine's
IOR	Inter-Observer Reliability
IPSAS	Interactive Portion Size Assessment System
LTV	Lisbon and Tagus Valley
MUFA	Monounsaturated Fatty Acids
NHANES	National Health and Nutrition Examination Survey
NDNS	British National Diet and Nutrition Survey
NCDs	Non-Communicable Diseases
NPV	Net Present Value
PANCAKE	Pilot Study for Assessment of Nutrient Intake and Food Consumption Among Kids in Europe
PAC24	Portuguese self-administered computerised 24-hour dietary recall

PUFA	Polyunsaturated Fatty Acids
SCRAN24	Self-Completed Recall and Analysis of Nutrition
SFA	Saturated Fatty Acids
SNAP	Synchronised Nutrition and Activity Program
TEE	Total Energy Expenditure
TFA	Trans Fatty Acids
UK	United Kingdom
USA	United States of America
Web-SPAN	Web-Survey of Physical Activity and Nutrition
WHO	World Health Organization
WebDASC	Web-based Dietary Assessment Software for Children
YANA-C	Young Adolescent's Nutrition Assessment on Computer
24-h DR	24-hour Dietary Recall

Contents

1. General Introduction

In the light of the growing awareness of the possible connection between the diets of children and adolescents and diseases of adulthood, the diets of young people have recently received increased attention. Cardiovascular diseases, cancer, and obesity are among the diseases that have been suggested to have their origin in childhood eating habits.

Increases in obesity prevalence over the last few decades have been dramatic in all age groups. The emergence of childhood obesity as a serious public health problem underscores the need for dietary assessment tools that are not only valid and reliable but also feasible to administer across multiple settings and age ranges and with diverse populations.

Accurate dietary assessment is critical for monitoring the nutritional status of children, examining associations between diet and health, and identifying dietary intake patterns and eating behaviours that are associated with unhealthy weight and weight gain over time. Such information is critical for developing intervention messages and behavioural targets for obesity prevention and treatment programmes and for evaluating their effectiveness.

The study of diets of children poses methodological problems relating to the accuracy of assessment. Dietary studies in children have an additional dimension of difficulty because children's cognitive ability to record or remember their diets as well as their limited knowledge of food and food preparation must be addressed. The use of a computerised 24-hour dietary recall has the potential not only to engage the user and make the task less onerous but also to reduce the amount of researcher time required. It also helps to improve the consistency of coding and reduce the potential for data entry errors.

1.1 Childhood nutrition & health

Non-communicable diseases (NCDs) are increasing in prevalence across the globe and are the biggest cause of death worldwide. More than 36 million people died from NCDs

in 2008, mainly cardiovascular diseases (48%), cancers (21%), chronic respiratory diseases (12%) and diabetes (3%) (1). In 2002, 1.2 million children and youth under age 20 died of NCDs (2).

The role of early nutrition in regulating the expression of later NCDs has been receiving an increase of attention in the last decades (3). Barker (4,5) carried out a landmark study where he demonstrated inverse associations between birth weight and the risk of the metabolic syndrome, cardiovascular diseases, stroke, hypertension and type 2 diabetes across the entire range of birth weight. The whole phenomenon is known as 'nutritional programming'. This definition implies that certain nutrients if exquisitely timed during sensitive periods may determine an endocrine-metabolic asset leading to permanent changes whose clinical expression might take place several decades later. However, most studies have limited validity because of their cross-sectional or retrospective design (6) and more research in this area is needed.

Unhealthy diet, particularly the excessive intake of energy, saturated fats and trans fats, free sugars and salt, as well as low consumption of fruit and vegetables, and physical inactivity is recognized by WHO's Global Strategy for the Prevention and Control of Noncommunicable Diseases as the main risk factors for NCDs (8), is addressed more specifically by WHO's Global Strategy on Diet, Physical Activity and Health (9) and is also acknowledged in the Vienna Declaration on Nutrition and Noncommunicable Diseases in the Context of Health 2020 (10). The diets people eat define to a large extent people's health, growth and development (11) and a Mediterranean-like dietary pattern, rich in cereals, vegetables, fruit, nuts, fish and low in meat and dairy products, is inversely associated with obesity in children. However, this dietary pattern is not common in children living in the Mediterranean region (12).

Childhood obesity is a major risk factor for NCDs and its prevalence has increased substantially, although the rise in obesity prevalence in several high-income countries might be reaching a plateau (13). Globally, an estimated 170 million children and adolescents are overweight (14). The prevalence of overweight (including obesity) among 6-9 years old children in the European Region was between 19.3-49.0% in boys and 18.4-42.5% in girls in 2008 (15), and was between 18.0-57.2% in boys and 18.2-50.0% in girls in 2010 (16). Rates were higher among children in southern Europe

(15,16). Portugal is one of the European countries with the highest prevalence of childhood obesity: 37.9% of school-age children are overweight (17).

Childhood obesity is a complex disorder that is affected by many interacting genetic and non-genetic factors (18) and can cause social, psychological and health problems, and is linked to obesity later in life and poor health outcomes as an adult (19,20). Much research has been developed to finding successful interventions that can prevent obesity in children. In a recent series about childhood obesity published in *The Lancet*, Lobstein et al (13) said that "A PubMed search showed that the number of published papers on child obesity prevention rose from about 20 per year in the late 1980s, to 60 per year in the late 1990s, and to more than 1000 in 2013 alone" emphasizing the extensive research that has been conducted on childhood obesity prevention.

It has been proposed that breastfeeding promotion might be an effective way to prevent the development of obesity (21,22). World Health Organization (WHO) recommends initiation of breastfeeding within 1 hour of birth, exclusive breastfeeding of infants till 6 months of age, and continued breastfeeding until 2 years of age or older (23,24). However, global progress on this intervention is both uneven and suboptimum (25). Data from WHO European Member States demonstrated that exclusive breastfeeding rates declined after 4 months and at 6 months there a minimum and a maximum of 1-49% of infants being exclusively breastfed (26). Particularly in Portugal, this prevalence is low: only 18.9% of mothers breastfed their children exclusively until 6 months (27).

Furthermore, some evidence suggests that very early introduction of complementary feeding (at or before 4 months), rather than at 4–6 months or >6 months, may increase the risk of childhood overweight (28). High intake of energy and protein, particularly dairy protein, in infancy could be also associated with an increase in body mass index (BMI) and body fatness, but further research in this field is needed (29).

The most effective, sustainable and beneficial effect on obesity prevention involves multiple strategies that focus on meals, classroom activities and involve home, school and the whole community (30–34). The Commission on Ending Childhood Obesity highlights in the Interim Report of the Commission on Ending Childhood Obesity (34) the need for a multisectorial holistic approach to prevent and treat childhood obesity,

which include the following strategic objectives: 1) tackle the obesogenic environment and norms (decrease intake of unhealthy foods and non-alcoholic beverages and also decrease sedentary behaviour and promote healthy living through physical activity); 2) ensure the risk of obesity is reduced by addressing critical elements in the life-course (preconception and pregnancy, infant and young child, and school-age child and adolescent); 3) treat children already affected by obesity to improve their current and future health. Interventions for children who are overweight or obese should ensure lifestyle changes within family and in social settings, encouraging parents or carers to take the main responsibility, especially if they are younger than 12 years old (35).

The emergence of childhood obesity underscores the need for dietary assessment tools that are not only valid and reliable but also feasible to administer across multiple settings and age ranges and with diverse populations in order to evaluate dietary intake in children and also the effectiveness of childhood obesity interventions (36). Accurate descriptions of dietary intake among school-age children are critical for monitoring the nutritional status of children; examining associations between diet and health; identifying biological, environmental and psychosocial factors influencing dietary intake, which could be targeted for change; assessing changes over time in diet; evaluating the outcome of dietary intervention (37).

1.2 Food consumption

Food consumption data reflects what individuals or groups consume in terms of solid foods, beverages, including drinking water, and supplements. Food consumption can be estimated through food consumption surveys at household level (household budget surveys), approximated through food supply (food balance sheets) or at individual level (individual dietary surveys).

Household budget surveys (HBS) and food balance sheets provide gross annual estimates of the type and the amount of food available for human consumption within a household or country and can be used to derive a gross estimate of average per capita food consumption with no indication of the distribution of consumption in the population (38).

HBS collect data on food availability at household level. The members of the participating households are asked to record mainly in open questionnaires all food purchases, contributions from the household's own production and the food items offered to members as gifts. Food availability per person per day was calculated by dividing the household availability by the product of the referent time period and the mean household size. Individual availability was estimated without making allowances for the proportion of food that was edible and under assumption of equal distribution of food within the household and during the survey period. They are conducted in all European Union (EU) Member States and their primary aim (especially at national level) is to calculate weights for the Consumer Price Index. Food consumed out of home, food losses and waste, food given to pets, meals offered to guests are not considered in HBS. Data Food Networking exploits food and socio-demographic data collected in the HBS, aiming at the development of a cost-effective food databank that allows monitoring of food availability both within and between European populations (39).

Food balance sheets present a comprehensive picture of the pattern of a country's food supply during a specified reference period of time. The food balance sheets show for each food item the sources of supply and its utilization. The per caput supply of each such food item available for human consumption is obtained by dividing the respective quantity by the related data on the population actually partaking of it. Data on per caput food supplies are expressed in terms of quantity and also in terms of energy, protein and fat (40).

Individual dietary surveys are the only surveys that provide information on the distribution of food consumption in well-defined groups of individuals and are therefore preferred for the assessment of dietary intake. Data from individual dietary surveys are also understood to more closely reflect actual consumption and possibly identifying sub-groups at nutritional risk. Numerous dietary surveys assessing nutrient intake have been conducted across the world at both national and local level, particularly in children.

Before analysing the data on individual dietary surveys in children, the dietary recommendations for children will be presented.

1.2.1 Which are the dietary recommendations for children?

The Institute Of Medicine's (IOM) Food and Nutrition Board released the Dietary Reference Intakes (DRIs) for energy, carbohydrate, including added sugars, fat, protein and fibre in 2002 (41); for water, potassium, sodium, chloride and sulphate in 2005 (42); for calcium and vitamin D in 2011 (43). Food and Agriculture Organization (FAO) and WHO had also released recommendations about energy requirements in 2001 (44); energy-supplying macronutrients in 2003 (11) and 2010 (45); sodium (46) and potassium (47) in 2012; sugars in 2015 (48). DRIs and nutrient intake goals are summarized in Table 1-1.

Energy intake is the sum of essential calories, the total energy intake necessary to meet recommended nutrient intakes, and discretionary calories, the additional calories necessary to meet energy demand and for normal growth. IOM calorie estimates are based on a sedentary lifestyle. More physically active children will require additional calories. Discretionary calories increase with age and increasing levels of physical activity. There is a large difference in the discretionary calorie allowance among sedentary, moderately active, and active children, with more physically active children needing more energy from foods to maintain normal growth: 163-173 kcal for 4-8 years children and 181-190 kcal for 9-13 years children (49).

Total water consumption is essential for the metabolism and for normal physiological functions and the recommendations for its intake are: 1.7 L per day for 4-8 years children (this includes approximately 1.2 L as total beverages, including drinking water), 2.1 L per day for 9-13 years girls (this includes approximately 1.6 L as total beverages, including drinking water) and 2.4 L for 9-13 years boys (this includes approximately 1.8 L as total beverages, including drinking water) (42). Furthermore, fruit and vegetables intake should be equal or higher than 400 g per day (11).

Table 1-1. Daily estimated energy requirement and recommended acceptable macronutrient distribution ranges as a percentage of energy intake for carbohydrate, total fat, saturated fatty acids, polyunsaturated fatty acids, trans fatty acids, monounsaturated fatty acids, protein, total sugars, and DRIs for total fibre, sodium, potassium and calcium, by gender and age according to IOM and FAO/WHO guidelines

	Gender	IOM		FAO/WHO			
		Age (years)		Age (years)			
		4-8	9-13	7-8	8-9	9-10	10-11
Energy (kcal)	Girls	1200	1600	1554	1698	1854	2006
	Boys	1400	1800	1692	1830	1978	2150
Carbohydrate (%E)	Girls Boys	45-65		55-75			
Total Fat (%E)	Girls Boys	25-35		25-35			
SFA (%E)		ND		8			
PUFA (%E)		ND		11			
TFA (%E)		ND		<1			
MUFA (%E)		ND		Total Fat – SFA – PUFA – TFA			
Protein (%E)	Girls Boys	10-30		10-15			
Total sugars (%E)	Girls Boys	<25		<10 (<5[a])			
Fibre (g)	Girls	25	26	From foods			
	Boys		31				
Sodium (g)	Girls Boys	1.2	1.5	<2[b]			
Potassium (g)	Girls Boys	3.8	4.5	3.510[c]			
Calcium (mg)	Girls	1000	1300	700			
	Boys			1300			

[a]The recommendation to further limit free sugars intake to less than 5% of total energy intake is based on very low quality evidence from ecological studies.
[b]A maximum of 2 g/day with downward adjustments for lower energy intake at younger ages.
[c]The recommended potassium intake of at least 3.510 g/day should be adjusted downward for children, based on the energy requirements of children relative to those of adults.
%E, percentage of total energy; SFA, saturated fatty acids; PUFA, polyunsaturated fatty acids; TFA, trans fatty acids, MUFA, monounsaturated fatty acids; ND, not determinable.

According to Dietary Guidelines for Americans 2010 (50), children should: 1) increase intake of whole grains, fruit and vegetables, although there is limited evidence that the consumption of these foods help in the control of the total caloric intake and management of weight gain in children; 2) reduce intake of sugar-sweetened beverages since there is a strong evidence showing that children who consume sugar sweetened beverages have higher body weight compared to those who drink less; 3) monitor intake of 100% fruit juice, especially those who are overweight or obese; 4) eat a nutrient-

dense breakfast because not eating breakfast has been associated with excess body weight.

The Academy of Nutrition and Dietetics also recommends nutritional guidance for children aged 2-11 years (49): 1) reduce the incidence and the prevalence of childhood obesity through the reduction of energy intake and increase of physical activity; 2) shift food intake patterns to a more plant-based diet that emphasizes vegetables, cooked dry beans and peas, fruits and whole grains, nuts and seeds; also increase the intake of seafood and fat-free and low-fat milk and milk products, and consume only moderate amounts of lean meats, poultry and eggs; 3) reduce intake of foods containing added sugars and solid fats and also sodium intake, and lower intake of refined grains, especially refined grains that are coupled with added sugar, solid fat, and sodium; 4) meet the 2008 physical activity guidelines for Americans (60 minutes or more of physical activity daily, including muscle and bone-strengthening physical activity on at least 3 days per week).

Finally, for Portuguese children in particular there is a Portuguese food guide in the form of a serving dish that highlights and promotes the relevance of social interaction within food habits (51). The guide is comprised of 7 food groups represented in a circle format, which acquire similar importance as they visually complement each other: 1) Potato, cereal and cereal products; 2) Vegetables; 3) Fruits; 4) Fats and oils 5) Meat, fish, seafood and eggs; 6) Milk and dairy products; 7) Pulses; 8) Water. The number of recommended portions depended on individual energy needs: the minimum value of 1300 kcal was considered for children between the ages of 1 and 3 years, whereas the maximum value (3000 kcal) was for active men and male adolescents. The middle value of 2200 kcal was used for the rest of the population. Children between the ages of 1 and 3 should follow the lower values for portion sizes, whereas male adolescents and active men should follow the upper values.

1.2.2 What are children really eating?

Most studies on dietary intake in the US population are provided from the following national representative surveys: Nationwide Food Consumption Survey (1977-1978); Continuing Survey of Food Intakes by Individuals (1989-1991); Continuing Survey of

Food Intake by Individuals (1994-1996, 1998); What We Eat in America, National Health and Nutrition Examination Surveys (2003–2004, 2005-2006, 2007-2008 and 2009-2010). Mean daily energy intake increased from 1842 kcal/day in 1977 to 2022 kcal/day in 2006 among children aged 2-18 years old (52). This was associated with a major shift toward increased energy consumed away from home (255 kcal/day), whereas the number of kilocalories eaten at home has declined only slightly (76 kcal/day). However, the decreased percentage of daily energy consumed at home resulted from the increased total daily energy.

Stores and fast food are the two predominant sources of energy for US children, and the proportion of energy from fast food and restaurants has been increasing. Nonetheless, in 2010 there was a decline in the mean daily energy intake consumed by 2-18 years old children (1914 kcal per day) (53).

Reedy & Krebs-Smith (54) identified the top dietary sources of energy, solid fats, and added sugars among 2-18 year olds in the US, based on data from NHANES (2003-04, 2005-06). They verified that the top five sources of energy were grain desserts, pizza, soda, yeast breads, chicken and chicken mixed dishes. Furthermore, the average daily intake of energy from solid fats was 433 kcal of which the major sources were pizza, grain desserts, whole milk, regular cheese, and fatty meats. The average daily intake of energy from added sugars was 365 kcal. Soda, fruit drinks, grain desserts, dairy desserts and candy were the major sources of added sugars. Finally, 40% of total calories consumed (798 kcal/day of 2027 kcal) were in the form of empty calories (the sum of calories from solid fat and added sugar).

A more recent study published in 2013 by Slining and Popkin (53) examined the trends in intakes and sources of solid fat and added sugars among US 2-18 year olds from 1994-2010. They found that the consumption of solid fats and added sugars decreased from 39% in 1994-1998 to 33% in 2009-2010. However, mean intakes continued to exceed recommended limits by 18 to 28% of total energy intake. The main sources of solid fats and added sugars intake over these 16-year period were sugar-sweetened beverages, grain-based desserts, candy, ready-to-eat cereals, dairy-based desserts, milk, pizza, cheese, processed meats and fried potatoes.

Larger portion sizes have also been linked to increased energy intake in US children and particularly in children aged 7-12 years old. Larger portion sizes (kcal, g and mL) of soft drinks and salty snacks were associated with significantly higher energy intake at meals. Also, larger portion sizes of pizzas coincide with higher energy intake at eating occasions among children from 2 to 18 years old (55).

Piernas and Popkin (56) presented data about daily snacking among children (ages 2-18). The authors defined snacks as eating occasions outside meals. They demonstrated that the prevalence of *snackers* increased from 74% in 1977-78 to 98% in 2003-06. Children were consuming almost three snacks per day, which accounted for up to 27% of children's caloric intake in 2006. Grams consumed per snack event increased significantly from 1977 to 2003 (around 50 g more per snack) and regarding the total energy intake coming from snacks, the authors observed that all children consumed approximately 168 more calories a day from snacking from 1977-2006. The main contributors to snacking calories were: desserts and sweetened beverages. Also, there was an increase in the intake of energy-dense salty snacks and candy as sources of snacking energy and children are consuming more beverages (fruit drinks, sport drinks, and fruit juice) while decreasing fruit as a snacking source.

Lambert et al (57) collected and evaluated data on nutrient intake and status across European children and adolescents. They included into the analysis seventy-nine surveys from 23 countries and collected data on energy, protein, fat, carbohydrate, alcohol, vitamins, minerals and trace elements. As regards 7-10 year old children, energy intake ranged from 1672 to 2412 kcal/day in boys and from 1600 to 2293 kcal/day in girls. With respect to carbohydrate intake, percentage of total energy intake ranged from 40.3% to 61.6% in boys and from 39 to 60% in girls, and declined with age. Fibre intake ranged from 0.9 to 3.5 g/MJ, with no discernible trend between ages. Mediterranean countries recorded the highest fat intake, which is more than 40% of total energy intake. Fat intake and age of children did not seem to be associated. Protein ranged from 11 to 16.6% and from 11 to 17.8% of energy intake in boys and girls, respectively. Reported intake of vitamins by children was inconsistent across Europe, but in general it can be said that intake levels for most vitamins increase with age in both boys and girls, in parallel with energy intake. The differences between the values found may be explained by seasonal food patterns and the use of supplements. Like

vitamins, the intake of minerals increases with age, which is related to increased food consumption.

According to data from the National Diet and Nutrition Survey (NDNS) (58), which combined results from 2008/09 to 2011/12 for a representative sample of the UK population covering different age groups including pre-school children, young people, adults and older adults, mean daily intake for total energy was 1532 kcal for children aged 4 to 10 years. The findings presented show that fruit and vegetables consumption was below recommendations (178 g/day). The percentage of consumption of 'chips, fried and roast potatoes and potato products' (79%), 'fruit juice' (62%) and 'sugar confectionary' and 'chocolate confectionary' combined (18 g/day) was highest in the 4-10 year age group.

Stahl et al (59) compare the food consumption and nutrient intake of German children and adolescents in the 1980s with 2006 dietary habits. They found notable differences between the food consumption and nutrient intake with respect to energy and most macronutrients and micronutrients. Positive changes were an increase in vegetable/pulses, fruits/nuts and pasta/rice/cereals (in boys) consumption, and decreased consumption of meat products/sausages, butter and fats/oils. However, they verified a decrease in consumption of potatoes/potato products, bread/pastries and fish/fish products. The macronutrient composition of the diet improved: fat intake decreased significantly due to declines of both saturated and unsaturated fatty acids; protein intake decreased; carbohydrate intake increased in all age and gender groups except 6 to 11 year old boys due to higher polysaccharide intake. The micronutrient content of the diet in relation to energy intake increased and the energy density became lower. Water intake increased in all age and gender groups.

Libuda et al (60) examined trends in fat intake between 2000 and 2010 in a sample of German children and adolescents participating in the Dortmund Nutritional and Anthropometric Longitudinally Designed Study. Fat quantity and quality did not change substantially between 2000 and 2010 but a large proportion of children and adolescents did not meet the recommendations for SFA and PUFA intake. Mean total fat intake in 4-12 years old children was 35.0%, with the largest portion coming from SFA (15.7%), followed by MUFA (14.3%) and finally by PUFA (4.8%). In all the age groups, milk

and milk products, fats and oils, meat and meat products, and candy were the main contributors to total fat intake in both 2000 and 2010. The decreasing intake of fat from milk and oils was at least partly compensated by increases in fat intake from sauces in 4–12 year olds.

Lioret et al (61) provided insight into the dietary of French children aged 3-17 years between 1999 and 2007. During this period, among children aged 3-10 years, there was a decrease in energy intake, partly due to the decline in the consumption of food products of animal origin (mainly milk, cheese and meat) and sweetened products. The overall amount of starchy foods (bread and crisp breads and potatoes) decreased by 7.4%. Sweetened foods (sweetened pastries and biscuits) decreased by 15%. Dairy products declined 11%, and the marked decreased in milk consumption is mainly responsible for this trend. Consumption of meat, seafood and eggs decreased, the decrease in meat consumption being the main factor accounting for this trend, with poultry and game accounting for a substantial reduction in the food group. Fruit and vegetables consumption remained stable. Savoury snacks declined by 10.7%, mainly due to decreased consumption of sandwiches and hamburgers.

Serra-Majem et al (62) evaluated the nutritional status of 3534 Spanish individuals aged 2 to 24 years. According to the study, the number of meals decreased with age and the percentage of those who usually ate breakfast was 85.3%, being higher in children aged 2-5 years (92.7%) and lower in adolescents (82.1%). Energy intake was 2189 kcal in males and 1781 kcal in females. Furthermore, the food patterns revealed high consumption of dairy products (425 g in males and 378 g in females) and meat (178 g in males and 137 g in females), moderate milk consumption intake (316 mL in males and 281 mL in females) and low consumption of fish (50 g in males and 45 g in females), fruit (197 g in males and 186 g in females) and vegetables (86 g in males and 95 g in females).

Valente et al (63) evaluated the prevalence of nutritional inadequacy in 4845 Portuguese children aged 7-9 years old. Mean energy intake was higher in boys than in girls (2319 kcal vs. 2522 kcal). Regarding macronutrient intakes in respect of percentage of total energy intake, the authors found a high fat and protein intake (35% and 17%, respectively) and a low carbohydrate intake (49%) compared with the WHO

recommendations. Inadequate intakes of calcium, vitamin E, folic acid, molybdenum and fibre were also found.

Moreira et al (64) showed that the diet of Portuguese 5-10 year old children from the city of Porto was high in fat, particularly SFA, sugars and protein, and low in total carbohydrate and dietary fibre for both genders. Regarding dietary fibre and total carbohydrate, boys exhibited a significantly higher consumption (25.7 vs. 24.1 g/day; 51.7% vs. 51.0% of total energy, respectively) and a lower consumption of protein (18.1% vs. 18.5% of total energy) than girls. On the other hand, girls consumed significantly lower amounts of meat (91 vs. 96 g/day), bread (47 vs. 52 g/day), and sweetened sweet beverages (106 vs. 132 g/day), and higher amounts of vegetables (103 vs. 91 g/day).

1.3 Dietary Assessment

Measuring the diets of school-aged children is an imprecise process because dietary assessment techniques are methodologically limited and usually rely on a child or parent's recall of food intake. As in adults, there is no perfect method of assessing dietary intake in children. Special consideration must be given to the age and cognitive ability of the child as well as methodological issues associated with nutrient analyses.

1.3.1 Overview of current dietary methods

Several dietary assessment tools directed at the individual are available. In general, these methods can be divided into two basic categories: those that collect data about the diet eaten in the recent past or over a longer period of time (retrospective methods such as the Food Frequency Questionnaire, 24-hour Dietary Recall and Diet History) and those that record data at the time of eating (prospective methods like Food Record). These methods are subject to bias and translating dietary information into quantitative estimates of energy and macronutrient intake is difficult (65).

A description of the main dietary assessment methods is given below:

Food Frequency Questionnaire

The Food Frequency Questionnaire (FFQ) measures usual food intake and is often used for epidemiological studies since it is relatively easy to administer, less expensive than other assessment methods, and easily adapted for population studies.

Walter Willett states in *Nutritional Epidemiology* (66) that the most important factor in the FFQ approach is the average long-term diet over weeks, months or years, rather than intake on a few specific days. The basic FFQ consists of two components: a food list and a frequency response section for subjects to report how often each food was eaten. Questions related to further details of quantity and composition may be also included.

A basic decision in designing a FFQ is whether the objective is to measure intake of a few specific foods or nutrients, or whether a comprehensive assessment of dietary intake is desired. A second questionnaire design issue is whether the primary objective is to rank individuals or to provide a measure of absolute intake. In both cases, it is important to select carefully the most informative items for the food list: 1) the foods must be used reasonably often by an appreciable number of individuals; 2) the foods must have a substantial content of the nutrients of interest; 3) the use of the foods must vary from person to person in order to be discriminating. A third approach to constructing a questionnaire is to use open-ended data to identify the foods that contribute most importantly to the total absolute intake of a nutrient by the group as a whole (provide subjects the option of answering in terms of frequency per day, week, or month).

Respondents report their habitual intake over a defined period of time in the past year, month, or week (the relevant reference period is dependent on the physiology or the pathophysiology of the outcome being studied). Walter Willet (66) uses nine frequency categories to estimate food intake: 1) almost or never; 2) 1-3 times per month; 3) once per week; 4) 2-4 times per week; 5) 5-6 times per week; 6) 1 per day; 7) 2-3 times per day; 8) 4-6 times per day; 9) over 6 times per day. For children, the list of the frequency should be presented vertically under each food item because this is easier for populations with lowers educational levels.

FFQ can be classified as non-quantitative (collect no additional information on portion sizes), semi-quantitative (specify a portion size as part of the question on frequency, e.g. "how often a glass of milk is consumed"), or quantitative (include an additional question for each food about the usual portion size, describing a medium portion size in words and asking subjects to describe their usual portion as small, medium or large). The questionnaire can be self-administered or conducted with individual or group assistance (67).

24-hour Dietary Recall

The 24-hour Dietary Recall (24-h DR) consists of a structured interview in which a trained nutritionist or other professional asks the child and/or adult caregiver to list everything she/he ate or drank during a specified time period, typically from midnight to midnight of the previous day or over the past 24-hour period. It probes for additional foods and food preparation methods by asking questions in a manner that puts the participant at ease and facilitates the ability to recall the previous day's intake. It is an estimate of actual intake that incorporates a detailed description of the foods, including brand names, ingredients of mixed dishes, food preparation methods, and portion sizes consumed.

Because of intra-individual variation in intake, multiple recalls are needed to accurately estimate habitual nutrient intake (67,68). The determination of the optimal number of 24-h DR to administer depends on both desired accuracy, the variability of the nutrient in question and also on the purpose of the study (for instance, if the purpose of the study is to estimate the distribution or to examine correlates of individuals intakes, more than one 24-h DR is necessary per individual). The administration of a greater number of 24-h DR or the increase in the number of individuals in the sample will be more representative of habitual individual intake. However, for many nutrients, obtaining a highly accurate estimate of individual intake by using repeated measurements is simply beyond practical possibilities in epidemiological studies.

The U.S. Department of Agriculture developed the automated multiple-pass method (AMPM). The AMPM employs five sequential passes in the interview (69): 1) asking the participant to start by quickly listing the foods consumed in the previous day (without respect to time sequence); 2) asking about any forgotten foods in nine

commonly forgotten categories of foods (non-alcoholic beverages, alcoholic beverages, sweets, savoury snacks, fruits, vegetables, cheese, breads and rolls, other foods); 3) asking the time and occasion of consumption for each food; 4) probing for specific details on foods, amounts consumed, and foods consumed between identified eating events; 5) probing for whether anything was forgotten. The AMPM is the procedure currently used for collecting 24-hour dietary intakes in the U.S. NHANES.

Intensive training of the dietary interviewer is critical for obtaining accurate and complete 24-h DR. If the participant does not provide adequate information about a food item, the interviewer must probe further for the necessary level of detail. There are some abilities of the interviewer that must be ensured in order to obtain complete and accurate information: ask non-judgmental questions, maintain a neutral attitude toward all responses, use open-ended questions in probing for foods and descriptive detail, and avoid asking questions in a manner that might influence the participant's responses. Asking about the previous day's activities and relating these activities to food intake may also help participants recall their food intake (68).

Diet History

Burke (70) developed a detailed Diet History (DH) that assesses the past diet of an individual in the form of usual meal patterns, food intake, and food preparation practices through three steps: an interview to determine the usual meal pattern, most frequently from a 24-h DR; a menu recorded for 3 days; an FFQ that checklists the foods consumed over the preceding month. This method was time consuming and expensive, and a highly skilled professional was needed for both the interview and the processing of the information.

The DH provides a measure of habitual intake that is appropriate for ranking individuals and predicting health outcomes. A DH is more qualitative than quantitative, allowing detailed information about food preparation, eating habits, and food consumption to be collected by a highly trained interviewer. Because this method requires an interview typically of 1 to 2 hours duration and also cognitive skills that include spatial relationships, and also math skills, the method are not often used to assess children´s diet (67).

Food Record

Food Record (FR) is a written account of actual intake of the foods and beverages consumed during a specified time period, usually 3, 5, or 7 days. Respondents record detailed information about their dietary intake, such as brand names, ingredients of mixed dishes, food preparation methods and estimates of amounts consumed. By collecting the information at the time of consumption, error due to memory loss is reduced and thus FR often serves as a validation standard (67,68).

Participants should be trained in methods of keeping complete and accurate FR. Procedures for reducing the extent of underreporting in FR include: careful training in methods of keeping accurate records (face-to-face training is preferred); providing written as well as verbal instructions for recordkeeping; emphasizing the importance of the participant's contribution to the research and the importance of the dietary information; stressing the need for timely recording of food intake; encouraging participants to maintain habitual eating habits during recording period.

Ideally, the recorder weights the individual portions of the cooked dishes using a calibrated scale, but other methods for measuring serving sizes may be needed (household measuring tools, such as standard measuring cups and spoons). Reviewing the FR with the participants right after data collection is desirable to capture adequate detail and should include probing for beverages and between-meal snacks that may have been inadvertently omitted. Meals eaten away from home often lack adequate descriptive detail.

Because young children have not been shown to accurately complete the FR independently, caution is suggested when interpreting studies that used the FR as the validation standard. Furthermore, the validity of FR increase with more days of recording and a multiple FR can introduce compliance issues for children because of high respondent burden. Changes in eating while keeping the FR (called reactivity) may be due to minimizing the burden associated with recording foods, especially mixed dishes containing many ingredients, or a tendency to select foods that are more socially acceptable to report (considered to be healthier) (68).

1.3.2 How is dietary intake assessed in children?

Assessment of dietary intake in children is particularly challenging and there is no consensus on which dietary assessment method is most accurate (71,72). If used in an appropriate manner, all methods presented previously could provide information regarding average habitual daily intake of foods and beverages, energy, macronutrients and selected vitamins, minerals and intake distributions. The choice of which instrument to use may depend on the study objectives and study design factors, all of which will influence the appropriateness and feasibility of different approaches.

McPherson et al (67) reviewed the validity and reliability studies of FFQ, 24-h DR, DH and FR among children and adolescents. The authors concluded that there were higher correlations between the validation standard for 24-h DR and FR than for FFQ, although it is difficult to generalize the validity and reliability of these studies because of discrepancies in study design, referent periods and validation standards.

Burrows et al (36) evaluated the accuracy of dietary assessment methods used to estimate the daily energy intake of children by comparing reported intake with total energy expenditure measured by Doubly Labeled Water (DLW). This review suggested that the 24-h DR conducted over at least a 3-day period, including weekdays and weekend days, and using parents as proxy reporters is the most accurate method to estimate total energy intake in children aged 4-11 years, compared to total energy expenditure measured by DLW. According to the authors, weighed FR provided the best estimate for younger children aged 0.5 to 4 years, whereas the DH provided better estimates for adolescents $\geq$ 16 years.

Forrestal (71) described energy intake misreporting (includes both underreporting and overreporting) among children and adolescents and suggested that retrospective methods may be preferable to use with younger respondents, which is contrary to the common acceptance of FR as the ‘gold standard’ for dietary assessment methods. Underreporting of approximately one-fifth was common particularly with the FR, although the studies reflect considerable methodological variability.

Within the European Food Consumption Validation Project (EFCOVAL), recommendations for harmonised dietary assessment in European national food consumption surveys among children advised for pre-schoolers (4-6 years) two non-consecutive 1-day FR and for school children (7-14 years) two non-consecutive 24-h DR combined with a simple FR, primarily for foods eaten at home (73). The authors concluded that the 24-h DRs are "logistically simple, applicable for cross-cultural surveys, less burdensome for the respondents and in line with the dietary assessment method, suggested among adults in trans-European surveys, this would logically be our first choice of method for children".

In view of a pan-European dietary survey, the European Food Safety Authority (EFSA) recommends the FR method including two non-consecutive days for all infants, toddlers and other children up to 10 years of age (38).

The Pilot Study for Assessment of Nutrient Intake and Food Consumption Among Kids in Europe (PANCAKE) tested two protocols - an FR on 3 consecutive days, as well as an alternative protocol with 2 non-consecutive 1-day FR – in two EU member states that differ in dietary habits and common field work practices (Belgium and Czech Republic) (74). The 3-day FR was more pre-structured than the 1-day FR. For the 1-day FR, completeness was considered less important because the recording was followed by a completion interview using EPIC-Soft© with the parent and the FR as a basis.

EPIC-Soft© was originally developed to conduct 24-h DR in a harmonised and standardised way in various European countries, allowing for the differences in food consumption across the countries with a common food grouping system. EPIC-Soft© is divided into 5 interview steps: 1) general non-dietary information; 2) quick list step; 3) description and quantification of foods and recipes reported in the quick list; 4) dietary recall summary and quality checks; 5) dietary supplement description and quantification. The main differences of the EPIC-Soft© and the Data Entry Application used in PANCAKE is that the quick list step and the probing question are deactivated (75).

The two tested dietary assessment methods and related protocols each had advantages and disadvantages. However, the two non-consecutive 1-day FR followed by an EPIC-

Soft© completion interview with the parent seemed to offer more advantages for the future pan-European survey in children aged 0–10 years than the 3-day FR. The main arguments presented by the authors were that non-consecutive days are more appropriate to estimate the prevalence of inadequate intake, and also the comparability with the advised methodology for adults.

In the US, the 24-h DR is the most commonly used method for dietary surveys and is often used to collect information about children's intake in national surveys and diet-health studies (76). Ollberding et al (77) determined the within-to between-individual variance ratios and number of 24-h DRs required to rank-order individuals on usual intake for select macro and micronutrients in a large, multiracial/ethnic sample of US children. They concluded that for children, 6-9 24-h DRs were required to classify individuals on habitual intake, with an accuracy of r=0.8 for most nutrients. Furthermore, when multiple days of intake are collected, the combination of days of the week for each individual should ideally be randomly assigned and non-consecutive, since studies indicated that consecutive days are not independent of one another.

Thus, the 24-h DR and FR have several strengths in common. Both methods record actual intake and thereby estimates absolute rather than relative intake of energy and other food components. Since both methods are open-ended, they can accommodate any food reported by the participant and allow an unlimited level of specificity regarding type of foods, food source, food processing method, food preparation, and other details relating to describing foods and amounts. Finally, the use of recall or record methods permits considerable flexibility for data analysis, since data may be analysed by nutrients as well as by individual foods, by any food-grouping scheme desired, or by meals. Table 1-2 presents the strengths and limitations of the 24-h DR and FR used to assess dietary intake in children.

Table 1-2. Strengths and limitations of the 24-hour Dietary Recall and FR used to assess dietary intake in children (68,78)

	24-h DR	FR
Strengths	- Does not require literacy skills - Does not alter habitual dietary habits - Less likely to be reactive (information is collected after the fact) - Low participant burden - Short administration time (30 min) - Covers a defined recall time period - Data entry can be automated - Single day of intake per person to obtain the mean value for a group or population	- Does not rely on memory - Covers a defined recording time period - Training can be group administered - Single day of intake per person to obtain the mean value for a group or population
Limitations	- Relies on memory - Portion size is difficult to estimate - Higher respondent burden for multiple days - Need for highly trained interviewers - Expensive to collect and code - Multiple recalls needed to report habitual intake of an individual	- Requires literacy skills (reading and writing skills required) - Procedure may alter habitual dietary habits - High participant burden - High level of motivation (increases with number of days) - Can lead to a poor response rate - Food eaten away from home less accurately reported - Expensive to collect and code - Multiple records needed to report habitual intake of an individual

24-h DR, 24-hour dietary recall; FR, food record

1.3.3 From what age is a child expected to report food intake accurately?

One key practical and important issue is from what age a child can be expected to report food intake accurately. It is also very important to know whether parents or others might be reasonable proxies. Factors that affect the reporting of dietary intakes in school-age children include: 1) lower literacy levels; 2) limited knowledge of food and food preparation methods; 3) lack of familiarity with recipe components; 4) difficulties in estimating portion sizes; 5) limited cognitive abilities (67).

Piaget proposed the major theory of cognitive development, which emphasizes the biological functions and environmental influences that promote intellectual growth. Piaget identified four major periods of cognitive development: 1) sensorimotor (birth to 2 years), 2) preoperational (2-6 years), 3) concrete operations (6-12 years) and 4) formal operations (12-19 years) (79). In particular, the development of concrete operational thought occurs after 6 or 7 years old. During this stage a number of conceptual skills are gradually achieved: 1) conservation skills, 2) classification skills, and 3) computational skills. The basic meaning of the conservation is that the properties of an object or a substance remain the same even though its appearance may have been altered in some superficial way. This concept can be applied to a variety of dimensions (mass, weight, number, length, volume). Three concepts that contribute to conservation are: identity, reversibility, and reciprocity. There appears to be developmental sequences in the capacity to conserve. Children generally conserve mass and number earliest, weight later, and volume last. The conceptual awareness of the process of classifying objects or the logic of conservation is not fully integrated until middle school age (6-12 years) and may not reach peak performance until later adolescence or adulthood. Classification refers to the ability to group objects according to some common dimension and to order subgroups in a hierarchy, and computational skills to the ability to understand that numbers represent quantities and to manipulate quantities using the operation of addition, subtraction, multiplication, and division (80,81).

There seems to be a fairly rapid increase in the ability of children to participate in unassisted recalls for foods eaten in the immediate past at around 7–8 years of age (82). Children under 8 years cannot conceptualize frequency correctly and need adult assistance to provide dietary information because of limited reading skills and vocabulary (83). As a child grows older (>8 years) there is a rapid increase in children's ability to provide accurate reports of their dietary intake (83) and research suggests that children may be able to respond to a 24-h DR by the age of about 10 years (84,85). Children aged 10 years old and over may have some of the food knowledge required, although they still may not be able to provide detailed information on food type and preparation methods. Previous work showed that 8-9 year olds were less accurate and took more time than 10-13 year olds finding foods in hierarchically organized categories (86) but could use pictures of foods to report portion size as accurately as older children

(87). More work is needed to address this issue, but asking children of 10 years or older for dietary intake data appears safe (68). Accuracy by age for FR hasn't been reported.

Whether the parent or the child is the reporter brings different perspectives and distinct biases to the report of intake. Parents are often used as proxy reporters of their children's dietary intake in research studies, particularly in children ages 6 to 11 years old, because of children's lower literacy levels, limited cognitive abilities and difficulties in estimating portion size (76,88). However, the assumption that parents are good reporters of their child's food intake can be challenged. Also, the joint parent-child recall method used in the majority of these studies appears to never have been validated (children by themselves did not provide recalls, so no comparison could be made of the accuracy of child-only recalls, parent-only recalls, and joint parent-child recalls of the child's intake).

It seems to be unrealistic to expect parents to accurately report their elementary-school children's dietary intake, especially for meals eaten in locations where parents are not present, such as school (83). Children spend a large part of the day outside home and parents are often unaware of what the child consumed during that period of time. It is necessary to rely on school-age children to self-report their own dietary intake information. Furthermore, 24-h DR has been provided by school-age children without parental assistance for research studies (89–91).

1.3.4 How do children remember food intake?

Memory is a very commonly cited problem in 24-h DR. Errors in a child's memory for foods in 24-h DR include: intrusions (recalling foods they never had), omissions (not recalling foods actually consumed), and limited knowledge of foods and preparation.

Baranowski and Domel (84) proposed a model to understand how children remember and process information (Figure 1-1). This model has three structural elements: a sensory register, short-term memory and long-term memory. According to these authors, when children are presented with food stimuli, they attend to only parts of those stimuli. What they attend may reflect how much they know about the stimuli, their prior experience with the stimuli, or the state they are in (e.g. fatigued). After that,

children form an initial (short-term) memory of the event and this memory must be in terms, units, and sufficient detail to be interpretable by the researchers. Later children must perform some elaboration of the event to develop a longer-term memory.

Cognitive processes involved in the recall of dietary information can be categorized as attention (noticing information), perception (what a child does with the information after it has been noticed), organization (referring to the categories used to store food information in long term memory and relationships among those categories), retention (as time from the event increases, more aspects of this event are lost from memory), retrieval (the process of obtaining information out of long term memory to form a response to a question where child must recall the events of the day to identify the foods eaten) and response formulation (some children may distort a self-report to achieve self-presentation goals).

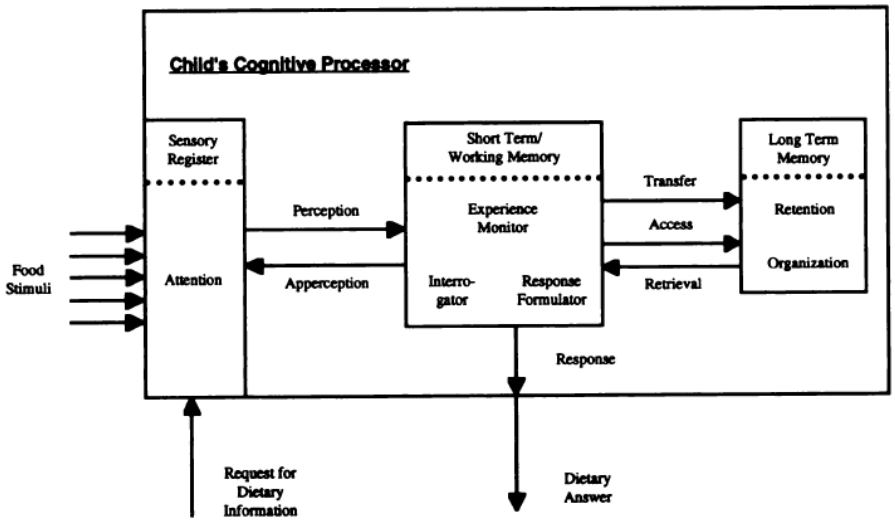

Figure 1-1. The cognitive model of children's dietary assessment proposed by Baranowski and Domel (84)

One of the research issues in applying the cognitive processing approach to children's self-reports of diet is to identify the strategies children use to retrieve information from their memory concerning what they have eaten, and to relate those strategies to the accuracy of self-reports. Some authors have published studies that aim to enhance understanding of the strategies in order to help children to recall more accurately what they have eaten.

Baxter et al (92) used the Delphi technique to develop and validate a set of retrieval categories for how children remember what they have eaten and to determine which retrieval categories were linked with the most accurate self-reports of diet. There were differences in accuracy by retrieval category but the more accurate students reported using "usual practice", "taste/smell/texture", "visual" and "second helping/mode of eating" in contrast to "interactions with other people", "portion left over" and "physiologic cue". However, given the wide variety of retrieval categories used by fourth graders, the authors acknowledged that they cannot assume to know which retrieval categories one student will use on the basis of the results from this study.

Food category prompting (specific questions used to clarify details and amounts about items already reported) slightly increased recall accuracy among fourth-graders who received it and may be used after free recall when obtaining dietary recalls (93). Interview format also influences children's dietary reporting accuracy. Because dietary intake may be organized in memory according to meals, a meal interview format that involves initial instructions or prompting with meal names may be preferred by children (94) than other interview formats. On the other hand, Baxter et al (95) suggested that for 24-h DR, free reports of intake – open interview format – may be more accurate than reports by meal. These authors found that the cues of the meal format led children to report more items than the open format. This resulted in relatively higher intrusion rates with no effect on omission rates.

Another important aspect is the reporting order. Reverse order reporting (most recent to past) may be better than forward order reporting (past to more recent) because recent events are easier to remember and may stimulate recall of earlier events. Baxter et al (96) observed and interviewed 121 fourth-graders regarding the previous day's intake and verified that prompting children to report meals and snacks in reverse order rather than forward order improved omission and intrusion rates for males. On the other hand, girls recalled items more accurately when prompted to report meals and snacks in forward order. However, children for both reverse and forward order reported <50% of items observed demonstrating a poor accuracy.

Accuracy should also depend on both target period and interview time, which is why recency hypothesis (the closer in time the interview is to the intake to be reported, the

more accurate performance should be) was also tested (97). Sixty fourth grade children were observed eating breakfast and lunch and were interviewed to obtain a 24-h DR using one of six conditions generated by crossing two target periods (previous day and prior 24 hours) with three interview times (morning, afternoon and evening). Reporting accuracy for the prior 24 hours was significantly better than for the previous day. When the target period was the previous day, omission and intrusion rates were lower for morning interviews compared to afternoon and evening interviews.

More recently, Baxter et al (98) tested eight different 24-h DR protocols in 48 fourth-grade children and verified that children's non-accuracy-related responses to these protocols varied as hypothesized: the interview length, in minutes, differed by retention interval (prior-24-h-afternoon 21.8, previous-day-morning.16.1; P<0.0008) and prompt (open 20.3, reverse 20.0, forward 19.1, and meal-name 16.3; P.0.079). The number of school meals reported eaten during the target period was greater using meal-name prompts than the other three prompts.

An understanding of the cognitive bases of intrusions might contribute to the design of protocols for collecting dietary information in which children would report fewer intrusions. Smith et al (99) determined whether items denoted by intrusions were available in school foodservice environments on the interview day, three school days prior to the interview day and the day following the interview. The availability in the school food service environment of school meal items denoted by intrusions decreased backward over school days before the target day, and decreased from the target day to the following day. Thus, intrusions may be based on specific memories of items encountered during the target period or before the target period, and also on individual's general knowledge of their dietary intake. The omnipresence of some items in school foodservice environments suggests that some items may be intruded because it is plausible to children that those items were consumed during the target period.

Reporting accuracy may be also related to cognitive ability, and cognitive ability may be a source of systematic error in epidemiological data (systematic errors may exaggerate or mask relations). Smith et al (100) investigated whether cognitive ability is a source of systematic error in dietary recalls. The Palmetto Achievement Challenge Tests (which measures achievement in 4 subject areas: language, arts, mathematics,

science, and social studies) was used to test cognitive ability of fourth grade children. They verified that as cognitive ability increased, dietary reporting error decreased. Children with higher cognitive ability reported more items, and what they reported better matched what they were supposed to report, than children with lower cognitive ability. The omission and intrusion rates were more strongly related to cognitive-ability for girls than for boys. Furthermore, the relation between cognitive ability and the omission rate was stronger than that between cognitive ability and the intrusion rate.

1.3.5 How do children estimate portion sizes?

Paralleling the problems in accurately identifying what was eaten are those in identifying how much was eaten (portion size served and any leftovers). Estimation of portion sizes has always been a challenge in dietary surveys and particularly in children presents unique difficulties (101). A measure is required to estimate the portion size of each food item consumed, which can then be converted into intakes of nutrients or other food constituents. There is no 'gold standard' for estimation of portion sizes; therefore the use of different aids will depend on survey methodology, target population and accuracy required.

Methods used to quantify food intakes may be divided into two broad categories: those in which foods are weighed directly and those in which foods are estimated. Weighing of foods can introduce changes in eating habits, increases the burden placed on the subject and there are circumstances where weighing is not suitable (e.g. large epidemiological studies). Furthermore, weighing foods consumed outside home and away from parents poses additional practical problems. Published standard portion sizes, digital images of foods (91,102–104), household measures (e.g. common sizes of mugs, glasses and bowls; standard measuring cups and spoons), food models (e.g. three-dimensional food models) (105), geometric shapes or drawings of foods have been used to quantify portion sizes (68,106). The use of these aids relies on the ability and willingness of subjects to remember and accurately estimate the amounts of foods consumed. Although the estimation of portion sizes is associated with a loss of precision as a result of over- and underestimation, without such aids, errors in assessment of portion sizes can be even larger.

Portion size estimation has been deconstructed into perception (what people see in front of them and can be defined as the ability to relate an amount of food that is present in reality to an amount depicted in a portion size assessment tool), conception (recall soon after meal is a subject's ability to make a mental construct of an amount of food which is not present in reality), and memory (recall 24 hours or more after meal) (107).

Foster et al (108) assessed the effect of timing on perception, conceptualization and memory on the ability of children to estimate food portion size using three portion size assessment tools: food photographs, food models and an Interactive Portion Size Assessment System (IPSAS). There is no evidence that children's ability to estimate portion size is significantly different 24-h after eating from just after eating a food, or indeed when the food is in view. These authors also found that children of all ages performed well using the IPSAS and food photographs. The accuracy and precision of estimates made using the food models were poor. An interval of 24-h appears to be a short enough interval between eating and estimating the portion size of a food.

Lillegaard et al (109) assumed that perception is the only element that could affect the process of using a photograph to identify portion size. For this purpose, they eliminated conceptualization and memory from their study once the estimates were made with no time delay between seeing the foods and using the photographic booklet. The authors assessed whether children and adolescents could accurately estimate portion sizes of pre-weighed foods by viewing 4 photographs of foods, and whether age influenced their abilities to estimate food portion sizes. The participants' ability to choose the correct photograph differed according to the photographic series and was easier when the served food and the photograph of the food appear to be exactly the same. However, nearly all food items were estimated within ±1 photograph from the correct photograph independent of the foods appearance on the plate.

The use of age-appropriate tools is particularly important when children are the target population. Frobisher & Maxwell (110) and Foster et al (111) found that errors in portion size estimation made by children using the adult food photographs were much greater than those observed when adults used the photographs. Single portion size photographs based on adult food portion sizes are unlikely to be suitable for use in children.

The Expert Group on Food Consumption Data (EGFCD) (38) reinforces the importance of using age-appropriate tools and portion size aids, which are representative of the food available on the market and of the food portions actually consumed. They also recommend the use of country-specific and validated picture books. These books should contain pictures of foods in portion sizes that are commonly used in the area where the study was conducted and should include foods commonly available on the market at the time of the survey. Furthermore, it should contain pictures of household measurement tools and standard units. Also leftovers should be estimated. Within the PANCAKE project, Trolle et al (112) validated a 38 common food picture series of six pictures each for portion size estimation of foods consumed by infants, toddlers and children. The 5^{th} and 95^{th} percentiles of Danish weighed portion sizes of foods consumed by children were used for defining the smallest to the largest portion of each series. This common age-appropriate picture series was developed for a pan-European dietary survey.

The effect of digital image size and the presence of size cues on the accuracy of portion size estimation by children was tested by Baranowski et al (87). These authors hypothesized that larger pictures (close to the size of the actual foods) would facilitate more accurate estimates of portion size and that the presence of image size cues would enhance accuracy, especially with the smaller pictures. Correct classification of foods using images was 60.3%. There were no differences in accuracy detected by either size of picture or size cues. There was more overestimation with larger images, and about equal over and underestimation with the multiple smaller images on the screen. Substantially less time was taken to classify foods using the smaller, rather than the larger pictures, with no differences in accuracy detected. Less time was likely due to children not having to scroll across pictures and greater ease in making perceptual equivalence relationships when all possibilities were on screens. This suggests that multiple small pictures on the screen at the same time are the preferred method for estimation of portion sizes in children.

1.3.6 What is the role of technology in dietary assessment?

The advancements and application of recent technologies to automate the more accurate methods of dietary assessment, making them less expensive and easier to use, could move usual practice away from the less accurate methods, and thereby result in broad

based benefits (113). 24-h DR may now be conducted interactively, using computer software that prompts the interviewer to collect all of the necessary information about food consumed by children.

In recent decades, the expansion of the Internet for personal and professional use has presented unique opportunities for collecting individual data in the research field. In particular, 91% of Portuguese children from the fourth, sixth and ninth grades of public and private schools have a computer at home and 79% have a computer with Internet access. The computer and Internet access was more frequent in families with higher educational level and with more qualified jobs (114). Schools are often the preferred setting used to collect dietary intake data from web-based questionnaires. In Portugal, the relationship between students and computer with Internet access in public and private schools is 3.5 and 1.3, respectively (115).

Data collected using auto-administrated web-based questionnaires tends to improve data quality for several reasons: it standardizes the data collection process, ensures the appropriate level of detailed obtained for every food consumed, and eliminates manual coding, which has been the most labour-intensive step in dietary data processing. For instance, if the participant forgets to click on an answer, an error message appears before they can move on to the next page. Validation control tools can be also incorporated with interactive audible and visual prompts that alert children when they enter an implausible answer in order to restrict omission of foods.

Web-based 24-h DR reduces interviewer workload and costs, provides great flexibility and freedom (allowing the subject to complete the questionnaire at any convenient time and location via a user-friendly interface), and is time efficient, as one researcher or nutritionist/dietician could guide 15-20 respondents at the same time. However, it requires literacy, computer skills and Internet access. Moreover, possible reporting difficulties could exist because of limited nutritional knowledge (116,117).

Therefore, technological alternatives might overcome some of the feasibility and financial issues but they will also introduce new challenges in dietary assessment (116) for researchers and also for developers. Buday et al (118) discussed in a recent paper different methods of software development that should be taken into account before the

development of new software's in order to maximize their chance for success: 1) requirements analysis (systematic way to gather and analyse information about a software development project), 2) development methodology (design phase, production, testing, implementation, and evaluation), 3) building a development team (researchers and software developers), and 4) software intellectual property.

Table 1-3 describes and summarizes some of the most important computerised dietary assessment methods used in children and adolescents.

Table 1-3. Summary of computerised dietary assessment methods for children and adolescents

Method	Country of origin	Target age (years)	Approach	Validation study
Food Intake Recording Software System (FIRSSt) (91,119)	USA	9-11	Online self-administered 24-h DR based on multiple pass method. Foods are identified within a hierarchically organized system of foods within groups. Children and adolescents are also permitted to type the name of foods not otherwise found. For each food recorded, the child is asked to identify the type, shape, and size of container and then adjusting the portion within the container to reflect the amount consumed.	Methods: n = 138 children and adolescents Mean age: 9.6 years Validator: school lunch observations; 24-h DR; hair sample ('bogus pipeline'[a]) Results: **FIRSSt vs. School lunch observations** Matches = 46% (42% with hair sample); Intrusions = 24% (23% with hair sample); Omissions = 30% (29% with hair sample) **FIRSSt vs. 24-h DR** Matches = 60% (67% with hair sample); Intrusions = 15% (12% with hair sample); Omissions = 24% (21% with hair sample) **24-h DR vs. School lunch observations** Matches = 59% (60% with hair sample); Intrusions = 17% (23% with hair sample); Omissions = 24% (15% with hair sample)
Young Adolescent's Nutrition Assessment on Computer	Belgium	≥ 11	Computerised 24-h DR based on 6 meal occasions (breakfast, morning snacks, lunch, afternoon snacks, evening meal, evening snacks) presented with a range	Methods: **Study 1** n = 136 adolescents

Method	Country of origin	Target age (years)	Approach	Validation study
(YANA-C) (102)			of sequential activities. Food (>400 items) and drink items are identified within a hierarchically organized system in 18 food groups. For food items, 800 photographs are provided and adolescents can modify the standard serving size presented (more/less) or type in a text box. For drinks it is possible to select a glass or a cup.	Mean age: 13.3 years Validator: 1-day FR **Study 2** n = 101 adolescents Mean age: 12.4 years Validator: 24-h DR interview Results: **Study 1** Matches = 90%; Intrusions = 5%; Omissions = 5% **Study 2** Matches = 89%; Intrusions = 5%; Omissions = 6%
Synchronised Nutrition and Activity Program (SNAP) (89)	UK	7-15	Self-administered web-based system to measure food behaviours and physical activity over the last 24-hours. Food (n = 40), drink (n = 9) and activity pictures (n = 29) are provided. Foods and drinks are analysed by counts (the number of times a particular food/drink is selected). Activities are analysed by transport activities, duration and intensity.	Methods: n =121 children and adolescents Mean age: 10.7 years Validator: 24-h DR interview based on multiple pass method & accelerometers (2 days) Results: SNAP underestimated dietary intake behaviour by ±1 count and moderate to vigorous activities <4 min. Time to complete SNAP: 15-40 min.
Web-Survey of physical Activity and	Canada	11-15	Self-administered web-based system based on multiple pass 24-h DR. First, food consumed is selected and	Methods: n = 459 adolescents

Method	Country of origin	Target age (years)	Approach	Validation study
Nutrition (Web-SPAN) (120)			afterwards the appropriate portion size. Adolescents are able to add or delete items at any time using a virtual meal plate and meal summary features.	Mean age: 12.8 years Validator: 3-day FR (including 1 weekend day) Reliability test: adolescents completed web-SPAN twice an average of 8 days apart <u>Results:</u> **Web-SPAN vs. 3-day FR** For total energy and selected nutrients[b], ICC was in the range 0.24-0.40 and correlations were weak (0.24-0.39). **Reliability test** For total energy and selected nutrients[b], ICC was in the range 0.38-0.64 and correlations were stronger for macronutrients (0.55-0.62) than for micronutrients (0.38-0.62).
Self-Completed Recall and Analysis of Nutrition (SCRAN24) (94)	UK	≥11	Self-administered online 24-h DR based on multiple pass method. SCRAN24 has the following structure: 1) Quick list (a meal-based structure with meals and snacks ordered chronologically throughout the day from the top of the page to the bottom); 2) Finding foods (free text search only); 3) Portion size (2055 images of 104 foods. The images are used for estimation of the amount of food served and the amount leftover, if any); 4) Time allocation (timeline	<u>Methods:</u> n = 38 adolescents and their parents Age: 11-16 years Validator: 1-day FR (kept by parents with input from the child) <u>Results:</u> Matches = 53% (15% approximate match); Intrusions = 6%; Omissions = 26% There was a tendency to underestimate energy intake by

Method	Country of origin	Target age (years)	Approach	Validation study
			method); 5) Prompts and probes (memory cues to aid recall).	20%. Time to complete SCRAN24: 25-30 min.
Web-based Dietary Assessment Software for Children (WebDASC) (88,121,122)	Denmark	8-11	Self-administered web-based 24-h DR. Children are guided through 6 eating occasions and inquired about food eaten at a given meal, sports and social activities at snack times by an animated armadillo. There are five search strategies for foods reported: 1) Category-based approach to locate items: 23 main categories, 160 sub-categories and 1300 food list terms; 2) Copy meal function (allowing children to select the same foods previously reported for a meal entered the day before); 3) Free text search (locate all food list terms); 4) A starts with search (locate food list terms that start with the same spelling); 5) Type in answer to report type and amount of items not found in the food list. For portion size estimation there are 320 photo series (each portion size series consists of 4 digital images) and 25 photos for small-prepacked food items.	Methods: n = 81 children assisted by parents Mean Age: 10.3 years Validator: school lunch observations; fasting blood samples (plasma carotenoid); accelerometers WebDASC was completed every evening during 7 consecutive days (at least 3 weekdays and 1 weekend). Fasting blood samples (plasma carotenoid) was compared with FVJ intake by WebDASC. Results: **WebDASC vs. School lunch observations** Matches = 82%; Intrusions = 14%; Omissions = 3%; Faults = 1% **FVJ intake by WebDASC vs. Plasma carotenoid** FVJ intake contributed on average 89% of estimated carotenoid intake. Spearman correlation = 0.58 **WebDASC vs. Accelerometers** At group level, no differences were found between EI and TEE (-0.02 MJ/day). At individual level, data

Method	Country of origin	Target age (years)	Approach	Validation study
				showed substantial variation in accuracy. **Time to complete WebDASC:** 35 min on the first time and 15 min on the following days.
Automated Self Administered 24™-Kids (ASA24-Kids) (123)	USA	≥ 10	Self-administered 24-h DR. ASA24-Kids-2012 was adapted from an adult version (124) and included detailed probes and up to 8 food images in progressively larger sizes for portion size estimation. An avatar guides the respondent through multiple passes.	Methods: **Study 1: ASA24-Kids & 24-h DR vs. School lunch observations** n = 38 adolescents Age: 9-11 years Validator: school lunch observations **Study 2: ASA24-Kids & 24-h DR vs. Dinner observation** n = 31 adolescents Age: 9-11 years Validator: dinner observations Results: **Study 1: ASA24-Kids & 24-h DR vs. School lunch observations** Matches = 37% & 57%; Intrusions = 27% & 20%; Omissions = 35% & 23% (ASA24-Kids & 24-h DR, respectively) **Study 2: ASA24-Kids & 24-h DR vs. Dinner observations**

Method	Country of origin	Target age (years)	Approach	Validation study
				Matches = 53% & 76%; Intrusions = 12% & 9%; Omissions = 36% & 15% (ASA24-Kids & 24-h DR, respectively) **Time to complete ASA24-Kids**: 12-58 min (mean 34 min) **Time to complete 24-h DR**: 6-35 min (mean 20 min)
Food Intake and Physical Activity of School Children (CAAFE) (90)	Brazil	7-10	Self-administered 24-h DR and physical activity recall. The food consumption section is divided into 6 meals (breakfast, morning snack, lunch, afternoon snack, dinner and supper). For each meal, 32 images of food or drinks are presented on the computer screen. An avatar in the form of a robot guides the child when completing the questionnaire, explaining the concept of each meal and the time of day at which it is consumed.	Methods: n = 602 children Mean age: 9.5 years Validator: school lunch observations Children were instructed to complete a 7-day FR previously and to take it to the computer room, in case they wished to consult their FR. Results: Matches = 43%; Intrusions = 29%; Omissions = 28% There were decreased omissions among children who completed the FR and increased children's matches that have a computer at home.

Matches: food items reported in both methods being compared.
Intrusions: food items reported in the test method but not in the validator.
Omissions: food items reported in the validator but not in the test method.
Faults: food items reported eaten does not describe the item observed eaten.
[a] 'bogus pipeline': informs children that there is another method of ascertaining the truth of a child's self-report against which their response would be compared, but the alternative assessment is never conducted.
[b] Selected nutrients: carbohydrate, protein, fat, fibre, vitamin A, vitamin C, iron, niacin, zinc, calcium, vitamin D
USA, United States of America; 24-h DR, 24-h dietary recall; FR, food record; ICC, intra class correlation; UK, United Kingdom; FVJ, fruit, vegetable and juice; EI, energy intake; TEE, total energy expenditure

1.4 Validation of dietary assessment methods

Collecting an absolutely accurate record of intake may be impossible because of subject's cognitive skills (72). For validity purposes, it is important to accept the limitations of any kind of method of measuring dietary intake in children. Three concepts are fundamental to understanding the limitations of dietary assessment: habitual intake, validity (accuracy) and precision (125).

The habitual intake of an individual is the individual's intake averaged over a prolonged period of time assuming that intake varies widely from day to day. A valid (or accurate) report is one that measures the true intake during the period of study, representing all the foods and drinks consumed on a specific day. Poor validity derives from systematic errors (bias) in the reporting of food intake. A precise technique is one that yields the same answer on repeat administrations. Poor precision derives from large random errors in the techniques of dietary assessment. When assessing diet intake it is important to identify and quantify sources of potential errors. The knowledge gained from validation studies can be used to minimize errors through design of the study and analyses of the data. Newly developed tools should be tested for validity and reliability.

1.4.1 Validity

Validity is the extent to which a measurement tool assesses the true dietary intake. It refers to the accuracy of measurement. A variable's validity reflects the extent to which it measures what it is intended to measure (126).

1.4.1.1 Content validity

Content validity indicates whether a particular measure covers all dimensions present in the concept intended to reflect. According to Hill and Magalhães Hill (127), the assessment of content validity involves four steps: 1) a literature review to write a list of all components of the variable under study; 2) a list of all aspects for each component; 3) a list of all relevant items to measure each aspect; 4) a comparison of the questionnaire items with the list of items written in the step 3. When the items of the questionnaire form a relatively representative sample of items written in step 3, we can assume that the questionnaire is valid for appropriate content. This is a subjective

measure, and there are no statistical tools to determine whether a variable has content validity.

1.4.1.2 Criterion and Relative Validity

Criterion validity is the highest standard of validity, capturing the extent to which a measure accurately reflects the exact concept it is intended to reflect. To determine a measure's criterion validity, a perfect indicator of the target concept is needed – a 'gold standard'.

Relative validity, by contrast, is determined by comparing a test method with a reference method where the reference method has a greater degree of demonstrated validity, even if not an exact measure of the underlying concept. In designing a strategy for assessing relative validity, two key design considerations are critical. First, both the test method and reference method must measure the same underlying concept over the same period of time. Second, measurement error from the test method and from the reference method should be independent.

Three different ways of understanding a measure's validity are described below:

Recovery biomarkers

Although recovery biomarkers reflect total absolute intake over a defined time, they only provide information on limited aspects of diet. They include DLW to assess energy intake (EI), urinary nitrogen excretion to assess protein intake, urinary potassium excretion to assess potassium intake, urinary sodium excretion to assess sodium intake, and finally, urinary sucrose and fructose excretion to assess sucrose intake (128).

Among these different biomarkers, the DLW technique is an example of a biomarker that can be used to validate self-reporter EI (129). Some authors consider the DLW as the 'gold standard' for the measurement of total energy expenditure (TEE) in children (36). The error of the DLW technique is independent of self-reported intake error, thus allowing true reporting bias to be detected. This method involves the administration of water containing enriched quantities of the stable isotopes deuterium (^{2}H) and oxygen-18 (^{18}O). The term doubly comes from the fact that both the hydrogen and the oxygen of

water are labeled. The oxygen-18 is eliminated from the body in the form of carbon dioxide ($C^{18}O_2$) and water ($H_2{}^{18}O$), and the deuterium is eliminated in water (^2H_2O). The difference in elimination rate between these two isotopes is a measure of carbon dioxide production. Carbon dioxide production can then be used to calculate TEE by use of standard equations for indirect calorimetry. Use of DLW as a biomarker of EI is based on the assumption of energy balance: under conditions of weight stability, EI and TEE are equivalent. During growth and development children are normally in positive energy balance.

Validation studies using estimates of TEE by the DLW method as a biomarker of EI have conclusively demonstrated that much of the data is prone to bias, mostly through underreporting. The extent of underreporting of total EI varies among individuals and tends to increase with age (125). Burrows and colleagues (36) demonstrated in their systematic review that significant underreporting of EI was found for estimated and weighed FR (19%-41% and 11%-27% of estimated EI, respectively) and overreporting for AMPM 24-h DR (7-11% of estimated EI) and FFQ (>59% of estimated EI). They also found that misreporting associated with gender was not related specifically to any dietary assessment method or the reporter of intake.

Bandini et al (130) found that reported EI was significantly lower than TEE in both nonobese and obese adolescents. Waling and Larsson (131) found that reported EI was underestimated by 14% when validated with DLW method but the underestimation did not differ between the children who were overweight and obese. Bornherst et al (132) evaluated the validity of proxy-reported EI by comparison with TEE measured by DLW in 4-10 years old children. They demonstrated an almost perfect agreement between EI and TEE in thin/normal weight children and a small mean difference (-86 kcal/day) in overweight/obese children.

However, DLW does not give information about foods consumed to obtain EI and it cannot differentiate whether reporting errors are due to reports of the omitted items or intrusion items (72). Thus, equality of a person's reported EI and his or her total TEE from DLW does not imply that the person reported the correct items and amounts; it would be possible to have such equality without a single reported item or amount being correct. DLW alone do not permit full investigation or understanding of the

complexities of dietary-reporting error. Furthermore, DLW requires urine samples and is expensive in terms of both administration and analysis (128).

Concentration biomarkers

Concentration biomarkers may be influenced by individual variability in absorption, availability and metabolism or use of supplements, and therefore they are correlated to but do not reflect total EI.

Vitamin C, folic acid, carotenoids, and polyphenols have been used for fruit and vegetables consumption (121). Vitamin C may be less suitable because plasma concentrations may plateau with high intake of vitamin C. Furthermore, non-smoking, a lower BMI, higher physical activity, and higher whole grain consumption has been associated with higher plasma vitamin C concentrations. Folic acid has a lack of specificity because foods other than fruit and vegetables are also important sources of folic acid, such as cereals. The bioavailability of carotenoids differs with the type of food consumed and could be affected by cooking process and co-ingestion of other nutrients. Finally, for polyphenols there is currently substantial uncertainly about time integration and the performance as markers of vegetables consumption, since major sources of various phenolic compounds do not only include fruit and vegetables but also coffee, tea, dark chocolate and whole grains.

Only a few validation studies using biomarkers as the reference method have been carried out with children (121,133,134).

Direct Observations

Simons-Morton and Baranowski (135) described direct observations as the ‘gold standard’ against which other measures can be compared. According to these authors unobtrusive observation provides a promising approach to assess the validity of self-report measures because it is practical and economical in school/institutional settings, independent of the subject’s memory, and can provide accurate unbiased information about the subject’s actual intake. Moreover, errors in the measurement of self-reports and that recorded by an observer are likely to be independent.

Observations of children eating school meals provide an excellent opportunity to

validate portions of children's dietary recall, whereas observation in homes may be too intrusive (135). Foods eaten at school are important because a significant percentage of children's total daily intake is consumed at school. Accuracy is defined as the extent to which the parts of the dietary method concerning school meals corresponded to what the child was observed to have eaten at school meals on the day about which the child was asked to report. Accuracy is assessed in terms of foods instead of kilocalories or nutrients because children report what they have eaten as foods, not kilocalories or nutrients. Reference information in most validation studies in which children have provided dietary recalls without parental assistance has been obtained by observing one or two school meals (86,91,93,123,135–140).

1.4.2 Reliability

Reliability refers to reproducibility of measurements (measurements give the same results when repeated under similar circumstances). Measurements are considered reliable if they are stable over time in stable subjects and are precise enough to detect differences.

Test-retest reliability

Test-retest reliability means that for a given individual, there are repeated values of the same measure of a given concept. The extent to which these repeated values of the measure for this subject are similar to another (or the correlation between these values) reflects the test-retest reliability of the measure. The usefulness of test-retest reliability depends on measurement costs, the feasibility of replicating the measure's reference period, and the possibility of second measurement being influenced by the first measurement (126).

Foods and drinks obtained from a 24-h DR cannot be used to measure test-retest reliability (126). A 24-h DR measures an individual's dietary intake on a specific day and when a second 24-h DR is administered on the next day or 15 days apart, it will refer to foods and drinks consumed on a different day. Administering the first 24-h DR in the morning and the second in the afternoon could be a possible strategy to overcome this limitation (67). However, the problem would still remain because the responses from the second 24-h DR would be influenced by the responses obtained on the first

recall (assuming that children remember what they had previously reported). For a true indicator of test-retest reliability, the test and re-test should be independent and the results should not be influenced by the results of the initial test.

Inter-observer reliability

Inter-observer reliability (IOR) is a type of reliability used among direct observations. It assesses the concordance of two observers who simultaneously observe the same subject (141). Assessment of IOR is necessary to determine that the information collected does not depend on who conducted the observation and may be defined as at least 85% of agreement (135). Rigorous observational training is an imperative part of direct observation because it affects the accuracy and reliability of data recorded (138).

1.5 Aim of the thesis

The review of the literature just presented previously in this chapter shows that accurate description of dietary intake among school-age children is critical for monitoring the nutritional status of children, examining associations between diet and health, and identifying dietary intake patterns and eating behaviours that are associated with unhealthy weight and weight gain over time.

The 24-h DR is among the most accurate methods to estimate total energy and nutrient intakes in school-age children. There seems to be a fairly rapid increase in the ability of children to participate in unassisted recalls for foods eaten in the immediate past at around 7-8 years old. Traditional 24-h DRs are expensive and impractical for large-scale research, because they rely on trained interviewers, and multiple administrations are needed to estimate habitual intakes.

The application of technology to automate the more accurate 24-h DR is being conducted in multiple countries across the world, making them less expensive and easier to use. This could improve not only participation rates, but also the quality of data collected, because the lower burden of the method is less likely to impact on habitual intake.

There is a need for the exploration of a less costly alternative to the dietitian-administered 24-h DR to be used by school-age children in Portugal. This new alternative should provide accurate data by capturing children's attention and displaying food images graphically to estimate portion size.

My research sought to develop, validate and test a new web-based recall for dietary assessment in second-, third- or fourth-grade (7-10 years old) Portuguese children, the PAC24 (Portuguese self-administered computerised 24-hour dietary recall).

<u>Specific aims:</u>

1. To identify and select an extensive list of food and drink items for PAC24 (Paper 1);

2. To understand how children organize their previous day's food intake when trying to report it (Paper 1);

3. To assess the content validity of PAC24 (Paper 3);

4. To develop usability testing to obtain information about the performance of the PAC24 and to evaluate if PAC24 is adapted to the children's cognitive abilities (Paper 3);

5. To study the accuracy of PAC24 (Paper 2);

6. To conduct a pilot study to check the feasibility of PAC24 in respect of procedures, methods and data processing (Paper 3).

2. Materials and methods

The development, validation and pilot study of PAC24 followed an approach as illustrated in Figure 2-1. Ethical approval to conduct the study was obtained from the Ethics Committee of the Faculty of Medicine, University of Lisbon.

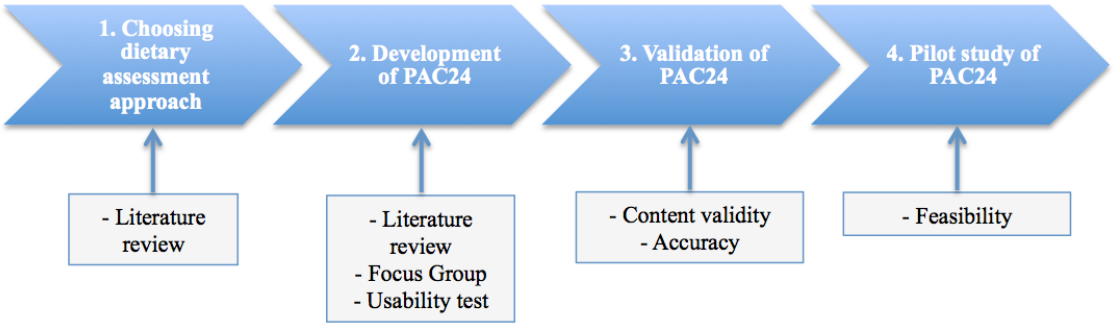

Figure 2-1. Diagram illustrating the methodology used for the development, validation and pilot study of the Portuguese self-administered computerised 24-h dietary recall (PAC24)

2.1 Portuguese self-administered computerised 24-hour dietary recall

The PAC24* comprises a software, designed for use with second-, third- or fourth-grade Portuguese children (7-10 years old), which uses interactive multimedia to facilitate a child's self-report of diet by simulating an AMPM 24-h DR. PAC24 is intuitive and visual elements were carefully selected. It comprises five forms (FORM 1-5), each of one represented by a different colour. Colours were selected to reinforce the meaning and importance of each form.

The FORM 1 (Figure 2-2) is the 'child identity card' where children provide their personal data (name, gender, age, school grade).

* For access, please send an email to macarvalho@campus.ul.pt for username and password.

Figure 2-2. Child identity card (FORM 1), the Portuguese self-administered computerised 24-h dietary recall (PAC24)

Then, the child is presented with an instruction box explaining what she or he is expected to do at the second stage. The FORM 2 (Figure 2-3) is the 'food list', where the child is asked about the meals and snacks she or he ate the previous day (first, the system asks for breakfast, then lunch, dinner and, finally, snacks). A search system (including spell check with many common misspellings of food names) then locates and displays foods automatically when similar correspondences are detected. Each meal has a box where children type in all of the foods and drinks they remember consuming on the previous day.

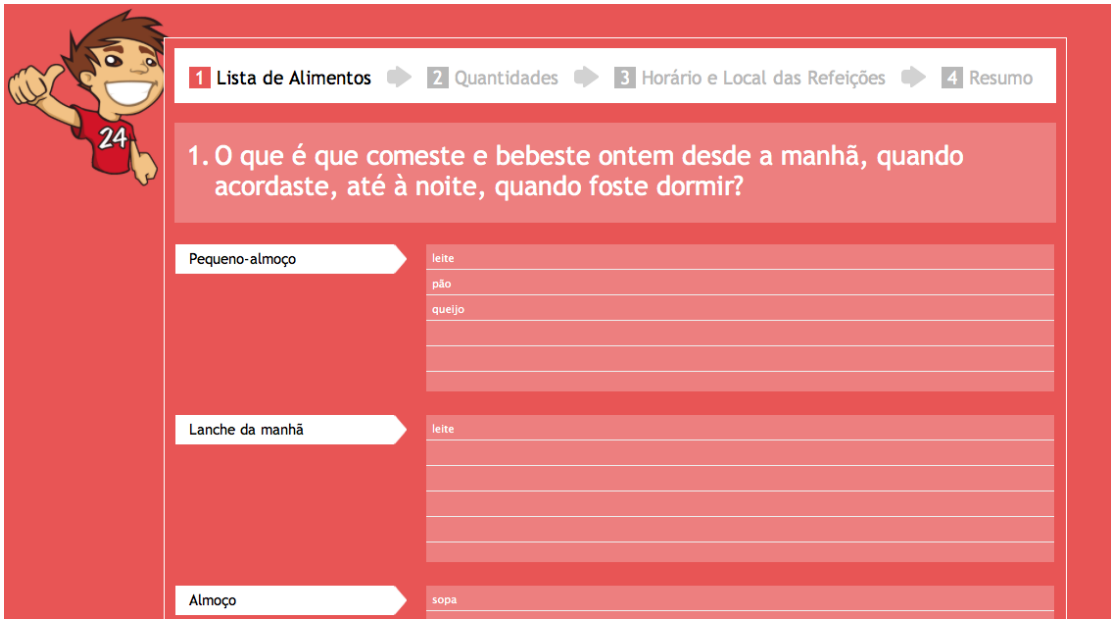

Figure 2-3. Food List (FORM 2), the Portuguese self-administered computerised 24-h dietary recall (PAC24)

Before children pass to the FORM 3 (Figure 2-4), a 'pop-up' message asks children to think about forgotten food items (soup, fruit, sweets, cakes, gums, candies, lollipops, water, and soft drinks). Next, they are presented with an 'incomplete food list', which contains food items requiring further information on the types and portion sizes of foods/drinks consumed. In the 'incomplete food list' children can click on an item resulting in a request for type of food and portion size information.

Figure 2-4. Incomplete and Complete Food List (FORM 3), the Portuguese self-administered computerised 24-h dietary recall (PAC24)

For the majority of foods recorded, the child is asked to identify the amount of food served, using seven food images (ranging from the 5th to 95th percentile of weight served to children in the UK NDNS (142) and the amount of food leftover, if any, using a selection form with seven food images (from the 5th percentile to the smallest presentable portion) to reflect the amount consumed (Figure 2-5).

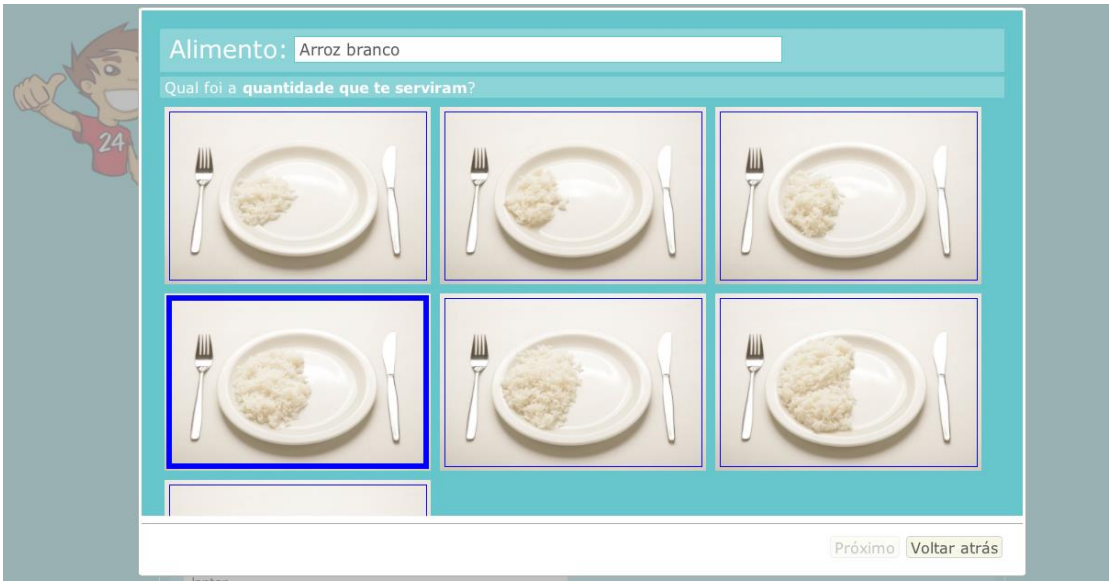

Figure 2-5. Seven food images for portion size selection (FORM 3), the Portuguese self-administered computerised 24-h dietary recall (PAC24)

For foods that are usually served in predetermined amounts, a range of commonly consumed portion sizes is displayed in one photograph (Figure 2-6) and the child is asked to select one portion size and then is asked about how many servings she or he ate.

Figure 2-6. Food served in predetermined amounts for portion size selection (FORM 3), Portuguese self-administered computerised 24-h dietary recall (PAC24)

If no image is available for a specific food item, a description of the amount served and leftover is entered manually (Figure 2-7).

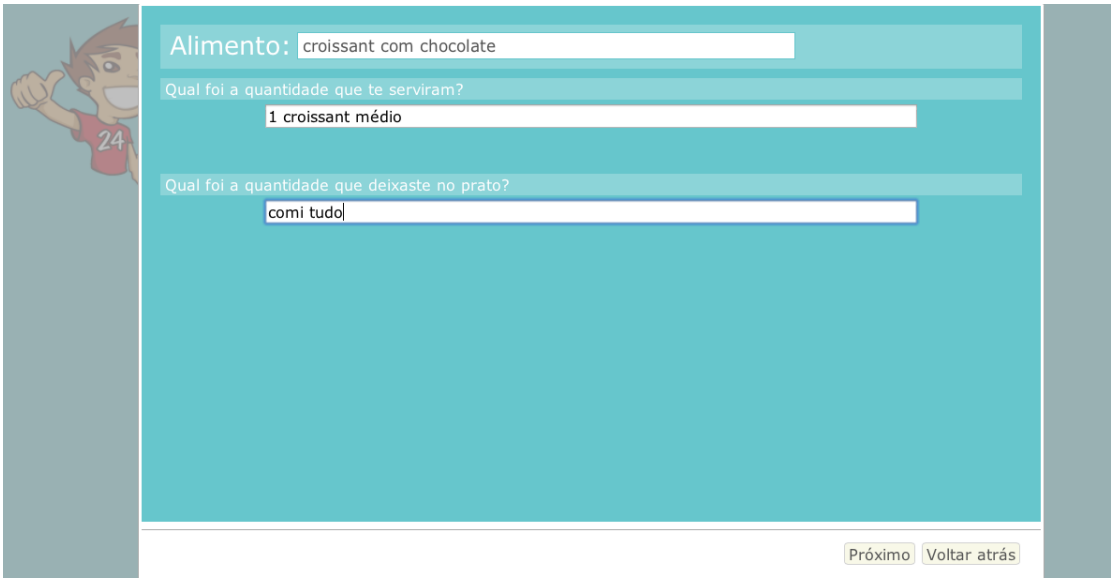

Figure 2-7. Description of food served and leftover if no image is available (FORM 3), Portuguese self-administered computerised 24-h dietary recall (PAC24)

Once all details for consumed foods have been entered, the application prompts the child to provide the approximate time and place each meal or snack was consumed and also asks the child if she or he watched television or used a computer during meals (FORM 4) (Figure 2-8).

Figure 2-8. Time, Place and Television & Computer use (FORM 4), the Portuguese self-administered computerised 24-h dietary recall (PAC24)

As a final check (FORM 5), the child is shown a summary of all food and drink items recorded throughout the day (Figure 2-9).

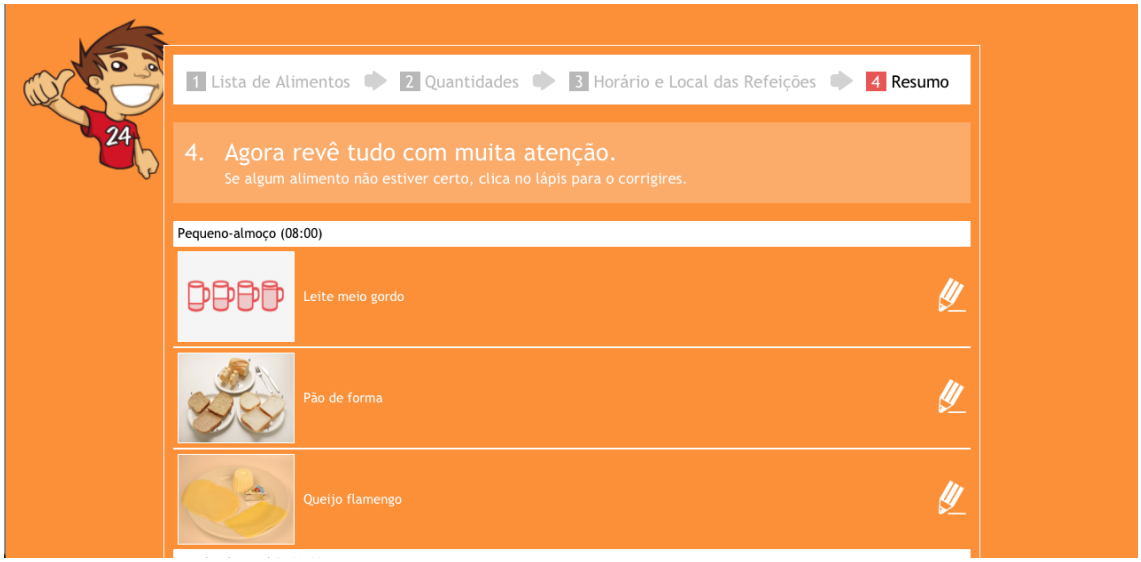

Figure 2-9. Summary Form (FORM 5), the Portuguese self-administered computerised 24-h dietary recall (PAC24)

If the child wants to correct or to add a forgotten item, there is a button that allows the child to return to FORM 3 at any time during the process. The food composition code and weight of all selected items are automatically allocated and stored. A database of 380 food items is available. Food, energy and nutrient information is linked essentially

to the Portuguese food composition database (143). In a nutshell, the PAC24 is a web application, developed in PHP (Hypertext Preprocessor; http://php.net) and backed by a MySQL database (http://www.mysql.com/). User data are collected through a web interface, rendered on any Javascript enabled browser and, subsequently, exported to Excel format (Microsoft Corp., Redmond, WA, USA).

2.2 Study population

The study population included children from the second-, third- or fourth-grade (7-10 years old). They were selected from elementary schools in Portugal. Schools were selected with the authorization and active collaboration of the Portuguese Ministry of Education from 2011 until 2013. The criteria for the inclusion of schools and children were different for each particular study of this thesis, namely: 1) Focus Groups (FG); 2) usability test; 3) accuracy of PAC24: school-lunch observations; 4) pilot study. Parents completed written informed consent forms (Appendix III), and assent was taken from children before they participated in these studies.

Focus Groups

Children were selected from seven schools from the seven regions of Portugal (including islands): North, Centre, Lisbon and Tagus Valley (LTV), Alentejo, Algarve, Madeira and Azores (March-September 2011). Schools were selected on basis of a convenience sampling process. The criteria for the inclusion of schools were: regional location of the school, covering second to fourth grades, and willingness to participate. Inside each school, participants were selected from class lists according to theoretical criteria (intentional sampling). According to these intentional criteria, FG were built up assuring homogeneity in terms of children's grade and area of residence; also, heterogeneity for gender and social-economic status. Of all 210 invited children from second to fourth-grade, 6 did not provide written parental consent.

Usability test

The usability test included children from one primary school in LTV region, Portugal (April 2013). This school was selected on basis of a convenience sampling process. The criteria for the inclusion of the school were: located in LTV region, covering second to fourth grades, being a school with Internet access and with computers/laptops available

to children, and willingness to participate. Inside the school, participants were selected from class lists according to theoretical criteria (intentional sampling). All the 12 children invited to participate in this study provide written parental consent.

Accuracy of PAC24: school-lunch observations

Children from two elementary schools in LTV region, Portugal, were asked to participate in the accuracy study (May-June 2013). Schools were selected using a purposive sampling. School inclusion criteria were: located in LTV region, covering second to fourth grades, being a school with Internet access and with computers/laptops available to children. The Portuguese Ministry of Education indicated three schools according to these inclusion criteria. Two agreed to participate (one of which was located in a lower income neighbourhood). In each school, children from second, third and fourth grades were randomly selected. Of all 56 invited children from second to fourth-grade, 12 did not provide written parental consent and data from 3 students were lost.

Pilot study

For the pilot study, children were recruited from one elementary school in LTV region, Portugal (November-December 2013). This school was selected using a purposive sampling. School inclusion criteria were: located in LTV region, covering second to fourth grades, being a school with Internet access and with computers/laptops available to children. In this school, one class from second, third and fourth grades were randomly selected. Children inclusion criteria included not having a physical, mental, or visual limitation that would inhibit computer use; being able to read and to use the computer; being able to read and write in Portuguese. Of all 55 invited children from second to fourth-grade, 3 did not provide written parental consent, 3 were not present on one of the scheduled school assessment days and 1 didn't fit the inclusion criteria to be included in the study.

2.3 Measures

Literature Review

A search strategy was undertaken to identify peer-reviewed studies published in the English and Portuguese language since 2000 using MEDLINE. Hand searching

journals, checking reference lists and contacting authors were also used as supplementary approaches to identify studies. This literature review was conducted with the main goals of examining the validity and reliability of dietary assessment methods used for school-aged children, evaluating the main measurement issues that may impact on reporting accuracy when assessing the dietary intake of children, defining the structure of food intake queries and building up the list of food and drink items used in PAC24, as well as the list of food categories created to group these items for data analysis. Keywords and combinations of these were used to search the databases comprehensively. These included: accuracy, children, cognition, computer, computerised 24-h DR, diet, dietary assessment, dietary intake, dietary surveys, feasibility, focus groups, memory, lunch observations, reliability, technology, validity, web-based, 24-h DR. The titles and abstracts of manuscripts were reviewed to assess eligibility for inclusion in this review. Abstracts provided key information that enabled to understand the scope, process and findings of each manuscript, and also to decide whether to read the full report or not.

Focus Groups

FG were carried out from March to September 2011. FG allow more abstract and in-depth exploration of food and nutrition issues than is possible with less interactive data collection tools such as structured questionnaires. It also permits the gathering of a considerable amount of data/information in a reduced data-collection timeframe, allowing the collection of several individuals' perspective as well. Therefore, these data-collection methods maximize the chances of gaining insight into how children refer to and speak about food-related habits and consumptions (144,145).

All FG were conducted in school setting, in private classrooms. In each school, three FG sessions were conducted: each one with children from second, third and fourth grade, respectively (a mean of 10 children per FG). Most of the FG were conducted during the morning (90.5%). This was done because it has been reported that accuracy is improved by conducting interviews in the morning, when the target period is the previous day (146).

FG were conducted and moderated by nutritionists and one psychologist, each lasting between 40 to 60 minutes. The same nutritionist conducted the FG in all regions, except

in Madeira and Azores regions, where FG were conducted by local nutritionists. Each nutritionist was trained in administering the same standardized questions to the children and was also informed about the objectives of the study. The psychologist conducted the first three sessions with the nutritionist and gave support in methodological issues about qualitative approaches directed to children. Topics for discussion were: 1) food consumption on the previous day, and 2) individual meanings and labelling of food items.

Content validity

In order to select a pool of all relevant items to measure food intake among Portuguese school-age children, and also, to adapt PAC24 to children's cognitive abilities, a literature review and a qualitative approach through FG was conducted, as described previously. Furthermore, input from researchers from Newcastle and Durham Universities, UK, with a vast experience with computerised 24-h DR, SCRAN24 (94) and SNAP (89) respectively, was given (February 2012).

Furthermore, five experts from different areas (a professor of paediatrics from Baylor College of Medicine (USA), a psychologist and a nutritionist from University of Lisbon (Portugal), a human-computer interaction expert from Catholic University of Portugal and a primary teacher, coordinator of a primary school in Portugal) participated in a face meeting during an afternoon to discuss and validate the content of PAC24 (February 2013).

Usability test

The prototype of PAC24 was tested to identify acceptance and usability issues, after amendments made following the expert meeting (April 2013). Usability testing is a technique used to evaluate the interface adequacy of digital applications, in this case PAC24, by testing it. The main objectives of this test were to: 1) identify any usability problems; 2) collect quantitative data on participant's performance (e.g. time to complete PAC24); 3) assess how easy/difficult it was to complete each FORM; 4) determine participants' satisfaction with the application.

Minimal instructions were provided and a 'think aloud' method (147) was encouraged. Participants were asked to verbalize what they were thinking while interacting with the

functional prototype to record their food intake. In the test, children completed typical tasks while a trained nutritionist-observer watched, listened and took notes.

Accuracy of PAC24: school-lunch observations

Data were collected by school lunch observations and PAC24 the day after (May-June 2013). The target reference period for this study was midnight to midnight of the previous day. No incentives were provided to students for participating.

One trained nutritionist and four trained nutrition science students conducted observations in the school cafeteria during usual school lunchtime. Two children were observed at the same table by one observer. Observers had school menus, but walked through the lunch line before the children arrived to assess whether what was served corresponded to what was on the menu and also to weigh the foods that would be served to children (Appendix IV). School lunches had several components: 1) soup as the first course, 2) meat or fish with rice, pasta, potatoes and/or pulses as the main course, 3) vegetables (lettuce, tomato or carrot), 4) fruit/dessert, 5) bread, and 6) water. All children had access to the same first and main course. Vegetables, fruit/dessert, bread and water were optional for all children because cooks only served these food items if children asked for them.

Children received the same food portion size of each food, because food was served to children by the cooks. Each child under observation was identified unobtrusively by their teacher at the beginning of the lunch period. As the child left the school service line, the observer recorded the number and amount of each item on the child's tray. The observer then positioned herself to clearly observe both children. During the meal, the observer recorded the amounts of all food traded (food obtained from or given to other children at the table) and any food spilled or dropped on the floor. At the end of the meal, the observer recorded the amount of each food left on the tray using kitchen scales (Vitalia, BC-200).

Standard observation training procedures were employed (135). Eaten foods and respective amounts were recorded and correlated with later student response options on the PAC24. Using IOR procedures (141), during training and data collection, observations for the same student were compared across pairs of observers. IOR was calculated as the percentage of agreement between two observers (amount of

food/beverage items served and amount of food/beverage eaten). IOR had to exceed 85% (IOR=86.9%), for data collection to proceed.

PAC24 was conducted the day after lunch observations in a private location at school on a computer or laptop computer with Internet access (most PAC24s were conducted in the morning before lunch to enable observation of school lunch for the following day's PAC24). PAC24 was completed by children who were observed the day before. During PAC24 administration, assistance was provided by one nutritionist to children who presented with questions such as: 1) how to spell a word; 2) what to do when the system didn't recognize more than one food per line at the FORM2; 3) what to do when the system didn't present exactly the same food in the portion size image as the child had reported consuming; 4) what to do if they didn't know what time they ate meals.

Pilot study

A pilot study was conducted to check the feasibility in respect of procedures, methods and data processing (November-December 2013). Two non-consecutive days of PAC24 were completed (73) in the morning with 15 days apart. Children were asked to complete PAC24 after a 15-minute explanation about PAC24, given by one nutritionist that provided assistance in completion of PAC24 for up to 10 children at one time. The nutritionist gave special attention to children who needed considerable help with writing and spelling.

2.4 Data analysis

Focus Groups

FG were audiotaped and transcribed to ensure proper thematic content analysis. For each FG, the transcription was done by the researchers who participated in the moderation of FG. All FG registered content (full corpus) was merged and included in the analysis. Content analysis followed a thematic coding process. Each unit of meaning was considered as important as any other, no matter the frequency of its verbalization. This was done because the main goal was to gather terms and meaning about food items. The analysis was entirely performed by one of the researchers, with a-posteriori validation from the other researcher. After the coding process, the coded transcripts were cut apart; that is, each piece of material relevant to a particular issue or theme was

cut and pasted so that all material relevant to a particular topic was placed together (creating categories). As the data were qualitative in nature, only frequencies were used for food item selection purposes and no formal statistical tests were applied in the study.

Accuracy of PAC24: school-lunch observations

Lunch observations were used to validate the PAC24. The PAC24 covered a full 24h period, whereas school lunch observation only covered the previous day's lunch consumption. Statistical weights were assigned to meal components to reflect their importance: combination entree (e.g. hamburger on bun) multiplied by 2, and remaining components (e.g. chicken, milk, apple, peas) multiplied by 1, so that errors in reporting entrees counted more than errors in reported sides and drinks (93,96,137,148). Condiments were not assessed, because condiments weren't available to children during the lunch period.

Nutritionists compared the sets of data by hand and assigned all foods by meal into the categories: matches (reported in both records being compared), intrusions (reported in the PAC24, but not by the validator), or omissions (reported in the validator, but not in the PAC24) for each individual separately. Because foods can be reported in many ways, items were scored as matches unless it was clear that the child's recall did not describe an observed food. Examples of items observed and reported as matches were all types of milk (e.g. skim, semi-skim), and all types of vegetable soup (pea soup, spinach soup). Fruit, vegetables and breads that differed were not considered matches. Rates per student for each lunch were calculated for each of the three categories.

In addition, to evaluate children's accuracy of reported amounts, observed and reported amounts were scored in servings (0.0 = none, 0.1 = taste, 0.25 = little bit, 0.5 = half, 0.75 = most, 1 = all, or the actual number of servings if more than 1) (93). Total innacuracy (total inaccuracy=(absolute difference between amounts reported and observed eaten for each match×statistical weight)+(each omitted amount×statistical weight)+(each intruded amount×statistical weight) summed over all items at school lunch for each child) was calculated as a measure that combined accuracy for reporting of items and amounts but it fails to indicate whether errors are due to omissions, intrusions, or incorrectly reported amounts. A total inaccuracy score of zero indicated a perfect recall compared to observation (137).

To analyze accuracy for reported amounts (in servings) for matches, arithmetic differences for matches (arithmetic differences for matches = {sum ([amount reported – amount observed for each match] x weight)} / (weighted number of matches)) and absolute differences for matches (absolute differences for matches = {sum ([absolute difference between amounts reported and observed for each match] x weight)} / (weighted number of matches)) were calculated between amounts observed and reported eaten; amounts for omissions (amounts for omissions = {sum ([amount observed but not reported for each omission] x weight)} / (weighted number of omissions)) and intrusions (amounts for intrusions ={sum ([amount not observed but reported for each intrusion] x weight)} / (weighted number of intrusions)) were also calculated to assess whether these errors in reporting involved small or large amounts of servings (137). Values close to zero for arithmetic and absolute differences for matches, and amounts for omissions and intrusions, represented high accuracy.

For those food items which were correctly reported (matches) the method of Bland and Altman (149) was used to assess the accuracy of estimates of food weight reported using PAC24 by calculating the ratio of estimated food weight (by PAC24) to actual food weight intake as measured by the lunch observations.

After cleaning and validation, data were converted and exported to a database for statistical analysis in SPSS (version 21). Differences between groups (gender and grade) were examined for percentage of foods matched, omitted and intruded and for total inaccuracy, arithmetic differences for matches, absolute differences for matches, amounts for omissions and amounts for intrusions. Variables were tested by gender and grade for normality. Percentage of foods omitted and intruded, and also total inaccuracy, amounts for omissions and amounts for intrusions were found to be highly positively skewed. The mean value between two independent samples was calculated using independent sample t-test. The non-parametric alternative was the Mann-Whitney Test. ANOVA was used to compare the mean values between more than two independent samples after testing for normality and homogeneity. The non-parametric alternative test was the Kruskal-Wallis test. A $p\text{-value}<0.05$ level was considered statistically significant.

Log transformations were applied to approximate normality. Accuracy of estimates of food weight using PAC24 was assessed by calculating the mean ratio of estimated weight to actual weight (1 indicated exact agreement of the two methods at the group level) and the limits of agreement were calculated as the mean ratio +/- 1.96 standard deviation (SD) to give a measure of precision.

Pilot study

The total energy and nutrient intakes were computed using the Portuguese food composition database. Descriptive analyses (mean values, standard deviations and percentages) of energy and nutrient intakes (protein, total fat, carbohydrate, fibre, calcium, sodium, potassium) were calculated. Variables were tested by gender and grade for normality. The mean value between two independent samples was calculated using an independent sample t-test. The non-parametric alternative was the Mann-Whitney U-test. Analysis of variance was used to compare the mean values between more than two independent samples after testing for normality and homogeneity. The non-parametric alternative test was the Kruskal-Wallis test. Wilcoxon signed-rank tests were used to compare, on a group level, the intakes of 12 food groups (1) Cereals, cereal products and potatoes; 2) Fruit; 3) Vegetables; 4) Milk and dairy products; 5) Meat, fish and eggs; 6) Pulses, fresh and processed; 7) Oils and fats; 8) Beverages; 9) Sweet products; 10) Snacks and fast food; 11) Mixed dishes; 12) Miscellaneous), energy and nutrients (protein, total fat, carbohydrate, fibre, calcium, sodium, potassium). Statistical analyses were performed using SPSS (version 21). A p-value <0.05 level was considered as statistically significant.

3. Studies for the development of PAC24

Development of a new computer program to assess dietary intake in Portuguese school-age children: a qualitative approach.[†]

3.1 Introduction

The burden of chronic diseases is rapidly increasing worldwide (11). Non-communicable diseases (NCDs), including cardiovascular diseases, cancers, chronic respiratory diseases and diabetes, are the leading cause of death in the world, responsible for 63% of the 57 million deaths that occurred in 2008 (150). Almost half of chronic disease-related deaths are attributable to cardiovascular diseases (150). Obesity, and particularly childhood obesity, is also showing worrying trends, not only because it affects a large proportion of children – 19.3-49.0% of boys and 18.4-42.5% of girls in Europe are overweight (15) – but also because it is established earlier in life. These wide variations in overweight and obesity prevalence estimates, among primary school children from twelve European countries, suggest the presence of a north-south gradient, with the highest prevalence values found in southern European countries (15). In Portugal, data from the COSI-Portugal study showed that 37.9% of children were overweight and 15.3% were obese (17).

Food and nutrition are important determinants of NCDs (151–153). Furthermore, children's diets must be suitable to support normal, and sometimes very rapid, growth and development (154). What makes food intake a NCD risk factor instead of a health protecting factor is imbalances in variety, quality and quantity. This distinction is often very subtle and so difficult to assess. Therefore, for both clinical and research purposes, reliable ways of assessing dietary intake (including reliable and valid data collection instruments) are required so that children's dietary intake can be effectively monitored (155). This is especially difficult to achieve for children of primary school age. A cognitive model of children's reporting of food intake was proposed by Baranowski and

[†] Carvalho MA, Santos O, Rito A, Foster E, Moore HJ, Pereira Miguel J. Development of a new computer program to assess dietary intake in Portuguese school-age children: a qualitative approach. Acta Pediátrica Portuguesa 2014; 45: 116-123. (Appendix I)

Domel (84). This model includes three structural components: sensory register, short-term memory, and long-term memory. In the 7–8 year age group, there seems to be a fairly rapid increase in children's ability to participate in unassisted recalls for foods eaten in the immediate past (82). However, children between 7 and 10 years old often need some help from parents or other adults, especially for providing details about types and quantities of consumed food (82). 24-hour Dietary Recalls (24-h DR) are logistically simple, applicable for cross-cultural surveys and not too burdensome for the respondents, and would be the method of choice (especially when assisted by parents) for assessing food intake among school-age children (73,89).

Furthermore, computers appear to be useful for this task since they (a) are seen as enjoyable devices for children, (b) reduce the costs of both the collection and processing of dietary intake information due to the amounts and complexity of data usually involved, (c) enhance consistency of interviewing, due to standardization of the probes used for query details of consumed foods and respective portions, and (d) minimize respondents' burden, if compared with other existing diet assessment systems (156,157).

In Portugal, data about food consumption are scarce for all age levels and especially for children. There are a few data sources. The Food Balance Sheets (158) and few national monitoring surveys (159), conducted on representative population samples, do not provide reliable estimates at the individual level, which are essential for identifying groups at risk and studying causal relationships between diet and disease (160).

A new method for assessing food and nutrition intake of Portuguese school-age children is currently being developed: the Portuguese self-administered computerised 24-h DR (PAC24). In order to design this web-based questionnaire, it would be helpful to (a) identify and select an extensive list of food items for PAC24, (b) better understand how children organize their previous day's food intake when trying to report this information, and (c) identify different meanings and labels children give to certain food items. To obtain such information, we followed a qualitative approach with a sample of second-, third- and fourth-grade Portuguese students.

3.2 Methods

This study follows a qualitative approach, with data collection carried out using Focus Groups (FG) between March and September 2011. FG allow more abstract and in-depth exploration of food and nutrition issues than is possible with less interactive data collection tools such as structured questionnaires. They also enable the gathering of a considerable amount of information in a short data-collection timeframe, and of several individuals' perspectives as well. This data-collection methodology maximizes the opportunity of gaining insight into how children refer to and speak about food-related habits and consumption (144,145).

3.2.1 Study population and design

The study included students from the second to the fourth grade. They were selected from seven schools in the seven regions of Portugal (including the islands): North, Centre, LTV, Alentejo, Algarve, Madeira and Azores. Schools were selected on the basis of a convenience sampling process, with the authorization and active collaboration from the Portuguese Ministry of Education. The criteria for the inclusion of schools were: regional location, presence of second to fourth grades, and willingness to participate. Within each school, participants were selected from class lists according to theoretical criteria (purposive sampling). In accordance with these purposive criteria, FG were constructed to ensure homogeneity for school grade and area of residence, and heterogeneity of gender and social-economic status. The study was approved by the Ethics Committee of the Faculty of Medicine, University of Lisbon. Parents completed informed consent forms, and assent was taken from children before they participated.

All FG were conducted at school, in private classrooms. In each school, three FG sessions were conducted, one each with children from the second, third and fourth grade (a mean of 10 children per FG). Most of the FG were conducted during the morning (90.5%). This was done because greater accuracy has been reported with interviews conducted in the morning when the target period is the previous day (146). The FG, each lasting between 40 and 60 minutes, were conducted and moderated by nutritionists and one psychologist. The same nutritionist conducted the FG in all regions, except in Madeira and Azores, where the FG were conducted by local nutritionists. Each

nutritionist was trained in administering the same standardized questions and was also informed about the objectives of the study. The psychologist conducted the first three sessions with the nutritionist and gave assistance with methodological issues concerning qualitative approaches for child subjects.

3.2.2 Focus group questions

FG questions were developed by the research team on the basis of a previous review of the literature. The discussion followed an enjoyable game format. Topics for discussion were:

3.2.2.1 Previous day's food consumption

Data on previous day's food consumption were obtained by simulating a multiple-pass 24-h DR, developed by US Department of Agriculture (69). The multiple pass method guides the respondent through a 24-hour reference period of food intake, providing different opportunities for the respondent to remember food details and also additional foods. It has been validated and shown to accurately estimate mean total energy and protein intakes. In the US, it has been used in the National Health and Nutrition Examination Survey (NHANES), and in Europe, a similar program, EPIC-SOFT, has been developed for use in the European Prospective Investigation into Cancer and Nutrition.

Children were asked to verbally report intake in any order they wished in response to the initial instruction *"Tell me everything you had to eat and drink yesterday, from when you woke up until you went to bed" ("Diz-me tudo aquilo que comeste e tudo aquilo que bebeste ontem, desde que acordaste até ao momento em que foste dormir.")*. They were then asked about items that might have been forgotten, including water, soft drinks, biscuits, sweets and ice cream. These forgotten food items were based on commonly forgotten categories of foods described previously (69). After that, the children were asked about time and occasion of each food, and for further information (details, amounts and place where each food was eaten). They were asked to report quantities of food in terms of units (e.g.: number of biscuits, number of slices of toast, number of slices of pizza) and/or household measures (e.g. spoons of sugar, glasses of water). In a final review, the children were asked if they had consumed anything else

(the moderator repeated what they have reported and gave a prompt like *"Did you eat anything yesterday that I didn't mention?"*).

Responses where obtained from each child during FG. But the interaction between children frequently prompted additional food items to be recalled (e.g., one child reminding another that she/he also ate a birthday cake). This possible bias was useful and informative for the main purpose of the data collection (i.e., recording food items as they are remembered and reported by children of this age).

3.2.2.2 Individual meanings and labelling of food items

We asked children if they could identify and differentiate wholegrain from white bread, commonly consumed low fat or reduced fat food (e.g. milk), and also if they knew what ice tea is made from. The reason for these questions was that in the first FG it became clear that the meanings for such items were not universal among these age-groups.

3.2.3 Data analysis

The FG were audiotaped and transcribed to ensure proper thematic content analysis. Each FG was transcribed by the researchers who participated as FG moderators. The recorded content of all the FG (full corpus) was merged and included in the analysis. Content analysis followed a thematic coding process. Each unit of meaning was considered as important as any other, no matter the frequency of its verbalization. This was because the main goal was to gather terms and meaning about food items. The analysis was performed entirely by one of the researchers, and was subsequently validated by the other researcher. After the coding process, the coded transcripts were sorted, each piece of material relevant to a particular issue or theme being cut and pasted so that all material relevant to a particular topic was placed in the same category. As the data were qualitative in nature, only frequencies were used for food item selection purposes and no formal statistical tests were applied in the study.

3.3 Results

A total of 21 FG were conducted. Overall, 204 children participated in the study. Regarding age, sample distribution was: 7-8 years (second grade; n=70), 8-9 years (third grade; n= 61), and 9-10 years (fourth grade; n=73). With respect to geographical distribution, 29 children lived in the North region, 37 in Centre, 19 in LTV, 34 in Alentejo, 29 in Algarve, 27 in Azores, and 29 in Madeira.

Analyses of the data resulted in the emergence of three key themes: 1) the previous day's food consumption; 2) the way children reported on the previous day's food consumption; and 3) meaning and labelling of specific food items.

3.3.1 Previous day's food consumption

Overall, 3959 food items were identified by children when asked about their previous day's food intake. These food items were classified by researchers (rather than children themselves) into the following food categories (Table 3-1): 1) Cereals, cereal products and potatoes (920 items); 2) Fruit (326 items); 3) Vegetables (376 items); 4) Milk and dairy products (591 items); 5) Meat, fish and eggs (546 items); 6) Pulses (30 items); 7) Oils and fats (150 items); 8) Beverages (449 items); 9) Sweet products (445 items); 10) Snacks (non-sweet) and fast-food (35 items); 11) Mixed dishes (84 items); and 12) Miscellaneous (7 items). The FG were run during spring and summer, which may explain the high frequently reported consumption of ice-cream.

Table 3-1. Food items included in the 12 food categories

Food categories	Description	Food items reported	
		n	%
1) Cereals, cereal products and potatoes	All types of bread made with different type of flour (wheat, whole wheat, rye) including toasted bread; all types of pasta; baby cereals; all types of rice; potatoes; sweet potatoes; potato crisps; mashed potatoes; breakfast cereals; crackers; biscuits without cream or chocolate; sweet corn	920	23.2
2) Fruit	Fresh fruit; 100% juice fruit; nuts; seeds; olives	326	8.2
3) Vegetables	Raw and cooked vegetables; vegetable soup	376	9.5
4) Milk and dairy products	All types of milk (whole, semi-skimmed, skimmed, flavoured); yogurt; cheese	591	14.9
5) Meat, fish and eggs	Beef; pork; hamburgers; chicken; poultry; raw, canned and cooked fish; fish products; crustaceans and molluscs; eggs (fried, boiled, scrambled, omelettes); ham; sausage; snails	546	13.8
6) Pulses, fresh and processed	All types of beans; lentils; peas; lupin seeds	30	0.8
7) Oils and fats	Butter; Olive oil and other vegetable oils; margarine; cream; mayonnaise; peanut butter	150	3.8
8) Beverages	Tap water; bottled water; fruit juice with sugar added; soft drinks; black coffee; tea; alcohol; other hot drinks (cocoa or chocolate beverages; coffee with milk); currant	449	11.3
9) Sweet products	Chocolate and chocolate products; ice-cream; biscuits (chocolate biscuits, butter biscuits); cakes; sweet snacks; sugar; jelly; milk-based desserts; sweets; jam; marmalade; honey; sweet breakfast cereals; sweet cereal-based snacks (e.g. bars); pancakes; waffles; brioches; milk bread rolls; croissants; croissants with chocolate filling	445	11.2
10) Snacks (non-sweet) and fast-food	Pizza; hot-dogs; quiches; savoury pies; pastry	35	0.9
11) Mixed dishes	Meat-based dishes; fish-based dishes; pasta-based dishes	84	2.1
12) Miscellaneous	Vinegar; ketchup; mustard sauce	7	0.2

The most popular breakfast choices were: chocolate cereals, honey cereals, toast, milk and bread with butter, cheese, ham or jam. Common to all children was the fact that their parents prepared breakfast for them whether they (the parents) were present at the

meal or not (e.g., when the breakfast was taken out-of-home). A wide variety of foods were reported to be eaten as snacks, such as sandwiches, biscuits, cakes, yogurt, flavoured milk, fruit and ice-cream. Snacks were most commonly eaten during school break-time and at home, straight after school. Snacks in school were typically brought from home, with the exception of the flavoured milk (usually with chocolate) that was offered by the school.

The majority of children had lunch in the school canteen and the reporting of lunch food consumption was more collective (involving all participants of each FG) than individual. All the lunches included vegetable soup, meat or fish with potatoes, pasta or rice. Salad and fruit were optional, and so some children did not report the consumption of those food items.

There were considerable differences in food composition for dinner between children. By contrast, the consumption of beverages was common during dinner, particularly soft drinks, especially ice tea. Of the total consumption of beverages reported by children, 56.6% were soft drinks. Finally, few children reported an additional snack before going to bed. When they did, it consisted of cake, sweets, milk or tea.

3.3.2 How children reported on the previous day's food consumption

In general terms, children reported foods chronologically (from the first item eaten in the morning to the last item at night), but beverages (e.g. water) were routinely reported non-chronologically.

Most children reported three main meals (breakfast, lunch and dinner). Without prompts for snacks (Table 3-2) participants did not spontaneously report the consumption of foods between breakfast and lunch, lunch and dinner, and/or after dinner. They reported food items using the time of day and other contexts, such as where they were, who they were with, and what they were doing as methods of remembering which food they had consumed. Individual children differed in the effort they made trying to remember what they ate during the previous day. A number verbalized having difficulties reporting what they ate and in reporting the quantities of those foods remembered. This was more evident among children in the second grade (7-8 years old), and was also more evident

when children were asked about quantities of sugar, chocolate, honey or coffee added to beverages (Table 3-2). Regarding water consumption, children reported different sources, including glasses of water, bottled water and drinking fountains. Most children reported the consumption of sweets and cakes that other pupils brought to school (especially on birthdays to share with their peers), after they were asked for forgotten foods (Table 3-2).

Table 3-2. Major reporting issues regarding previous day's food consumption and individual meanings and labeling of some food items

Food reporting issues	Typical comments
Children reported the three main meals first (breakfast, lunch and dinner) and then snacks, after specific prompting for snacks.	**Moderator** I would like to know what you ate yesterday since the time you wake up until you went to bed. **Child** I ate bread with butter and a glass of milk with *nesquick*[1]. **Moderator** And after? **Child** I ate cabbage soup and codfish with potato. **Moderator** And that was your lunch? **Child** Yes. **Moderator** And after what was it? **Child** Pizza. **Moderator** And then? **Child** Then is the next day. **Moderator** You told me that you ate in the morning, bread with butter and milk with *nesquick*[1]. And between breakfast and lunch, did you eat or drink something? **Child** Ah, I drank milk and I ate a *chipicao*[2].
Description of food quantities was difficult for some children, especially for sugar, chocolate, honey or coffee added to beverages.	**Moderator** Ok. And if I ask you about how much sugar was on your milk, are you able to tell me? **Child** No. **Moderator** How many spoons of sugar did you add to milk? **Child** I don't know. My mother puts sugar on my milk every day.
The majority of children reported sweets and cakes that children brought to school on birthdays after prompting for forgotten food items.	**Moderator** One thing that I am surprised is that anyone besides these two girls ate chocolate or candies yesterday. **Child** I ate. **Child** I think I ate the day before yesterday. **Child** I ate a croissant. **Child** Yesterday I drank a juice. **Child** I only eat on birthdays. **Child** Every day I eat at least two chocolate cookies. **Child** I eat more at Sundays, it is on that day that I go to my grandmother´s house and she gives me pastries. **Child** Yesterday I ate a *pastel de nata*[3]. **Moderator** So, I think that is better, at the end of the game that I am developing, to add a question like this: "Did you eat candies yesterday?" What do you think about that? **Children** Good.

Individual meanings and labelling of some food items	Typical comments
Some children thought that wholegrain bread was a special type of bread for people who are trying to lose weight; for other children it was like a toast.	**Moderator** That bread *[you referred to have eaten yesterday]…* was it very white or rather dark? **Child** Dark. **Moderator** Who eat white bread? **Children** Me. **Moderator** And dark? **Child** Just him. **Moderator** Ok, but before the bread went to the toaster, how was the colour? **Child** White. It was normal bread. It was dark outside but inside it was white. **Moderator** Who can say what is 'wholegrain bread'? **Child** Wholegrain bread is for people who are trying to lose weight. (…) **Child** It is something that allows us to lose weight and it has also little brown dots.
The majority of children classified ice tea as flavoured water with no or little added sugar.	**Moderator** And you? Tell me what do you think what ice-tea is? **Child** It seems a little like tea. **Moderator** It seems a little like tea. And do you think that it has a little or a lot of added sugar? **Child** A little.

[1]Nesquik: chocolate powder for milk
[2]Chipicao: a sweet filled "croissant"
[3]Pastel de nata: a traditional Portuguese cake

3.3.3 Meaning and labelling of specific food items

With regard to wholegrain bread, some children thought that it was a type of bread for people who are trying to lose weight; other children understood it to be toasted bread (Table 3-2). Most children differentiated whole, semi-skimmed and skimmed milk on basis of the colour of the bottle (Table 3-2).

When children were asked *"What is ice tea made from?"*, a considerable percentage (15.8%) of children who reported consuming this soft drink said that it is made from water with a small quantity of sugar (Table 3-2).

Regional or culture-specific terms were also identified for some of the food-items.

3.4 Discussion

There is a need to develop tools for assessing food intake among Portuguese children. This study was undertaken in order to identify and select food items that will comprise a computer-based, self-administered 24-h DR for second-fourth grade Portuguese children. It also aimed to gain a better understanding of the way that children of this age report their previous day's food consumption, through FG methodology that enabled a more in-depth exploration of food consumption issues than is possible with less interactive data collection tools such as structured questionnaires. The results could also be used to better understand how to ask children about their recent food intake through a computerised food recall, such as PAC24.

Usually, qualitative methods aim to capture the ways and/or processes in which people think and behave. In this study, the main goal was to gather an extensive list of words, terms or expressions used by Portuguese second to fourth children to refer to food items. So, rather than conducting a phenomenological or interpretative analysis of the content, analysis of the corpus (i.e., transcripts of the FG) was mainly targeted at identifying those food words and terms.

Although the FG technique has significant advantages in gathering data, it also has some limitations. For instance, the results cannot be used quantitatively and the quality of the data obtained relies to a large extent on the skills of the researcher(s) in charge of the FG. This should be taken into account when reviewing the results of qualitative research such as this and when considering how they can, and should, be used. Another limitation is that we have no way of knowing whether or not what children said was really what they had eaten on the previous day, because the data were not validated with a method such as face-to-face 24-h DR or direct meal observations. Furthermore, since the objective of this study was not to analyse children's dietary reporting accuracy, the results should not be interpreted as such. Another potential limitation of this study is the generic nature of the author's questions in the FG regarding quantities of food consumed. Future research should use more appropriate tools for assisting children in this estimation, such as food photographs. Finally, it is also possible that some children were unwilling to talk about their food consumption in a group setting because of the sensitivity of these issues.

In this study, children from second to fourth grade (7-10-year-olds) were asked to report the previous day's food consumption, without assistance from their parents or teachers. This is important, because literature suggests that parents lack first-hand knowledge of their children's intake at school and also because there is evidence that children of this age are able to respond adequately to self-report methods such as dietary recalls (82). Answers regarding food items were grouped by researchers (when analysing the collected data) into 12 food groups. The categorization of these groups was based on a combination of findings from international dietary surveys (58,59,61,161,162).

When asked about what they had eaten the previous day, children generally reported foods chronologically (from the first item eaten in the morning to the last item at night). But some foods, as beverages (e.g. water) were routinely reported non-chronologically. Subar *et al* (163) found the same results in a formative research on a 'quick list' for a computerised dietary recall. Regarding the interview format (open or structured by main meals), Baxter *et al* (95) found that although more items were reported as being eaten in a structured meal interview format than in an open interview format, accuracy was better with open format interviews, with lower intrusion and total inaccuracy rates. We found that children did not report the consumption of snacks spontaneously, but in the majority of cases only reported when specific meal/snack name prompts were used. Subar *et al* (163) and Foster *et al* (94), after testing two versions of a 'quick list' for remembering foods consumed on the previous day (open format versus meal format), found that participants showed a strong preference for the meal-based format. Further studies should be carried out before deciding on the interview format for PAC24.

Students used a wide variety of retrieval categories when reporting consumption (92). FG participants from this study used the time of day and other contexts as cues for remembering which foods they had consumed. According to Baxter *et al* (93), food category prompting slightly improves recall accuracy among fourth graders, but only in half of the children who received it. We found that most children reported the consumption of sweets only after specific prompting for forgotten foods. This suggests that asking children about easily forgotten foods (e.g., foods that are usually taken outside main meals) may have an important role in increasing the accuracy of self-administered automated recalls. Further research should thus be conducted in order to validate the food prompts that will be included in PAC24.

Furthermore, not all children were able to report foods without a significant effort; both descriptions and quantities of food were difficult for some children to recall. Research indicates that children have considerable difficulties in accurately estimating quantities eaten (164).

We identified some regional or culture-specific names attributed by children to some food items that will be taken into account for the software development. The FG also showed that the majority of children did not understand the nutritional composition of some food items (e.g., ice tea and wholegrain bread). This highlights the need to increase the nutritional literacy of this age-group.

In summary, a new method for assessing food and nutrition intake of Portuguese school age children is currently being developed: PAC24. In order to design this web-based questionnaire, a qualitative approach was followed, with data collection carried out using FG. This study enriched the pool of food items that had been developed based on a literature review and also revealed the main ways in which children report their previous day's food consumption, as well as different meanings and labelling of some specific food items, that should be taken into account in the development of PAC24. Future research, particularly content validation by experts, usability tests and criteria validation, should be carried out in order to validate PAC24 for use in Portuguese school-age children.

4. Studies for the validation of PAC24

Validation of the Portuguese self-administered computerised 24-hour dietary recall among second-, third- and fourth-grade children.[‡]

4.1 Introduction

Valid methods of assessing dietary intake are required to better understand what children are eating, what correlates with intake, and evaluate dietary change intervention programmes (82). The interviewer-administered 24-h dietary recall (24-h DR) is the most commonly used method for dietary surveys and is often used to collect information from children, despite self-report being prone to errors (67,73). Moreover, interviewer-administered 24-h DRs are expensive because of the need for highly trained interviewers, multiple days of assessment to attain acceptable reliability, and specialised software to elect and record the foods consumed, and to convert this detailed information into servings and nutrients consumed (91). Interactive multimedia provides potentially powerful tools for assessing diet by capturing children's attention, graphically displaying foods and manipulating images to estimate portion size (91). Computerised 24-h DRs have been developed and used successfully with adults and children in the USA (91,119,124) and in children and adolescents in Europe (89,94,102). Although 8-9-year-old children tended to have more difficulty with food-categorization tasks and took more time to complete these tasks (165), there appears to be a fairly rapid increase in the ability of children to participate in unassisted recalls for foods eaten in the immediate past at approximately 7–8 years of age (82).

The school environment provides a unique opportunity to validate parts of children's 24-h DR through lunch observations. Foods eaten at school are important because a significant percentage of a child's total daily intake is consumed at school. Reference information in most validation studies in which children have provided diet recalls without parental assistance has been obtained by observing one or two school meals

[‡] Carvalho MA, Baranowski T, Foster E, Santos O, Cardoso B, Rito A, Pereira Miguel J. Validation of the Portuguese self-administered computerised 24-hour Dietary Recall (PAC24) among second-, third- and fourth-grade children. Journal of Human Nutrition and Dietetics 2014; doi: 10.1111/jhn.12280. [Epub ahead of print] (Appendix II)

(86,91,93,135–140). Direct observation of meals is often considered the 'Gold standard' by which dietary assessment tools are validated (135) because it is practical and economical in school/institutional settings, independent of the subject's memory, and can provide accurate unbiased information about the subject's actual intake.

The present study validated a new multimedia dietary assessment program – the Portuguese self-administered computerised 24-h DR (PAC24) - completed directly by second-, third- or fourth-grade children (7-10 years old) on a computer against observation of consumption at school lunch. Validation of the PAC24 is critical since it will be used to monitor the dietary intake of Portuguese school-age children, which will provide the basis for epidemiological studies on the links between diet and health, in turn contributing to public health policy and the design of national health programmes.

4.2 Material and methods

The Ethics Committee of the Faculty of Medicine, University of Lisbon approved the present study. Second-, third- or fourth-grade students (7-10 years old) from two elementary schools in 2013 were asked to participate. Schools were selected using a purposive sampling with authorization and active collaboration from the Portuguese Ministry of Education. School inclusion criteria were: located in Lisbon and Tagus Valley region, covering second to fourth grades, being a school with internet access and with computers/laptops available to children. The Portuguese Ministry of Education indicated three schools according to these inclusion criteria. Two agreed to participate (one of which was located in a lower income neighbourhood). In each school, children from the second, third and fourth grades were randomly selected. Written informed consent was obtained from parents. Data were collected by school lunch observations and PAC24 the day after. The target reference period for this study was midnight to midnight of the previous day. No incentives were provided to students for participating.

4.2.1 Portuguese self-administered computerised 24-h dietary recall

The PAC24 comprises software, designed for use with second-, third- or fourth-grade Portuguese children, which uses interactive multimedia to facilitate a child's self-report

of diet by simulating a multiple pass 24-h DR. The system automatically records and stores the appropriate food composition code and gramme-weight of each item selected with portion size assessment based on a system developed specifically for use with children (103). Multiple food images are presented in progressively larger amounts on the same screen to enable children to quickly report food portion size (104).

The first stage is the 'child identity card' where children provide their personal data (name, age, school grade). The second stage is the 'food list' where the user is queried about what meals and snacks were eaten on the previous day (first, the system asks for breakfast, then lunch, dinner and, finally, snacks). A search system (including spell check with many common misspellings of food names) then locates and displays foods automatically when matches are detected. Each meal has a box where children type in all of the foods and drinks they remember consuming the previous day. Next the user is presented with an 'incomplete food list', which contains food items requiring further information on the types and portion sizes of food/drink consumed. Clicking on an item in the 'incomplete food list' results in a request for portion size information. For the majority of foods recorded, the child is asked to identify the amount of food served using seven food images (ranging from the 5th to 95th centile of weight served to children in the UK National Diet and Nutrition Survey (142)) and the amount of food left over, if any, using a selection form with seven food images (from the 5th percentile to the smallest presentable portion) to reflect the amount consumed. For foods that are usually served in predetermined amounts, a range of commonly consumed portion sizes is displayed in one photograph and the child is asked to select one portion size and then is asked about how many servings they ate. If no image is available for a specific food item, a description of the amount served and left over is entered manually. Once all details for consumed foods have been entered, the system prompts the user to provide the approximate time and place where each meal or snack was consumed. As a final check, the user is shown a summary of all items of food and drink recorded throughout the day. A button allows the user to return to the 'incomplete food list' at any time during the process to add a forgotten item.

In a nutshell, the PAC24 is a web application, developed in PHP (Hypertext Preprocessor; http://php.net) and backed by a MySQL database (http://www.mysql.com/). User data are collected through a web interface, rendered on

any Javascript enabled browser and, subsequently, exported to Excel format (Microsoft Corp., Redmond, WA, USA).

4.2.2 Measures: School lunch observations and the Portuguese self-administered computerised 24-h dietary recall

One trained nutritionist and four trained nutrition science students conducted observations in the school cafeteria during usual school lunchtime. Two children were observed at the same table by one observer. Observers had school menus but walked through the lunch line before the children arrived to assess whether what was served corresponded to what was on the menu and also to weigh the foods that would be served to children.

School lunches had several components: (i) soup as the first course, (ii) meat or fish with rice, pasta, potatoes and/or pulses as the main course, (iii) vegetables (lettuce, tomato or carrot), (iv) fruit/dessert, (v) bread and (vi) water. All children had access to the same first and main course. Vegetables, fruit/dessert, bread and water were optional for all children because cooks only served these food items if children asked for them. Children received the same food portion size of each food because food was served to children by the cooks.

Each child under observation was identified unobtrusively by their teacher at the beginning of the lunch period. As the child left the school service line, the observer recorded the number and amount of each item on the child's tray. The observer then positioned herself to clearly observe both children. During the meal, the observer recorded the amounts of all foods traded (i.e. food obtained from or given to other children at the table) and any food spilled or dropped on the floor. At the end of the meal, the observer recorded the amount of each food left on the tray using kitchen scales (Vitalia, BC-200, Fagor, Mondragon, Spain).

Standard observation training procedures were employed (135). Eaten foods and respective amounts were recorded and correlated with later student response options on the PAC24. Using inter-observer reliability (IOR) procedures (141), during training and data collection, observations for the same student were compared across pairs of

observers. IOR was calculated as the percentage of agreement between two observers (amount of food/beverage items served and amount of food/beverage eaten). IOR had to exceed 85% (IOR=86.9%), for data collection to proceed.

The PAC24 was conducted the day after lunch observations in a private location at school on a computer or laptop computer with Internet access (most PAC24s were conducted in the morning before lunch to enable observation of school lunch for the next day's PAC24). The PAC24 was completed by children who were observed the day before. During the PAC24 administration, assistance was provided by one nutritionist to children who presented with questions such as: (i) how to spell a word; (ii) what to do when the system didn't recognize more than one food per line at the second stage; (iii) what to do when the system didn't present exactly the same food in the portion size image as the child had reported consuming; (iv) what to do if they didn't know what time they ate meals.

4.2.3 Statistical analysis

Lunch observations were used to validate the PAC24. The PAC24 covered a full 24h period, whereas school lunch observation only covered the previous day's lunch consumption. Statistical weights were assigned to meal components to reflect their importance: combination entree (e.g. hamburger on bun) multiplied by 2, and remaining components (e.g. chicken, milk, apple, peas) multiplied by 1, so that errors in reporting entrees counted more than errors in reported sides and drinks (93,96,137,148). Condiments were not assessed, because condiments were not available to children during the lunch period. Nutritionists compared the sets of data by hand and assigned all foods by meal into the categories: matches (reported in both records being compared), intrusions (reported in the PAC24 but not by the validator) or omissions (reported in the validator but not in the PAC24) for each individual separately. Because foods can be reported in many ways, items were scored as matches unless it was clear that the child's recall did not describe an observed food. Examples of items observed and reported as matches were all types of milk (e.g. skim, semi-skim) and all types of vegetable soup (pea soup, spinach soup). Fruit, vegetables and breads that differed were not considered matches. Rates per student for each lunch were calculated for each of the three categories (Table 4-1).

In addition, to evaluate children's accuracy of reported amounts, observed and reported amounts were scored in servings (0.0 = none, 0.1 = taste, 0.25 = little bit, 0.5 = half, 0.75 = most, 1 = all, or the actual number of servings if more than 1)(93). Total innacuracy (total inaccuracy=(absolute difference between amounts reported and observed eaten for each match×statistical weight)+(each omitted amount×statistical weight)+(each intruded amount×statistical weight) summed over all items at school lunch for each child) was calculated as a measure that combined accuracy for reporting of items and amounts, although it fails to indicate whether errors are the result of omissions, intrusions, or incorrectly reported amounts. A total inaccuracy score of zero indicated a perfect recall compared to observation (137).

To analyse accuracy for reported amounts (in servings) for matches, arithmetic differences for matches (arithmetic differences for matches = {sum ([amount reported – amount observed for each match] x weight)} / (weighted number of matches)) and absolute differences for matches (absolute differences for matches = {sum ([absolute difference between amounts reported and observed for each match] x weight)} / (weighted number of matches)) were calculated; amounts for omissions (amounts for omissions = {sum ([amount observed but not reported for each omission] x weight)} / (weighted number of omissions)) and intrusions (amounts for intrusions ={sum ([amount not observed but reported for each intrusion] x weight)} / (weighted number of intrusions)) were also calculated to assess whether these errors in reporting involved small or large amounts of servings(166). Values close to zero for arithmetic and absolute differences for matches, and amounts for omissions and intrusions, represented high accuracy.

For those food items which were correctly reported (matches) the method of Bland & Altman (149) was used to assess the accuracy of estimates of food weight reported using PAC24 by calculating the ratio of estimated food weight (by PAC24) to actual food weight intake as measured by the lunch observations (Table 4-2).

After cleaning and validation, data were converted and exported to a database for statistical analysis in SPSS, version 21 (ibm Corp., Armonk, NY, USA. Differences between groups (gender and grade) were examined for percentage of foods matched,

omitted and intruded and for total inaccuracy, arithmetic differences for matches, absolute differences for matches, amounts for omissions and amounts for intrusions (Table 4-1). Variables were tested by gender and grade for normality. Percentages of foods omitted and intruded, and also total inaccuracy, amounts for omissions and amounts for intrusions were found to be highly positively skewed. The mean value between two independent samples was calculated using independent sample t-test. The non-parametric alternative was the Mann-Whitney U-Test. Analysis of variance was used to compare the mean values between more than two independent samples after testing for normality and homogeneity. The non-parametric alternative test was the Kruskal-Wallis test. $P<0.05$ was considered statistically significant.

Log transformations were applied to approximate normality. Accuracy of estimates of food weight using the PAC24 was assessed by calculating the mean ratio of estimated weight to actual weight (1 indicated exact agreement of the two methods at the group level) and the limits of agreement were calculated as the mean ratio ($\pm$1.96 SD) to give a measure of precision (Table 4-2).

4.3 Results

In total, 44 students returned signed assent and parental consent forms indicating their agreement to participate. However, PAC24 data from three students were lost. Accordingly, data collection included 41 students (24 girls corresponding to 58.5% of the sample). More children were 10 years old (34.1%), with some being 9 years (31.7%), 8 years (24.4%) and 7 years (9.8%). The mean (SD) age was 8.9 (1.0) years.

Sixty-seven percent of foods reported were matches of specific foods, 21.5% were omissions and 11.5% were intrusions (Table 4-1). Items that were most often omitted were vegetables (39.7%) and sweets (15.1%). Items with the highest percentage of intrusions were beverages (38.2%).

Table 4-1 also shows results for total inaccuracy, amounts for matches, omissions and intrusions by gender and grade. The total inaccuracy measure for each recall, based on all items observed and recalled across lunch, captured the total error, in servings, of the dietary recall. Total inaccuracy (3.44 servings) was low. For matches, mean arithmetic difference per serving in amounts reported was -0.17, indicating an overall slight

tendency to under-report amounts of items actually eaten; mean absolute difference per serving was 0.23. Mean amounts of omitted and intruded items per serving were 0.61 and 0.55, respectively. There were no statistically significant differences by gender or grade ($P>0.05$).

Table 4-1. Mean (SD) frequencies for outcome variables comparing the Portuguese self-administered 24-h dietary recall (PAC24) to lunch observations among children ages 7-10 (n=41) by gender and school grade

Characteristic	n (%)	% Foods matched at food level (SD)[a,i]	% Foods omitted at food level (SD)[b,i]	% Foods intruded at food level (SD)[c,i]	Total inaccuracy (in servings)[d,i]	Arithmetic differences for matches (in servings)[e,i]	Absolute differences for matches (in servings)[f,i]	Amounts for omissions (in servings)[g,i]	Amounts for intrusions (in servings)[h,i]
Gender									
Boy	17 (41.5)	65.0 (27.1)	21.2 (23.8)	13.8 (11.6)	3.46 (2.72)	0.16 (0.14)	0.19 (0.17)	0.46 (0.48)	0.66 (0.51)
Girl	24 (58.5)	68.4 (18.9)	21.7 (16.8)	10.0 (12.4)	3.43 (2.05)	0.18 (0.25)	0.26 (0.20)	0.71 (0.43)	0.47 (0.52)
p-value		0.639[j]	0.565[l]	0.219[l]	0.740[l]	0.796[j]	0.210[j]	0.075[l]	0.315[l]
Grade									
2-nd	12 (29.3)	69.7 (21.2)	18.7 (14.5)	11.7 (10.9)	2.76 (2.08)	0.11 (0.13)	0.16 (0.18)	0.67 (0.49)	0.58 (0.51)
3-rd	15 (36.6)	60.3 (27.3)	29.7 (24.9)	10 (12.9)	4.28 (2.79)	0.18 (0.27)	0.28 (0.18)	0.64 (0.41)	0.47 (0.52)
4-th	14 (34.1)	71.9 (16.8)	15.1 (13.8)	13.1 (12.9)	3.13 (1.79)	0.21 (0.19)	0.24 (0.20)	0.52 (0.50)	0.61 (0.56)
p-value		0.350[m]	0.248[n]	0.586[n]	0.163[n]	0.450[m]	0.252[m]	0.254[n]	0.554[n]
Total	41 (100.0)	67.0 (22.4)	21.5 (19.5)	11.5 (12.1)	3.44 (2.32)	0.23 (0.19)	- 0.17 (0.21)	0.61 (0.46)	0.55 (0.52)

[a]% Foods matched at food level = [sum of weighted matches/(sum of weighted matches+sum of weighted omissions+sum of weighted intrusions)]×100.

[b]% Foods omitted at food level = [sum of weighted omissions/(sum of weighted matches+sum of weighted omissions+sum of weighted intrusions)]×100.

[c]% Foods intruded at food level = [sum of weighted intrusions/(sum of weighted matches+sum of weighted omissions+sum of weighted intrusions)]×100.

[d]Total inaccuracy = (absolute difference between amounts reported and observed eaten for each match×statistical weight)+(each omitted amount×statistical weight)+(each intruded amount×statistical weight) summed over all items at school lunch for each child.

[e]Arithmetic differences for matches = {sum ([amount reported – amount observed for each match] x weight)} / (weighted number of matches).

[f]Absolute differences for matches = {sum ([absolute difference between amounts reported and observed for each match] x weight)} / (weighted number of matches).

[g]Amounts for omissions = {sum ([amount observed but not reported for each omission] x weight)} / (weighted number of omissions).

[h]Amounts for intrusions = {sum ([amount not observed but reported for each intrusion] x weight)} / (weighted number of intrusions).

[i]A statistical weight was assigned to each item by meal component with combination entree=2, and meal components=1.

[j]t-test. [l]Mann-Whitnney U-test. [m]One-way analysis of variance. [n]Kruskal-Wallis test.

Use of the PAC24 led to underestimates the weight of food on average by 32% of the actual intake. The limits of agreement for food consumption ranged from under-estimation of 85% to an over-estimation of 218%. Accuracy of estimates of intake using the PAC24 were lower for the intake of pulses with wide limits of agreement (from an under-estimate of 94% to an over-estimate of 359%) (Table 4-2). Sweet products and vegetables were the most accurately estimated foods (Table 4-2).

Table 4-2. Accuracy of estimates of intakes using the Portuguese self-administered 24-h dietary recall (PAC24) compared with lunch observations among children ages 7-10 (n=41)

Food categories	Mean Ratio	Limits of Agreement	
		Lower	Upper
Beverages	0.66	0.21	2.05
Cereals and potatoes	0.68	0.11	4.30
Fruit	0.47	0.10	2.28
Meat, fish and eggs	0.61	0.10	3.66
Milk products	1.23	0.59	2.58
Pulses	0.51	0.06	4.59
Sweet products	0.77	0.39	1.53
Vegetables	0.74	0.19	2.91

Observers indicated some problems occurred in completing the PAC24. Younger children (second grade) experienced more difficulty in completing the PAC24, than third- and fourth-grade children. Other problems included: (i) instruction boxes were frequently ignored and sometimes children were unable to understand their meaning; (ii) misspelled search terms and more than one food item per line at the second stage resulted in search failures; (iii) in some cases, the food images shown at the third stage did not correspond to the food item written by the children at the second stage (e.g. children write mackerel and the image shown is salmon filets); (iv) unintentional clicking of buttons (e.g. some children, instead of clicking on the 'back' button of the PAC24 to return to the previous page, some children clicked on the Internet 'back' button, which meant they had to start over again); (v) unable to understand what to do at a specific stage, particularly in third stage regarding food type and portion sizes, and in fourth stage where younger children were unable to give information about what time they ate the meals (Table 4-3).

Table 4-3. Problems and suggestions for simplifying and modifying the Portuguese self-administered 24-h dietary recall (PAC24) among children ages 7-10 (n=41)

Problems detected	Suggestions for simplifying (1) and modifying (2) PAC24
Instruction boxes were frequently ignored and sometimes children were unable to understand their meaning.	(1) Give assistance to children. (2) Replace the instruction boxes with an audio tutor and/or an interactive avatar explaining what to do before each specific stage.
Misspelled search terms and more than one food item per line resulted in search failures.	(1) Give assistance to children. (2) Improve the spell check system by adding more misspellings of food names.
Some food images did not correspond to the food item written by the children.	(1) Give assistance to children. (2) Increase the food images database.
Unintentional clicking of buttons	(1) Give assistance to children.
Some children were unable to understand what to do at specific stages.	(1) Give assistance to children. (2) Use an interactive avatar.

4.4 Discussion

Use of the PAC24 attained a high match rate (67.0%) and a low level of intrusions (11.5%) and omissions (21.5%), although there was substantial variability, especially for omissions (±19.5%) and intrusions (±12.1%). Mean match values were somewhat higher than previously reported for FIRSSt (8-13-year-old children) (91) and an early version of ASA24, both of which employed observation of school lunch as the criterion measure (86). Food items were scored as matches unless it was clear that the child's recall did not describe an observed food. This broad interpretation maximized the score correctness of the child's recall; this may contribute to the high match rate found in the present study. Although some studies have reported higher accuracy matches for girls (167), others did not (146), in our sample, there were no statistically significant differences by gender or grade. Similar to our findings, other studies reported sweets were frequently omitted (168) and beverages were the most frequently intruded item at lunch (99). Accuracy of estimates of intake using the PAC24 were lower for pulses because the food images for pulses often did not match the way in which pulses were served to children: pulses were mostly served with pasta or potatoes, so it was very difficult for children estimate the quantity of food served and left over.

Mean arithmetic differences for matches indicates a slight tendency overall to underreport amounts of items observed eaten (-0.17). This is similar to results from previous studies with fourth-graders (96,137,146). When children failed to report items observed eaten, the average amount per omission was 0.61 servings and when children falsely reported items that were not observed eaten, the average amount per intrusion was a half serving (0.55).

The weight of food was under-estimated by 32% on average using the PAC24 compared to lunch observations. Although wide limits of agreement were found in the present study (from an underestimation of 85% to an overestimation of 218%), Foster *et al.* (103) also showed wide limits of agreement ranging from an under-estimate of 41% to an over-estimate of 72%. These may reflect the small sample size and indicate that, on an individual level, considerable differences between both methods is possible. Other factors possibly contributing to the under-estimation of weight of food are that the food photographs in the PAC24 did not include some of the foods served at lunch in school canteens and/or the presentation of food on the plate was not the same. This happens because there are no national data available in Portugal regarding school-age children's food consumption and so we had to use food photographs from another country. We developed FG sessions in the seven regions of Portugal before developing the PAC24 to identify food items reported specifically by Portuguese school-age children. However, although this qualitative methodology enriched the food-items pool that was originally developed by a literature review and also identified some regional specific names attributed by children to some food items, it did not allow us to know how food was presented to children in the school canteens (e.g. the presentation of pulses and fish differs from the presentation in the food photographs). Thus, it might be difficult for children to estimate the quantity of food served and left over for some food items. Future research is necessary to adapt the PAC24 to include food photographs more appropriate for Portuguese children.

Although no statistically significant differences were detected by grade, observers reported second-graders experienced more difficulty in completing the PAC24, than third and fourth grade children, perhaps as a result of their cognitive immaturity (148), which was not assessed. Therefore the children, especially the younger children, required assistance to complete the PAC24. The problems that observers detected in the

PAC24 administration might be addressed by training nutritionists to assist the children. In the present validation study, a single nutritionist was able to provide assistance in completion of the PAC24 for up to 10 children.

The limitations of the present study include the small sample size (n=41), primarily because of the limited time and financial support to collect data; the sample of children was limited to the Lisbon region, reflecting local and regional educational and food practices. It is not clear how these procedures may work in other cities or regions.

Success in using the tool with this population suggests its usefulness with similar populations; however, the tool must be validated for use in each specific population to analyse differences in accuracy of dietary reporting by socioeconomic and racial/ethnic groups among children. To redress the problems detected, and to improve accuracy of the PAC24, system improvements need to be made, including: (i) replacing the instructions boxes by an audio tutor and/or an avatar to guide the user through the system; (ii) increasing the food image database; and (iii) developing and testing additional prompts based on data on the types of foods that were more frequently omitted during this validation study. Further validation research, usability testing, and experience will also direct future development.

The PAC24 requires less professional labour than other interview-administered methods. In the present study, conducted in a small sample of children, the PAC24 was found to have a higher validity compared to lunch observations than comparable tools reported in the literature. Children were able to complete the PAC24, although most required assistance. Future research will need to determine how to adapt and simplify the PAC24 to better meet children's abilities and preferences.

5. Studies for the development, validation and pilot study of PAC24

The Portuguese self-administered computerised 24-hour dietary recall (PAC24): a web application for dietary assessment in children.[§]

5.1 Introduction

Measuring dietary intake in school-age children is important to monitor what children are eating, to understand what correlates with intake and also to evaluate dietary change after intervention programmes (119). The main dietary assessment tools for collecting dietary data among children are Food Records (FRs), Food Frequency Questionnaires (FFQs), Diet Histories (DHs) and 24-hour Dietary Recalls (24-h DRs) (67,68). Each method has its own strengths and weaknesses.

FRs avoid reliance on memory but tend to be time consuming, require literate and motivated respondents, can affect the types of food chosen and quantities consumed and are expensive to collect and code (169). FFQs are inexpensive and extremely practical in epidemiological studies because they are often self-administered (68,169); however, they consist of finite food lists and are cognitively difficult for children because they rely on memory and require cognitive skills such as the capability to estimate average consumption, that are lacking in many school-age children (68,148,169). The DH is a combined method which is very labour-intensive and time consuming for both the interviewer and the respondent, and thereby a very costly method (169). The 24-h DR is considered among the most precise methods of assessing dietary intake: the respondent burden is low, it is cost effective, and there is no requirement for subjects to be literate (68,169), it avoids the lack of detail associated with FFQs, and also avoids the reactivity issues associated with FRs. It also has some disadvantages: it relies on memory, portion size is difficult to estimate, it requires a trained interviewer and is expensive to collect and code (67).

[§] Carvalho MA, Foster E, Cardoso B, Santos O, Rito A, Pereira Miguel J. The Portuguese self-administered computerised 24-hour dietary recall (PCA24): a web application for dietary assessment in children. *(Submitted)*

Technology in dietary assessment solves some of these problems and has resulted in the introduction of self-administered web-based 24-h DRs which have low administration and coding costs, and animated guides to be more engaging for children (157). The increased availability of computers in schools has made it technically, financially and practically feasible and attractive to use computer-based questionnaires in large-scale dietary surveys (117). Some errors and bias are reduced when using this methodology to assess food consumption: 1) eliminate interviewer bias; 2) minimize data entry errors; 3) decrease reactivity. They also allow data collection from big samples of children for multiple days over different time periods.

Some such computer-based tools have been used with children and adolescents and have proven to be feasible and acceptable. Examples of computerised 24-h DRs include the Automated Self Administered 24-h DR for children (ASA24-Kids) (123) adapted from an adult version (124) to children (10 years old or older) where children are guided by an animated talking penguin for intake across a 24-h DR period through multiple passes (69); the Self-Completed Recall and Analysis of Nutrition (SCRAN24) (94) based on the Automated Multiple Pass Method (AMPM) to self-report adolescents' (11-16 years old) dietary intake on the previous day; the Synchronised Nutrition and Activity Program^{TM} (SNAP^{TM}) (89), developed to assess energy balance-related behaviours in children and adolescents (7-15 years old) at the group or population level; the Young Adolescents' Nutrition Assessment on Computer (YANA-C) (102) developed to collect dietary data in children and adolescents (11 years old or older) through a single 24-h DR structured according to six meal occasions.

The Portuguese self-administered computerised 24-hour dietary recall (PAC24) was developed for Portuguese children (7-10 years old). Comparison of PAC24 against lunch-time observations (170) indicated, in general, a good agreement at the food level and a tendency to under-estimate the weight of food. So, PAC24 is recommended to assess dietary intake at a group or population level in school-aged children.

The present study describes the structure of PAC24, the research undertaken in the development of this web application, and the results of the pilot study among children aged 7-10.

5.2 Methods

The Ethics Committee of the Faculty of Medicine, University of Lisbon approved the study.

5.2.1 Development of PAC24

Literature review

A search strategy was undertaken to identify peer-reviewed studies published in the English and Portuguese language since 2000 using MEDLINE. Hand searching journals, checking reference lists and contacting authors were also used as supplementary approaches to identify studies. This literature review was conducted with the main goals of examining the validity and reliability of dietary assessment methods used for school-aged children, evaluating the main measurement issues that may impact on reporting accuracy when assessing the dietary intake of children, defining the structure of food intake queries and building up the list of food items used in PAC24, as well as the list of food categories for grouping food items for data analysis. Keywords and combinations of these were used to search the databases comprehensively. These included: accuracy, children, cognition, computer, computerised 24-h DR, diet, dietary assessment, dietary intake, dietary surveys, feasibility, focus groups, memory, lunch observations, reliability, technology, validity, web-based, and 24-h DR. The titles and abstracts of manuscripts were reviewed to assess eligibility for inclusion in this review. Abstracts provided key information that enabled our research team to understand the scope, process and findings of each manuscript and to decide whether or not to read the full article.

Focus Groups (for the food-items pool generation)

The results from the Focus Group (FG) study are described in detail elsewhere (171). In brief, twenty-one FG were conducted from March to September 2011, enrolling a total of 204 second- to fourth-grade Portuguese students (7-10 years old). These FG were done in seven primary schools, one in each of the seven macro-regions of Portugal. Children participated in FG after parent's written informed consent and child assent. In each school, three FG sessions were conducted with a mean of ten children per FG. Most of the FG were conducted during the morning, lasting between 40-60 minutes and

were moderated by nutritionists and one psychologist. Topics for discussion were food consumption on the previous day and individual meanings and labeling of some specific food items in order to identify and select an extensive list of food items for PAC24. Content analysis followed a thematic coding process (171).

Prototype System

The first prototype of PAC24 was developed after the literature review, FG and additional input from research groups involved in computer-based dietary assessment among children, namely those from Newcastle University (UK) and Durham University (UK). Input was sought in order to identify the required elements needed to perform an effective self-administered dietary assessment tool with children and to map the problems most likely to occur during the development and validation process.

PAC24 adapted the AMPM developed by US Department of Agriculture (USDA) (69). PAC24 is a web application, developed in PHP (Hypertext Preprocessor) and backed up by a MySQL database. User data are collected through a web interface, rendered on any JavaScript enabled browser and, afterwards, exported to an Excel format. The PAC24 includes two user interfaces: a 'front office' designed for children to answer the PAC24 questionnaire, and a 'back office' administration area, where the researcher can create new password and username-protected surveys, and download dietary data from previously created surveys. The main methodological aspects of each part of this web application are described below:

- Quick list

Based on the findings from Subar *et al* (163) and Foster *et al* (94) and also on the results from the FG (171), a meal-based structure to the quick list with free text search, aided by a spell check application, is provided. Although the system has meals and snacks ordered chronologically throughout the day from the top of the page to the bottom, the participant can add foods to meals or snacks in any order.

The need to prompt and probe for forgotten foods is essential to the success and accuracy of the system. Therefore, asking children about easy to forget foods mostly by food category prompting may play an important role in increasing the accuracy of recalls, particularly in fourth-grade children (93). Specific prompts at the end of this

form ask about commonly forgotten foods (soup, fruit, sweets, cakes, gums, candies, lollipops, water, and soft drinks).

- Portion size assessment

PAC24 includes 706 images of 80 foods from one computerised portion size assessment atlas developed specifically for use in primary children in UK (105). These images are used for estimation of the amount of food served (ranging from the 5th to 95th percentile of weight served to children in the UK National Diet and Nutrition Survey (142)) and of the amount leftover (from the 5th percentile to the smallest presentable portion), if any. This is important because children do not always consume all of the food served to them and may never have seen the amount of food they consumed (105). Portion sizes are presented on the same screen (87). For foods that are usually served in predetermined amounts, a range of commonly consumed portion sizes is displayed in one photograph and the child is asked to select one portion size and how many servings she or he ate the previous day.

Based on the findings from FG, the food images from the atlas were supplemented with 24 images: a) 7 images of 9 foods (in predetermined amounts) such as bread, biscuits and cakes, specifically developed for PAC24 (these photographs were taken using a plain white dinner plate of the same diameter as that used by Foster et al (172) and a plain white tray); b) 17 food images from the Portuguese Food Atlas (173). For a small proportion of the foods, there was no suitable photograph for estimation of the amount served and leftover. For these foods, a description of the amount served and leftover can be entered manually.

- Time & Place

In order to add value and context about the food consumption of children, each participant is asked to manually enter the time next to each meal or snack, using a 24-h format, as well as the place where they ate each meal.

<u>Usability test</u>

The prototype of PAC24 was tested to identify acceptance and usability issues, after amendments were made following the expert meeting. Usability testing is a technique used to evaluate the interface adequacy of digital applications, in this case the PAC24,

by testing it. The main objectives of this test were to: 1) identify any usability problems; 2) collect quantitative data on participant's performance (e.g. time to complete PAC24); 3) assess how easy/difficult it was to complete each FORM (Figure 5-1)); 4) determine participants' satisfaction with the application.

Twelve children from second to fourth-grade (7-10 years old) from one primary school in Lisbon and Tagus Valley region, Portugal, were invited to participate in this usability test (April 2013). These children participated in the usability test after parent's written informed consent and child assent. Minimal instructions were provided and a 'think aloud' method (147) was encouraged. Participants were asked to verbalize what they were thinking while interacting with the functional prototype to record their food intake. In the test, children completed typical tasks while a trained nutritionist-observer watched, listened and took notes.

5.2.2 Validation of PAC24

Content validity: meeting with experts

Five experts from different areas (a professor of pediatrics from Baylor College of Medicine (USA), a psychologist and a nutritionist (with extensive train in dietary assessment) from University of Lisbon (Portugal), a human-computer interaction expert from Catholic University of Portugal and a primary teacher, coordinator of a primary school in Portugal) participated in a face-to-face meeting to discuss and validate the contents of PAC24 (February 2013).

Accuracy of PAC24: lunch observations

Lunch observations were used to validate PAC24, the results are described in detail elsewhere (170). After parent's written informed consent and children assent, forty one 7-10 year-old children from two elementary schools in Lisbon and Tagus Valley region, Portugal, were observed during school lunch and completed PAC24 the following day (May-June 2013). Accuracy for reporting items was measured in terms of matches, intrusions and omissions; accuracy for reporting amounts was measured in terms of arithmetic and absolute differences for matches and amounts for omissions and intrusions; and accuracy for reporting items and amounts combined was measured in terms of total inaccuracy. The ratio of the estimated weight of food consumed to the

actual weight consumed was calculated along with the limits of agreement using the method of Bland and Altman. After cleaning and validation, data were converted and exported for statistical analysis in SPSS (version 21).

5.2.3 Description of the PAC24 (final version)

PAC24 is intuitive and visual elements were carefully selected. It comprises five forms (FORM 1-5), each one represented by a different colour. Colours were selected to reinforce the meaning and importance of each form. Figure 5-1 shows an overview of the PAC24 application.

FORM 1 is the 'child identity card' where children provide their personal data (name, age, school grade). Then, the user is presented with an instruction box explaining what children are expected to do at the second stage. FORM 2 is the 'food list', where the user is asked about the meals and snacks she or he ate the previous day (first, the system asks for breakfast, then lunch, dinner and, finally, snacks). A search system (including spell check with many common misspellings of food names) then locates and displays foods automatically when similar items are detected. Each meal has a box where children type in all of the foods and drinks they remember consuming the previous day. Before children pass to FORM 3, a 'pop-up' message asks children to think about forgotten food items (soup, fruit, sweets, cakes, gums, candies, lollipops, water and soft drinks). Next, the user is presented with an 'incomplete food list', which contains food items requiring further information on the types and portion sizes of food/drink consumed. Clicking on an item in the 'incomplete food list' results in a request for the type of food to be specified and for portion size information. For the majority of foods recorded, the child is asked to identify the amount of served food, and the amount of food leftover, if any, using a selection form with seven food images in order to estimate the amount consumed. Once all details for consumed foods have been entered, the system prompts the user to provide the approximate time and place each meal or snack was consumed, and also whether children watched television or used a computer during meals (FORM 4). As a final check (FORM 5), the user is shown a summary of all items of food and drink recorded throughout the day. A button allows the user to return to FORM 3 at any time during the process, where children can add forgotten items.

The food composition code and weight of all selected items are automatically allocated and stored. A database of 380 food items is available. Food, energy and nutrient information is linked to the Portuguese food composition database (143).

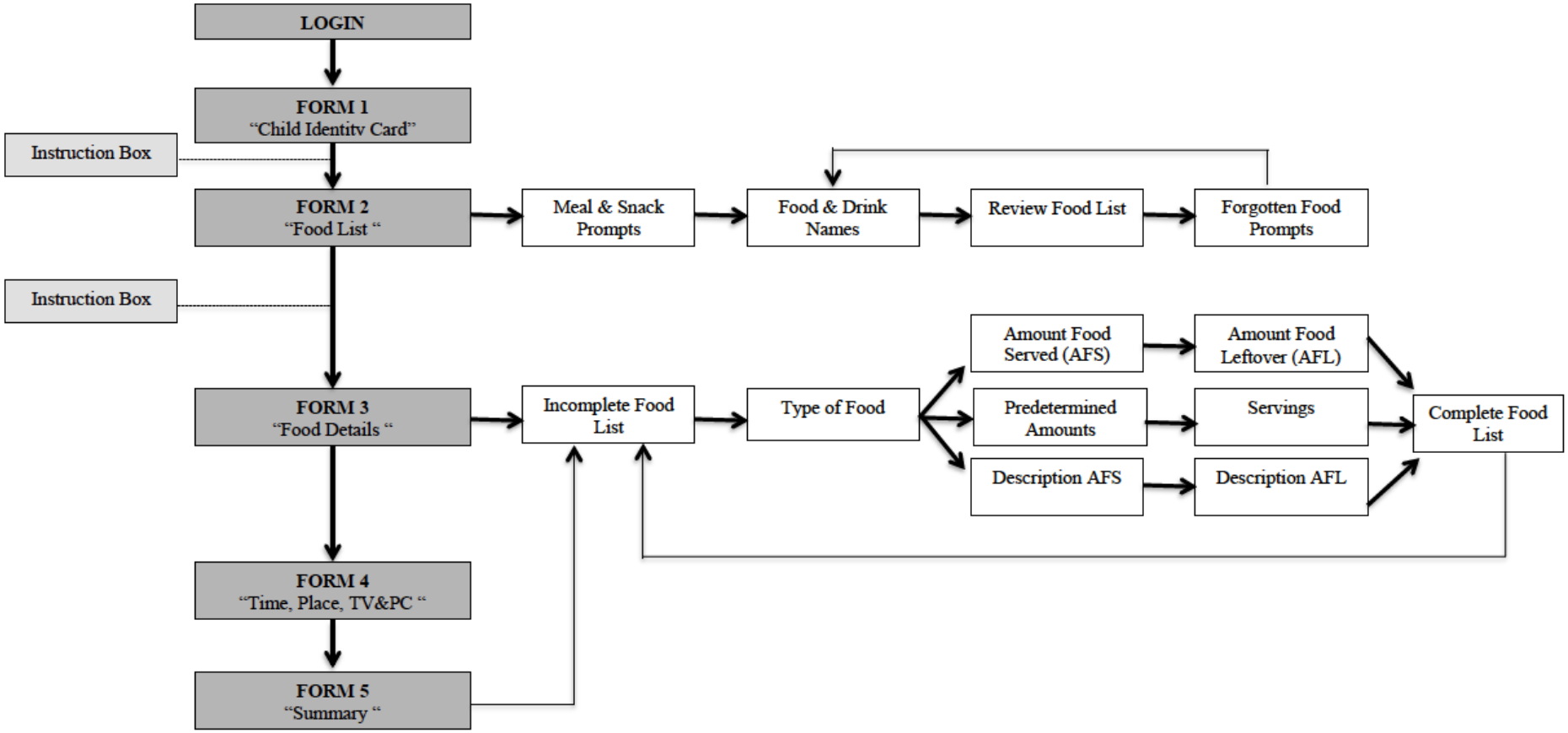

Figure 5-1. Flow chart of the Portuguese self-administered computerised 24-h DR (PAC24)

TV, television; PC, computer; AFS, amount food served; AFL, amount food leftover

5.2.4 Pilot study

A pilot study was conducted to check the feasibility with respect to procedures, methods and data processing. Children were recruited from one elementary school in Lisbon and Tagus Valley region, Portugal, from November to December 2013. This school was selected using a purposive sampling with authorization and active collaboration from the Portuguese Ministry of Education. School inclusion criteria were: located in Lisbon and Tagus Valley region, covering second to fourth grades, being a school with Internet access and with computers/laptops available to children. In this school, one class from second-, third- and fourth-grade were randomly selected. Written informed consent was obtained from parents and assent was obtained from children prior to participation. Child inclusion criteria included not having a physical, mental, or visual limitation that would inhibit computer use; being able to read and to use the computer; being able to read and write in Portuguese. Of all 55 invited children from second to fourth-grade, 3 did not provide written parental consent, 3 were not present on one of the scheduled school assessment days and 1 didn't fit the inclusion criteria.

PAC24 was completed on a computer connected to the Internet, and a nutritionist was present to observe and provide assistance in completion of PAC24 for up to 10 children at one time. The nutritionist noted any difficulties encountered (e.g., problems when searching for foods and how to report multi-ingredient foods such as sandwiches), solved the major problems that impeded further progress related to unintentional clicking of buttons, answer any questions that the child had, and help children with writing and spelling of particular food items. Children were asked to complete PAC24 after a 15-minute explanation about PAC24, given by the nutritionist. Two non-consecutive days of PAC24 were completed (73) an average of 15 days apart. The total energy and nutrient intakes were computed using the Portuguese food composition database.

Descriptive analyses (mean values, standard deviations and percentages) of energy and nutrient intakes (protein, total fat, carbohydrate, fibre, calcium, sodium, potassium) were calculated (Table 5-1). Variables were tested by gender and grade for normality. The mean value between two independent samples was calculated using an independent sample t-test. The non-parametric alternative was the Mann-Whitney U-test. Analysis of

variance was used to compare the mean values between more than two independent samples after testing for normality and homogeneity. The non-parametric alternative test was the Kruskal-Wallis test. Wilcoxon signed-rank tests were used to compare, on a group level, the intakes of 12 food groups (1) Cereals, cereal products and potatoes; 2) Fruit; 3) Vegetables; 4) Milk and dairy products; 5) Meat, fish and eggs; 6) Pulses, fresh and processed; 7) Oils and fats; 8) Beverages; 9) Sweet products; 10) Snacks and fast food; 11) Mixed dishes; 12) Miscellaneous), energy and nutrients (protein, total fat, carbohydrate, fibre, calcium, sodium, potassium) (Table 5-2). Statistical analyses were performed using SPSS (version 21). A p-value <0.05 level was considered as statistically significant.

5.3 Results

5.3.1 Development of PAC24

Literature review

The key points emanating from this review were:

- 24-h DR method is considered one of the most precise methods of assessing diet among the school-age children (67,68,73,169) but because of intra-individual variation in intake, multiple recalls are needed to accurately estimate usual nutrient intake (38,67,77)
- there seems to be a fairly rapid increase in the ability of 7-8 year old children to participate in unassisted recalls for foods eaten in the immediate past (82)
- computers appear to be useful for dietary assessment (117,157)
- the AMPM developed by USDA can be adapted to a web-based 24-h DR format (94,119)
- meal-based recall is preferred to open format recalls by children (94) and also by adults (163)
- when the target period is the previous day, accuracy is improved by conducting interviews in the morning (146)
- there are three main methods of searching for foods used in computerised systems: 1) searching via categorization of foods (102); 2) a mixture of categorization and free text searching (119); and 3) free text search only (94)

- portion sizes should be age-appropriate (111) and multiple small pictures on the screen at the same time decrease the time needed to make size judgments with no decrease in accuracy (87)
- prompts appropriate to age seem to help the process of memory retrieval (93)
- the 'gold standard' to validate a dietary recall in children is the school lunch observation (91,93,97,123,135,137–140)

Focus Groups (for the food-items pool generation)

The results obtained from FG were described previously (171). The principle results were: a) 3959 food items were identified by children when asked about their previous day's food intake; b) foods were reported chronologically (from the first item eaten in the morning to the last item at night) but some foods, as beverages (e.g. water) were routinely reported non-chronologically; c) the consumption of snacks wasn't reported spontaneously: in most cases, the consumption of snacks was only reported when specific meal name prompts were used; d) children used the time of day and other contextual episodes as cue methods for remembering which foods they had consumed; e) regional specific names were attributed by children to some food items. FG enriched the pool of food items of PAC24 and also revealed the different meanings and labelling of some specific food items that were taken into account in the development of PAC24.

Usability test

Mean time to complete PAC24 was 28 minutes (range: 19-50 minutes), depending primarily on reading ability and Internet connection speed. All children (n=12) considered PAC24 an enjoyable application. Children were asked to select the easiest and the most difficult FORM to complete. Overall, six children identified FORM 3 and FORM 4 as the easiest forms, while five children said that it was difficult to remember and to report the foods eaten on the previous day in FORM 2. Regarding FORM 2, the majority of children (n=11) said that they didn´t understand the instruction box displayed before this part of the questionnaire; seven children didn't understand that they could only enter one food item per line in the meal boxes; six children couldn't find the 'Next' button at the bottom to move to the next form; and four children didn't know how to spell some food items and asked for help and/or misspellings were detected.

Considering the usability findings, the prototype was amended accordingly. Major improvements were: 1) a new instruction box for FORM 2; 2) additional information was included in the database and in the search mechanism to safeguard against eventual typos and phonetic misspellings, while accounting for the use of synonyms and brand names to designate foods; 3) descriptions of some food items were changed to be more child-friendly, for example the food description 'pork ham' and 'turkey ham' was amended to 'Pork ham (dark pink ham)' and 'Turkey ham (soft pink ham)', respectively.

5.3.2 Validation of PAC24

Content validity: meeting with experts

Seven key point messages resulted from this meeting: 1) make PAC24 more intuitive, simple and fast for children to report food items and search for different types of food; 2) avoid too much text and replace it with symbols and instruction boxes, when necessary and possible; 3) add six meal boxes, to the 'quick list', asking whether children ate the respective meal or snack on the previous day (first ask for breakfast, then lunch, dinner and, finally, snacks); 4) add a food image to each type of food in FORM 3 of PAC24, so that children can find and recognize the respective type of food eaten, before portion size assessment; 5) use animated avatar to engage children; 6) prioritize simple terms instead of professional designations (e.g.: replace 'scrambled egg made with butter' by 'scrambled egg'); 7) ask children about associated behaviours (e.g.: 'watching TV', 'using computer/tablet', 'eating at the table') beyond just time and place.

Accuracy of PAC24: school-lunch observations

The results obtained from the accuracy study of PAC24 were published previously (170). Sixty-seven percent of foods reported were matches of specific foods, 21.5% were omissions and 11.5% were intrusions. PAC24 under-estimated the weight of food on average by 32% of the actual intake. The limits of agreement for the weight of food consumed ranged from an under-estimation of 85% to an over-estimation of 218%. Accuracy of estimates of intake using PAC24 was lowest for pulses with wide limits of agreement (from an under-estimate of 94% to an over-estimate of 359%). Sweet products and vegetables were the most accurately estimated foods.

Observers indicated some problems (e.g. instruction boxes were frequently ignored and sometimes children were unable to understand their meaning, misspelled search terms at the FORM 2 resulted in search failures, in some cases the food images shown at the FORM 3 did not correspond to the food item written by the children at the FORM 2, unintentional clicking of buttons) occurred in completing PAC24.

5.3.3 Pilot study

Data were collected from 48 children (50% were girls). Mean age was 8.1 years old (SD=0.8). Most children were from third-grade (43.8%), with some from fourth-grade (33.3%) and a few from second-grade (22.9%).

Recalls took between 5 and 50 minutes (mean=27 minutes) to complete. The majority of children ate breakfast every day (95.8% and 97.8% in the first and second measurement occasion, respectively). Children consumed between 4 to 6 meals per day (mean=5.3 meals). The greatest dietary sources of energy were: potato, bread, rice, meat, milk, cookies, fish, breakfast cereals and fruit.

Mean energy and nutrient intake by gender and grade are presented in Table 5-1. Mean energy intake per day was 1799 kcal (SD=576) (Table 5-1). Mean protein, carbohydrate and total fat intakes (in percentage of energy intake) were 17.2%, 47.8% and 29.0%, respectively.

Table 5-2 presents the intakes of food groups, energy and nutrients for the first and second measurement occasions. Significant differences were not observed, based on Wilcoxon signed-rank tests ($p>0.05$). Mean fruit and vegetables intake was 276.6 g (SD=210.6) and 181.6 (126.2), respectively, on the first measurement occasion; 236.4 g (SD=156.8) and 190.2 g (SD=138.0), respectively, on the second measurement occasion. Regarding soft drinks, 43.8% (mean=119.8 ml (SD=155.2)) and 35.4% (mean=90.4 ml (SD=131,8)) of children reported their consumption in the first and second measurement occasion, respectively.

Table 5-1. Mean values (SD) for energy and nutrient intake by gender and school-grade from two Portuguese self-administered computerised 24-h dietary recall (PAC24) (mean of first and second measurement occasion*)

		Mean energy and nutrient intake (SD)								
	n (%)	**Total energy (kcal)**	**Total energy (kJ)**	**Protein (g)**	**Carbohydrate (g)**	**Total Fat (g)**	**Fibre (g)**	**Calcium (mg)**	**Sodium (mg)**	**Potassium (mg)**
Gender										
Girls	24 (50)	1761 (391)	7398 (1674)	75.5 (21.4)	224.0 (46.6)	55.5 (20.9)	16.5 (4.7)	708.0 (276.2)	2803.7 (183.1)	2313.2 (124.3)
Boys	24 (50)	1838 (723)	7660 (3059)	79.3 (28.0)	234.8 (77.6)	60.4 (38.0)	15.6 (5.9)	914.4 (424.3)	3035.4 (250.5)	2492.7 (194.0)
p-value		0.726[a]	0.665[a]	0.604[b]	0.562[b]	0.741[a]	0.560[b]	0.087[a]	0.459[b]	0.789[a]
Grade										
2nd	11 (22.9)	1612 (690)	6751 (871)	68.9 (28.4)	216.8 (58.0)	50.5 (43.7)	15.2 (6.1)	604.2 (228.1)	2444.4 (343.9)	2230.0 (313.6)
3rd	21 (43.8)	1881 (1540)	7927 (492)	79.1 (22.9)	233.2 (64.0)	63.9 (26.4)	16.7 (4.9)	834.2 (375.4)	2936.7 (169.2)	2473.4 (156.1)
4th	16 (33.3)	1821 (547)	7542 (596)	81.0 (24.6)	233.2 (69.4)	55.4 (24.7)	15.9 (5.5)	923.3 (398.6)	3223.6 (321.4)	2429.3 (184.8)
p-value		0.160[c]	0.185[c]	0.430[d]	0.838[c]	0.068[c]	0.762[d]	0.047[c]	0.178[d]	0.328[c]
Total	48 (100)	1799 (576)	7529 (2443)	77.4 (24.7)	229.4 (63.6)	58.0 (30.5)	16.1 (5.3)	811.2 (369.2)	2919.5 (1069.8)	2402.9 (794.9)

*Two PAC24 completed on average 15 days apart.

[a] Mann-Whitney U-test

[b] t-test

[c] Kruskal-Wallis test

[d] One-way analysis of variance

SD, standard deviation

Table 5-2. Food consumption (food groups, energy and nutrients) on the first and second measurement occasion (n=48): mean (SD) and significance of difference

	First measurement occasion mean (SD)		Second measurement occasion mean (SD)		p-value[+]
	n	Mean (SD)	n	Mean (SD)	
Food groups					
Cereals, cereal products and potatoes (g)	47	304.7 (175.5)	48	310.7 (164.7)	0.841
Fruit (g)	29	276.6 (210.6)	27	236.4 (156.8)	0.326
Vegetables (g)	29	181.6 (126.2)	22	190.2 (138.0)	0.796
Milk and dairy products (g)	45	399.0 (272.5)	42	480.5 (414.2)	0.789
Meat, fish and eggs (g)	45	177.4 (137.4)	48	142.7 (79.1)	0.370
Pulses, fresh and processed (g)	1	91.5	8	111.4 (178.9)	-[a]
Oils and fats (g)	22	20.0 (24.4)	18	11.1 (5.5)	0.085
Beverages (ml)	35	533.9 (399.0)	39	462.5 (491.5)	0.674
Sweet products (g)	36	82.2 (74.6)	38	76.2 (46.7)	0.902
Snacks and fast food (g)	16	294.4 (276.2)	3	209.0 (82.9)	-[a]
Mixed dishes (g)	3	400.8 (135.1)	15	281.5 (125.4)	-[a]
Miscellaneous (g)	0	-	3	8.3 (2.9)	-[a]
Energy and nutrients					
Energy (kcal)	48	1882 (788)	48	1717 (679)	0.615
Energy (kJ)	48	7906 (3340)	48	7152 (2867)	0.498
Protein (g)	48	81.4 (35.7)	48	73.4 (33.1)	0.580
Carbohydrate (g)	48	237.3 (80.7)	48	221.5 (84.3)	0.305
Fat (g)	48	62.5 (43.8)	48	53.5 (30.6)	0.878
Fibre (g)	48	16.6 (8.4)	48	15.6 (6.8)	0.630
Calcium (mg)	48	901.7 (533.9)	48	720.7 (469.0)	0.055
Sodium (mg)	48	3082.9 (1693.7)	48	2756.2 (1152.5)	0.389
Potassium (mg)	48	2555.5 (1134.8)	48	2250.4 (965.0)	0.142

[+]Wilcoxon test.; [a]There are not enough valid cases to perform the Wilcoxon test; SD, standard deviation.

5.4 Discussion

PAC24 is a 24-h DR designed to be self-administered by Portuguese children from second to fourth grade (7-10 years old). It's development followed previously reported principles for intuitive, simple and cost effective dietary assessment tool (174), targeting an engaging method to collect accurate data about children's dietary intake and designed to be carried out in school time with Internet access.

The main objective of the FG was to gather an extensive list of words, terms and expressions used by second-, third-, or fourth-grade Portuguese children to refer to food items. The FG was the selected methodology for this purpose instead of structured questionnaires because this allows a more abstract and in-depth exploration of food and nutrition issues than is possible with less interactive data collection tools (144). Since the objective of the FG was not to analyse children's dietary reporting accuracy, the results should not be interpreted as such. Due to substantial variability in the naming of food items given by children, free text search only was chosen for PAC24 to identify food items eaten on FORM 2 (Figure 5-1) as the most intuitive way. The same methodology was adopted by Foster *et al* (94). Some computerised 24-h DR, like SNAP (89) and WebDASC (88), include a low level of detail, while in YANA-C (102) and FIRSSt (91), respondents are asked, if relevant, to provide additional information about the food item chosen such as preparation method (e.g., cooked, baked, fried). On the other hand, in SNAP the objective is to estimate food behaviour instead of to evaluating the whole diet; information about preparation method is not collected. Although we are aware that most of dietary assessment is built around the answers that would be ideally obtained in a study and not around the answers that the study population is able to provide, as our main purpose was to evaluate the whole diet of children, we consider that the food preparation method is important to estimate dietary intake.

Furthermore, Foster and co-workers (111) underline the importance of using age appropriate food portions when estimating portion size by images. In PAC24, as in WebDASC (88), the use of appropriate portions could not be fully accomplished because there is no national data available in Portugal regarding school-age children's food consumption. So, in this study, we used food photographs from more than one source. Future research is necessary to adapt PAC24 to include food photographs more

appropriate for Portuguese children, particularly for pulses; cereals and potatoes; meat, fish and eggs, which were the food categories with the lowest accuracy and widest limits of agreement (170).

One of the problems children faced when completing PAC24 in the usability test, was related with the fact that the majority of children didn't understand the instruction boxes relating to FORM 2 and FORM 3. Diep et al (123) found that children ignored tutorials and did not correctly understand what to do at a given time. Amendments to the instruction boxes were made after the usability test and before the accuracy study but the same problem remained. Further research needs to be done to improve the systems usability such as replacing the instruction boxes with an avatar explaining what to do in each FORM.

It is very important when assessing the validity of any method of measuring dietary intake in young children that we accept the limitations that the subject's cognitive skills impose. Collecting an absolutely accurate recall of intake is virtually impossible and web-based dietary recalls have some disadvantages compared to a personal interview (91,123), such as lack of personal guidance, and the requirement for participants to have writing and spelling skills, as well as computer literacy.

A pilot study was conducted to check the feasibility with respect to procedures, methods and data processing. EFSA (38) recommends the collection of dietary information for two non-consecutive days for the 24-h DR. Days are considered as non-consecutive if there is at least a two weeks interval between them. More than three days of dietary recalls are not recommended for avoiding excessive burden for the respondent and a potentially high non-response bias. From a statistical point of view it is more efficient to extend the number of participants rather than the number of days. This is why we decided to apply PAC24 on two non-consecutive days with 15 days apart in order to estimate habitual intake.

The pilot study showed that children took about 27 minutes to complete PAC24, approximately the same time that children took to complete other computerised-questionnaires (89,94,123,175).

A rough comparison between data from a review on dietary intake of European children and adolescents (57) with data from PAC24 was done for girls and boys of the same age range. Energy intakes ranged from 1601 to 2294 kcal/day in girls and from 1673 to 2414 kcal/day in boys. Data from PAC24 fit into these ranges.

In Portugal, Valente et al (63) developed a study with Portuguese school-age children (7-9 years old). Mean energy intake in PAC24 was lower both for girls and boys (1761 kcal vs. 2522 kcal and 1838 kcal vs. 2319 kcal, respectively). One possible explanation is the fact that Valente et al (63) used a different dietary assessment method (a FFQ) that tends to overestimate dietary intake (36).

Furthermore, participants macronutrient intakes fit in the recommended ranges of IOM (49): 45-65% for carbohydrate, 25-35% for total fat and 10-30% for protein. On the other hand, compared with the WHO guidelines (11), carbohydrate intake is below the recommendations (55-75%) and protein intake is above the recommendations (10-15%). Intakes of fibre, calcium and potassium were below the DRI for children (41,43) (fibre: 25 g for 4-8 years old children, 26 g and 31g for 9-13 year old girls and boys, respectively; calcium: 1000 mg for 4-8 year old children and 1300 mg for 9-13 year old children; potassium: 3800 mg for 4-8 year old children and 4500 mg for 9-13 year old children). Sodium intake is above the recommendation from WHO (<2 g per day) (46). Fruit and vegetables intake met the WHO recommendations (≥400 g/day) (11).

Comparing outcome measures from children completing PAC24 twice with an interval of 15 days, didn't result in significant differences, indicating that respondents were willing to complete the application the second time as accurately as the first time. The same findings were found in YANA-C (102). However, these findings are based on a low number of respondents (n=48) and need to be confirmed in a higher-powered study sample.

Limitations of the current study include the small sample size used in validation and pilot studies. Second, validation and pilot studies included children from three different schools in Lisbon, so findings cannot be generalize to other populations. And third, the consistency that aims to evaluate the variance accounted for between observed and recalled values between two recalls was not determined.

In summary, PAC24 was developed on a limited budget and within a short time period to be a simple, quick and engaging method of assessing dietary intake in Portuguese school-age children (7-10 years old). In this first stage, this web application has shown that it can accurately estimate dietary intake in children at the group level in 27 minutes on average. It will be continually refined and future research is necessary to improve the usability of PAC24 and also to enhance its user-friendliness.

6. General Discussion

The present chapter discusses key issues emerging from the development (Paper 1 and 3), validation (Paper 2) and the pilot study (Paper 3) of the PAC24. Also, the strengths and limitations of the present study will be presented and discussed, and finally future research for the improvement of the PAC24 will be suggested.

6.1 Development of PAC24

PAC24 was designed to be self-completed by Portuguese children from second-, third- or fourth-grade (7-10 years old). Although children would have the advantage of getting help from their parents, once children begin attending school, parent's reports cannot be taken as truth (82). Furthermore, getting help from parents may introduce socially desirable answers given by children to confirm to what parents think is an appropriate diet. For example, many foods are regarded as good or bad, so a respondent who answers in a socially desirable way might under-report intake of bad foods and over-report intake of good foods. Finally, children of this age are able to respond adequately to self-report methods such as dietary recalls.

The main objective of the twenty-one FG conducted in the seven regions of Portugal with 204 participating 7-10 years old children was to gather an extensive list of words, terms and expressions used by second- to fourth-grade Portuguese children to refer to food items. The FG was the selected methodology for this purpose instead of structured questionnaires because FG allows more abstract and in-depth exploration of food and nutrition issues than is possible with less interactive data collection tools. Since the objective of this study was not to analyse children's dietary reporting accuracy, the results should not be interpreted as such.

The twelve food categories used to categorize the 3959 food and drink items identified in the FG were used for data analysis purposes only because children reported food categories different from those specified by nutritionists, dietitians and researchers (176–178). Thus, due to substantial variability in the naming of food categories given by children, free text search only was chosen for PAC24 to identify food items eaten on

FORM 2, as the most intuitive way. The same methodology was adopted by Foster *et al* (94).

Another important issue raised by the FG was the way children seem to report foods eaten. The majority of foods were reported chronologically but beverages, particularly water, were routinely reported non-chronologically. Taking this finding into account, specific probes of water were incorporated into the PAC24 to encourage children to remember to report it. Water queries and probes were both included at the end of FORM 2. Furthermore, a recent study described the intake of water and all beverages in children and adolescents (4-17 years old) from 13 countries based on a 7 consecutive day fluid-specific record (179). Although the FR was indicated as the preferred method for the collection of water intake data, when it is not feasible then a 24-h DR, rather than a FFQ, is the best alternative for obtaining valid and complete water reports (180).

The extensive list of words and terms collected through FG were gathered together with food items taken from literature review and included in the PAC24 in order to help children search for and identify accurately and faster different types of food items eaten, specifically in FORM 3. Regional and culture-specific names attributed to some food items were also identified and included to make PAC24 suitable for children from different regions of Portugal.

Some computerised 24-h DR, like SNAP (89) and WebDASC (88), includes low level of detail, while in YANA-C (102) and FIRSSt (91) the respondents are asked, if relevant, to provide additional information about the food item chosen such as preparation method (e.g., cooked, baked, fried). On the other hand, in SNAP information about preparation method was excluded because the objective is to estimate food behaviour instead of evaluating the whole diet. Although, we are aware that most of dietary assessment is built around the answers that would be ideally obtained in a study and not around the answers that the study population is able to provide, as our main purpose was to evaluate the whole diet of children, we decided to maintain some level of food detail regarding food preparation, considering that the food preparation method is important to estimate dietary intake (e.g., if a child is reported to have eaten a beef, the system will question if the beef was fried or grilled but will not question about

the fat or oil used to cook). With the resulting loss of detail on some foods there will be some loss of precision in estimates of nutrient intake.

Furthermore, Foster and co-workers (111) underlines the importance of using age appropriate food portions when estimating portion size by images. In PAC24, as in WebDASC (88), the use of appropriate portions could not be fully accomplished because there is no national data available in Portugal regarding school-age children's food consumption so, in this study, we had to use food photographs from more than one source: 1) a computerised portion size assessment atlas developed specifically for use in primary children in UK (105); 2) food pictures, based on food items taken by FG, developed specifically for use in PAC24; 3) food pictures from the Portuguese Food Atlas (173). This may be responsible for the underestimation of the weight of food on average by 32% using PAC24 compared to lunch observations. Future research is necessary to adapt the PAC24 to include food photographs more appropriate for Portuguese children, particularly for pulses; cereals and potatoes; meat, fish and eggs, which were the food categories with low accuracy and wide limits of agreement.

Another possible strategy to overcome this problem is to apply novel approaches where the respondent does not have to perform this task of portion size estimation (181). The appearance of mobile telephones with cameras and wireless transmission greatly increased attractiveness of images as a food record research tool. Technology Assisted Dietary Assessment (182,183) estimates the food consumed at a meal from an image acquired from a mobile device, before and after eating, and calculates daily food and nutrient intake among adolescents and adults. Food Intake Visualisation and Voice Recogniser (184) uses visual techniques to calculate volume of food images captured by camera embedded in a mobile telephone by selecting three images from a video recording of the food plate before and after eating. Food identification begins with a voice recording by the user naming each food and ends with a final step matching the foods consumed to a food composition database.

eButton (185) is a device to use on the chest, which contains a miniature camera and other sensors that captures data and information on health activities, eliminating the need for daily self-reporting. As a result, the entire eating process is recorded and these

pictures are processed from the detection of the shaped utensils and food items until the information about calories and nutrients.

Thus, how portion size can be more easily and accurate estimated, particularly in children, remains to be investigated.

One of the problems children faced when completing the PAC24 in the usability test, was the fact that the majority of children didn't understand the instruction boxes before FORM 2 and FORM 3. Amendments to the instruction boxes were made before the validation study but the same problem remained. Although technology has made dietary assessment convenient for children, their compliance usually declines because of the burden of answering detailed questions, boredom and fatigue. Lu *et al* (186) identified motivation as one of the most important factors that influences dietary assessment of children and suggested three strategies to enhance motivation among children: 1) use animated, customised agents; 2) embed the dietary assessment process into a video game; 3) add narratives to the dietary assessment program. Thus, further development on PAC24 should be done in order to replace the instruction boxes by an avatar explaining what to do in each FORM, particularly in FORM 2 and 3 that were the two main FORMs that presented the major problems.

6.2 Validation of PAC24

It is very important when assessing the validity of any method of measuring dietary intake in young children that we accept the limitations that the subject's cognitive skills impose. Collecting an absolutely accurate recall of intake is impossible and web-based dietary recalls are less accurate and have some disadvantages compared to a interviewer-administered 24-h DR (91,123), such as lack of personal guidance, writing and spelling skills. Computer literacy is also required.

6.2.1 Content validity

Content validity was studied not only to indicate whether PAC24 covers all dimensions present in the concept intended to reflect – the assessment of dietary intake in school-age children – but also to discuss some relevant aspects regarding to the structure of

PAC24, particularly those where there is no consensus in the literature. Among the seven key point messages resulting from this meeting and presented in chapter 5, there are three that should be discussed in detail:

1. Open vs. Meal-based format

Data from FG showed that children did not report the consumption of snacks spontaneously, but in the majority of cases only when specific meal/snack name prompts were used. Although, Baxter et al (95) found that accuracy was better with open-format interviews than meal-format interviews for intrusion rates and total inaccuracy, Subar *et al* (163) and Foster *et al* (94) found that participants (adults and children, respectively) showed a strong preference for a meal-based format. The open-format and meal-format were discussed by experts, who concluded that because dietary intake may be organized in memory according to meals, meal name prompts may enhance recall accuracy in children. Thus, a meal-based format was adopted for PAC24.

2. Food prompts

Data from FG showed that students used a wide variety of retrieval categories when reporting consumption (e.g., the time of the day and other contexts as cues for remembering which foods they had consumed). According to Baxter et al (93), food category prompting slightly improves recall accuracy among fourth graders, but only in half of the children who received it. We found that most children reported the consumption of sweets only after specific prompting for forgotten foods. This suggests that asking children about easily forgotten foods may play an important role in increasing the accuracy of self-administered automated recalls. In the expert meeting it was decided that at the end of the FORM 2, prompts for forgotten foods (soup, fruit, sweets, cakes, gums, candies, lollipops, water, and soft drinks) should be included.

3. Food type search strategy

The experts found the food search strategy in FORM 3 little intuitive for children and reported that many children from previous studies (165) tended to rely on the collages of pictures, rather than the category labels, to identify categories where the food items should be introduced. Thus, the tree-view procedure to identify the type of food consumed could be enhanced by adding small pictures of foods.

6.2.2 Accuracy of PAC24: school-lunch observations

Simons-Morton and Baranowski (135) described direct observations as the 'gold standard' against which other measures can be compared. Most validation studies in which children have provided DRs without parental assistance have been obtained by observing one or two school meals (89,91,132–137). Another possible way to validate the PAC24 would be using a biochemical indicator that it is independent of self-reporting. However, many food components have no suitable biomarker, and biochemical indicators of dietary intake are also subject to non-dietary influences that can alter their relationship with the dietary component of interest (128). Furthermore, accuracy is assessed in terms of foods instead of kilocalories or nutrients because children report what they have eaten as foods, not kilocalories or nutrients.

Lunch observations were used to validate the PAC24. Use of the PAC24 attained a high percentage of matches of specific foods (67.0%) and a low level percentage of intrusions (11.5%) and omissions (21.5%), although there was substantial variability, especially for omissions (±19.5%) and intrusions (±12.1%). Mean match values were somewhat higher than previously reported for FIRSSt (8-13 years old) (91) and ASA24-Kids (9-11 years old) (123), both of which employed observation of school lunch as the criterion measure. Food items were scored as matches unless it was clear that the child's recall did not describe an observed food. This broad interpretation maximized the score correctness of the child's recall and may contribute to the high match rate found in this study. Other dietary-reporting methodological studies with children have coded in a similar manner (95–97,137). Although some studies have reported higher accuracy matches for girls (167), others did not (146); in our sample, there were no statistically significant differences by gender or grade.

Similar to our findings, other studies reported that sweets were frequently omitted (168) and beverages were the most frequently intruded item at lunch (99). Accuracy of estimates of intake using the PAC24 were lower for pulses because the food images for pulses often did not match the way in which pulses were served to children: pulses were mostly served with pasta or potatoes, so it was very difficult for children to estimate the quantity of food served and leftover.

Correlation is often used to demonstrate agreement between two methods (91,123) but in fact it simply measures the strength of linear association between the methods and provides no information on magnitude of bias (72). The correlation between portion size estimates for PAC24 against observation was 0.797 (a result not presented in Paper 2). Even the Pearson correlation was high; it doesn't give any information about over- or under-estimation of food intake. Thus, the Bland & Altman (149) was the selected methodology to assess the accuracy of estimates of food weight reported using the PAC24.

It is crucial to recognise that self-reported dietary intake is likely to be biased, mainly in the direction of underreporting and this has implications for the way in which the results are interpreted. The weight of food was under-estimated on average by 32% using the PAC24 compared to lunch observations. Although wide limits of agreement were found in the study (from an underestimation of 85% to an overestimation of 218%), Foster *et al.* (103) also showed wide limits of agreement ranging from an under-estimate of 41% to an over-estimate of 72%. These may reflect the small sample size and indicate that, at an individual level, considerable differences between both methods are possible. Other factors possibly contributing to the underestimation of weight of food are that the food photographs in the PAC24 did not include some of the foods served at lunch in school canteens and/or the presentation of food on the plate was not the same. This happens because there are no national data available in Portugal regarding school-age children's food consumption and so we had to use food photographs from another country. Although FG enriched the food-items pool that was originally developed by a literature review and also identified some regional specific names attributed by children to some food items, it did not allow us to know how food was presented to children in the school canteens (e.g., the presentation of pulses and fish differs from the presentation in the food photographs). Thus, it might be difficult for children to estimate the quantity of food served and leftover for some food items. Future research is necessary to adapt the PAC24 to include food photographs more appropriate for Portuguese children.

Furthermore, it would be important to evaluate if under-reporters have a higher BMI and also stratified these results by social desirability. Although, accuracy was tested in two schools, one of which was located in a lower income neighbourhood, the small sample size didn't allow a subgroup analyses to examine differences by race/ethnicity.

Although no statistically significant differences were detected by grade, observers reported second-graders experienced more difficulty in completing the PAC24, than third and fourth grade children, perhaps as a result of their cognitive immaturity (148), which was not assessed. Therefore the children, especially the younger children, required assistance to complete the PAC24. The problems that observers detected in the PAC24 administration might be addressed by a training nutritionist to assist the children (a single nutritionist was able to provide assistance in completion of the PAC24 for up to 10 children).

6.3 Pilot study

A pilot study was conducted to check the feasibility in respect of procedures, methods and data processing.

EFSA (38) recommends the collection of dietary information for two non-consecutive days for the 24-h DR. Days are considered as non-consecutive if there is at least a two weeks interval between them. More than three days are not recommended in order to limit the respondent burden and a potentially high non-respondent bias. From a statistical point of view it is more efficient to extend the number of participants rather than the number of days. This is why we decided to apply PAC24 on two non-consecutive days with 15 days apart in order to estimate habitual intake.

A rough comparison between data from a review on dietary intake of European children and adolescents (57) with data from PAC24 was done for girls and boys of the same age range. Energy intakes ranged from 1601 to 2294 kcal/day in girls and from 1673 to 2414 kcal/day in boys. Data from PAC24 fit into these ranges.

In Portugal, Valente et al (63) developed a study with Portuguese school-age children (7-9 years old). Mean energy intake in PAC24 was lower both for girls and boys (1761 kcal vs. 2522 kcal and 1838 kcal vs. 2319 kcal, respectively). One possible explanation is the fact that Valente et al (63) used a different dietary assessment method, the FFQ, that tends to overestimate dietary intake (36).

Furthermore, participants macronutrient intakes fit in the recommended ranges of IOM

(49): 45-65% for carbohydrate, 25-35% for total fat and 10-30% for protein. On the other hand, compared with the WHO guidelines (11), carbohydrate intake is below the recommendations (55-75%) and protein intake is above the recommendations (10-15%). Intakes of fibre, calcium and potassium were below the DRIs for children (41,43) (fibre: 25 g for 4-8 year old children, 26 g and 31g for 9-13 year old girls and boys, respectively; calcium: 1000 mg for 4-8 year old children and 1300 mg for 9-13 year old children; potassium: 3800 mg for 4-8 year old children and 4500 mg for 9-13 year old children). Sodium intake is above the recommendation from WHO (<2 g per day) (46). Fruit and vegetables intake met the WHO recommendations (≥400 g/day) (11).

Comparing outcome measures from children completing PAC24 twice with an interval of 15 days, didn't result in significant differences, indicating that respondents were willing to complete the program the second time as accurately as the first time. The same findings were found in YANA-C (102). However, these findings are based on a low number of respondents (n=48) and need to be confirmed in a higher-powered study sample.

6.4 Business Plan

A business plan for PAC24 was designed by Kadosh (174) with the main objective being to evaluate its economic and financial feasibility. There are four major business plan models that can be followed: Harvard methodology, Kuratko methodology, Ernest & young, and Deloite & Touché. Kurakto was the chosen methodology. This lay in the fact that along with the Harvard methodology, also suggested by Kuratko, it is the most thorough methodology, which implies addressing all aspects of a business.

In order to analyse the interest of the market in PAC24 and also to establish strategic objectives, a series of interviews were conducted. The interviewers were people with influent positions in entities identified as strategic clients such as the Ministry of Education and Science, Lisbon City Hall and directors of public and private schools. Each interview took an average of 54 minutes and was carried out in June 2014. For the financial plan an IAPMEI (*Agência para a Competitividade e Inovação*) calculus sheet was used. This is a pre-defined calculus sheet, which was based on a series of assumptions; it automatically calculates the Net Present Value (NPV).

Based on the interviews, it was estimated that in the next 5 years 25% of the market share would be gained. The price of the service (dietary intake assessment on two non-consecutive days of second-, third- and fourth-grade children) was mostly based on PAC24 costs and set at 1500 euros per school. Having identified a strong dependence on the public sector (89% of schools are public (187)) a risk analysis was conducted in order to evaluate under which scenarios PAC24 would not be a good financial investment. The only scenario that showed a negative NPV was if no public school acquired PAC24. What this means is that even though the market share could be lower than 25%, only under the scenario of a 0% to 4,5% market share will PAC24 not be a good investment.

The business plan of PAC24 showed that it is in fact an innovative application with great margin for growth financially wise.

6.5 Strengths and Limitations

6.5.1 Strengths

This study had several notable strengths:

First, a combination of formative research and professional judgement was used to guide the development and validation of PAC24. This ensured that PAC24 is based on sound research combined with professional experience.

Second, the PAC24 has the benefit of ensuring standardisation of methods, as the quality of the interview process, the accuracy of food coding and data entry in interviewer-administered 24-h DR vary with the experience and the diligence of the nutritionist, dietitian or researcher. The removal of the need for a trained interviewer vastly reduced the cost of dietary surveys.

Third, FG enriched the list of food and drink items that was developed for PAC24 with regional specificities from the seven main regions of Portugal. It also gave insight into how children refer to and speak about food and food-related habits that were taken into

account in PAC24 development. This data wouldn´t be possible with less interactive data collection tools such as questionnaires.

Fourth, the results from a usability test and accuracy study showed that the PAC24 was well accepted by participants, completed within a short time period (mean=28 minutes) and relatively intuitive to use. They also provided useful feedback for improvements. In particular, the accuracy study showed that children aged 7-10 years old are able to complete the PAC24 on their own without parental assistance.

Fifth, lunch school observations were used to validate PAC24. Meal observations are the 'gold standard' for validating dietary reports and should be used instead of methods that rely on self-reports provided by subjects (e.g., 24-h DR), which fail to provide the truth about actual intake.

Sixth, IOR was calculated in the accuracy study, reflecting the consistency between observations of the same children by different observers (IOR=86.9%). IOR is essential to determine that the information collected does not depend on who conducted the observation.

Finally, the validation and the pilot study of PAC24 was performed under exactly the same circumstances as it is intended to be used in dietary assessment study in schools including same procedures, same setting and same age group.

6.5.2 Limitations

This study had also limitations that must be addressed:

Regarding the FG, the results found cannot be used quantitatively and the quality of the data obtained relies to a large extent on the skills of the researcher(s) in charge of the FG. This should be taken into account when reviewing the results of qualitative research such as this and when considering how they can, and should, be used. Another limitation is that we have no way of knowing whether or not what children said was really what they had eaten on the previous day, because the data were not validated with a method such as direct meal observations. Furthermore, since the objective of the FG

was not to analyse children's dietary reporting accuracy, the results should not be interpreted as such. Another potential limitation of the FG is the generic nature of the author's questions regarding quantities of food consumed. Finally, it is also possible that some children were unwilling to talk about their food consumption in a group setting because of the sensitivity of these issues.

The limitations of the accuracy study include the small sample size (n=41), primarily because of the limited time and financial support to collect data; also the sample of children was limited to the LTV region, reflecting local and regional educational and food practices. It is not clear how these procedures may work in other cities or regions. Food items were scored as matches unless it was clear that the child's recall did not describe an observed food. This may maximized the score correctness of the child's recall and contribute to the high match rate. However, other dietary-reporting methodological studies with children have coded in a similar manner (95–97,137).

Since there are no national data available in Portugal regarding school-age children's food consumption we had to use food photographs for portion size estimation from another country (UK). Furthermore, although we are aware that single portion size photographs based on adult food portion sizes are unlikely to be suitable for use in children, we had to include 17 food images from the Portuguese Food Atlas in PAC24.

Lastly, the pilot study presented the following limitations: the small sample size (n=48), limiting its power; the sample of children was limited to LTV region, so findings cannot be generalize to other populations; the consistency that aims to evaluate the variance accounted for between observed and recalled values between two recalls (137) was not determined because of financial constraints.

6.6 Further development of PAC24 and additional research

PAC24 was developed on a limited budget. In this first stage of development, the application has shown real potential and further development could improve both the usability and the accuracy of the PAC24.

Firstly, validation studies are needed to investigate the accuracy of information about children's dietary intake when information is obtained from child-only recalls, parent-only recalls, and joint parent-child recalls. For most computerised dietary recalls (94,102,123), children only report their dietary intake without assistance from an adult household member from 10-11 years old or older. However, the joint parent-child recall method before 10 years old appears to never have been validated and it is plausible that adult characteristics could impact information in joint parent-child recalls about children's intake.

Second, there is a crucial need for validation studies to investigate the consistency of PAC24 in terms of matches, omissions and intrusions, because a single 24-h DR is a poor estimate of a child's typical intake. Baxter et al (137) used the term consistency instead of reliability for 24-h DRs because each recall regards a different dietary event, whereas the term reliability regards measuring the same event multiple times.

Third, an avatar with audio-assistance should be included to assist children explaining what to do in each FORM, particularly in FORM 2 and 3, which presented the major problems during the usability, accuracy and pilot studies. These may prove beneficial to participants with lower levels of literacy (123).

Fourth, the development or combination of new algorithms could substantially reduce the number of misspellings, which need to be stored to improve the system's ability to recognise the search terms entered. The spell checking functionality incorporated in PAC24 follows a simple model and improvement is necessary.

Fifth, additional prompts, which may help to improve accuracy, must be developed. The PAC24 needs to prompt appropriately for forgotten items. This includes identifying and prompting for foods which are commonly consumed together such as milk and cereal, bread and butter, or ham, or cheese, or jam, beyond commonly items such as drinks and snacks.

Sixth, new and more appropriate food photographs for Portuguese children, particularly for food items with low accuracy and wide limits of agreement (pulses; cereals and potatoes; meat, fish and eggs) should be developed. More research is required to

identify the types of foods for which portion size is least accurately estimated and to explore the optimum way in which to present these foods.

Seventh, further validation of the system with a larger and a more representative sample of participants are needed with adequate samples of children by BMI, gender, and race to investigate these potential correlates of dietary recall accuracy. Other potential correlates of children's dietary recall accuracy that need to be investigated in these validation studies include children's age (grade level), children's memory/cognitive ability, children's social desirability, children's self-esteem, children's body image, and children's socioeconomic status.

Finally, in the future the PAC24 might be further adapted to other age groups by making some changes in the visual design and also by updating the food list and the portion size images. It can also be developed to fit android mobile phones.

6.7 Conclusion

This study demonstrated that it is possible to develop, validate and test a new web-based recall for dietary assessment in Portuguese school-age children (7-10 years old): the PAC24.

The PAC24 is a self-administered web-based 24-h DR based on multiple pass method directed to second, third or fourth grade Portuguese children (7-10 years old). It automatically records and stores the appropriate food composition code and gramme-weight of each item selected with portion size assessment, based on a system developed specifically for use with children.

The PAC24 comprises five forms: FORM 1) 'child identity card', where children provide their personal data; FORM 2) 'food list', where the user is queried about what meals and snacks were eaten on the previous day; FORM 3) 'incomplete food list', which contains food items requiring further information on the types and portion sizes of foods/drinks consumed, and 'complete food list'; FORM 4) 'time, place & food behaviours', where children provide the approximate time and place where each meal or snack was consumed, and also whether they watched television or used a computer during meals; FORM 5) 'summary', where all food and drink items recorded throughout the day are reviewed.

The main conclusions of this study are presented below:

1. A literature review was conducted and a qualitative approach was followed with data collection carried out using FG for the identification and selection of an extensive list of food and drink items for PAC24. Overall, children identified 3959 food items in the FG. These food items were categorized into 12 food groups.

2. The FG revealed the main ways in which children report their previous day's food consumption. Children generally reported foods chronologically organized into the three main meals. Snacks and some foods like sweets were only

reported after specific prompts, and not all children were able to report foods successfully. Different meanings and labelling of some specific food items were identified. These findings were taken into account in the development of PAC24.

3. The development of PAC24 was supported by a literature review, FG sessions with school-age children from all the main regions of Portugal, and also input given by researchers from Newcastle and Durham Universities, UK, with a vast experience with computerised 24-h DR. The content of PAC24 was discussed and validated by five experts from different scientific areas (pediatrics, psychology, nutrition sciences, human-computer interaction, primary education) that participated in a face-to-face meeting.

4. The usability test demonstrated that PAC24 was engaging to school age children and therefore children maintained attention while completing the questionnaire. Children identified the FORMs 3 and 4 as the easiest forms and the FORM 2 as the most difficult one to complete. This study addressed some technical problems that were simplified and modified before the accuracy study.

5. Lunch observations (the 'gold standard') were used to study the accuracy of PAC24. Sixty-seven percent of specific foods reported were matches (foods/drinks reported in PAC24 and by observers), 21.5% were omissions (foods/drinks reported by observers but not in PAC24) and 11.5% were intrusions (foods/drinks reported in PAC24 but not by observers). The use of PAC24 led to underestimates of the weight of food on average by 32% with limits of agreement from an underestimation of 85% to an overestimation of 218%. The level of matches, omissions and intrusions observed in the accuracy study were comparable with other computerised 24-h DR currently in use in dietary surveys.

6. A pilot study was conducted on two non-consecutive days with 15 days apart. Children took on average 27 minutes to complete PAC24. Mean energy intake per day was 1799 kcal. Mean protein, carbohydrate and total fat intakes (as a percentage of energy intake) were 17.2%, 47.8% and 29.0%, respectively.

Significant differences were not observed in food consumption, in terms of food groups and nutrients, between the two measurement occasions ($p>0.05$). Therefore, respondents were willing to complete the application the second time as accurately as the first time.

In summary, PAC24 is a web-based 24-h DR designed to be self-administered by Portuguese school-age children (7-10 years old). It should be administered in a school setting, on computers/laptops with Internet connection, in the morning and with a trained observer (e.g., Nutritionist) giving assistance in completion for up to 10 children. This study demonstrated that, in the study population, PAC24 could be used to estimate accurate dietary intake on a group level, which will provide useful information for epidemiological studies on the links between diet and health, and contribute to the improvement of public health policies at national level.

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Appendices

Appendix I: Development of a new computer program to assess dietary intake in Portuguese school-age children: a qualitative approach.

Appendix II: Validation of the Portuguese self-administered computerised 24-hour Dietary Recall (PAC24) among second-, third- and fourth-grade children.

Appendix III: Parent Inform Consent used for the accuracy study of PAC24.

Appendix IV: Lunch Observation Record Sheet used in the accuracy study of PAC24.

Appendix I:

Development of a new computer program to assess dietary intake in Portuguese school-age children: a qualitative approach

DEVELOPMENT OF A NEW COMPUTER PROGRAM TO ASSESS DIETARY INTAKE IN PORTUGUESE SCHOOL-AGE CHILDREN: A QUALITATIVE APPROACH

DESENVOLVIMENTO DE UM NOVO INSTRUMENTO ONLINE DE AVALIAÇÃO DO CONSUMO ALIMENTAR PARA CRIANÇAS PORTUGUESAS EM IDADE ESCOLAR: ABORDAGEM QUALITATIVA

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Acta Pediatr Port 2014;45:116-123

ABSTRACT

Introduction: Twenty-four-hour dietary recall is the method of choice for assessing food intake among school-age children. Because they require highly trained interviewers, recalls are expensive and impractical for large-scale nutrition research. A new method for assessing dietary intake in children is being developed: the Portuguese self-administered computerized 24-hour dietary recall (PAC24). The objectives of this study were to identify and select food items for inclusion in PAC24; to better understand the way children report their previous day's food consumption; and to identify the different meanings and labels children give to certain food items.

Methods: Data were collected through 21 focus groups (FGs), conducted in seven primary schools from the seven regions of Portugal in 2011. A total of 204 children in second to fourth grades participated. The FGs were homogeneous for school grade and area of residence and heterogeneous for gender and socioeconomic status. Children participated in FGs after their parents' written informed consent was obtained. Topics for discussion were the previous day's food consumption and individual meanings and labelling of certain food items. Content analysis followed a thematic coding process.

Results: A total of 3959 food items were identified and classified into 12 food groups. Children generally reported foods chronologically, organized into the three main meals (breakfast, lunch and dinner). Consumption of snacks and sweets were reported after prompting for snacks and forgotten foods. Not all children were able to record foods successfully; both descriptions and quantities of food posed problems. Different regional- or culture-specific terms were identified for some of the food items.

Conclusions: This qualitative approach enriched the pool of food items that had been developed based on a literature review and revealed the main points that should be taken into account in developing PAC24.

Keywords: children; computerized dietary recall; dietary intake; focus groups; 24-hour dietary recall.

RESUMO

Introdução: O questionário às últimas 24 horas é o método de eleição para avaliar o consumo alimentar em crianças em idade escolar. Contudo, requer entrevistadores treinados, é dispendioso e inadequado para estudos de grandes dimensões. Está atualmente em desenvolvimento um novo instrumento de avaliação do consumo alimentar para crianças portuguesas: o questionário às últimas 24 horas, *online* e de auto-preenchimento (PAC24).

O objetivo do presente estudo foi identificar e selecionar os itens alimentares para inclusão no PAC24, compreender melhor a forma como as crianças reportam o consumo alimentar do dia anterior e conhecer a forma como as crianças verbalizam e interpretam alguns itens alimentares.

Métodos: Foram conduzidas 21 sessões de Focus Groups (FGs) em sete escolas do primeiro ciclo do ensino básico nas sete regiões de Portugal, em 2011. Participaram 204 crianças do segundo ao quarto ano. Os FGs foram homogéneos para o ano de escolaridade e área de residência e heterogéneos para o género e estado socioeconómico. A participação nos FG foi feita após autorização das escolas e preenchimento do termo de consentimento informado pelos pais das crianças. Os tópicos para discussão foram: consumo alimentar do dia anterior e verbalização e interpretação de alguns itens alimentares. A análise de conteúdo seguiu um processo de codificação temática, identificando todos os termos e expressões associadas a itens alimentares.

Resultados: Foram identificados 3959 itens alimentares, agrupados posteriormente em 12 grupos de alimentos. O relato espontâneo das crianças relativamente ao consumo alimentar do dia anterior foi feito de forma cronológica e organizado em três refeições principais (pequeno-almoço, almoço e jantar), tendo sido necessário colocar questões específicas para obter informação referente ao consumo dos lanches e de bolos. Muitas crianças revelaram ser difícil, para elas, descrever e quantificar os alimentos. Foram ainda identificados termos com especificidade regional para alguns itens alimentares.

Conclusões: Esta abordagem qualitativa enriqueceu a lista de itens alimentares inicialmente criada a partir da

revisão da literatura e revelou aspetos fundamentais a incluir no desenvolvimento do PAC24.
Palavras-chave: crianças; questionário online; consumo alimentar; focus groups; questionário às últimas 24 horas.

INTRODUCTION

The burden of chronic diseases is rapidly increasing worldwide[1]. Non-communicable diseases (NCDs), including cardiovascular disease, cancer, chronic respiratory disease and diabetes, are the leading cause of death in the world, responsible for 63% of the 57 million deaths that occurred in 2008[2]. Almost half of chronic disease-related deaths are attributable to cardiovascular disease[2]. Obesity, and particularly childhood obesity, is also showing worrying trends, not only because it affects a large proportion of children – 19.3-49.0% of boys and 18.4-42.5% of girls in Europe are overweight[3] – but also because it is established earlier in life. These wide variations in overweight and obesity prevalence estimates, among primary school children from twelve European countries, suggest the presence of a north-south gradient, with the highest prevalence values found in southern European countries[3]. In Portugal, data from the COSI-Portugal study showed that 37.9% of children were overweight and 15.3% were obese[4].

Food and nutrition are important determinants of NCDs[5-7]. Furthermore, children's diets must be suitable to support normal, and sometimes very rapid, growth and development [8]. What makes food intake an NCD risk factor instead of a health protecting factor is imbalances in variety, quality and quantity. This distinction is often very subtle and so difficult to assess. Therefore, for both clinical and research purposes, reliable ways of assessing dietary intake (including reliable and valid data collection instruments) are required so that children's dietary intake can be effectively monitored[9]. This is especially difficult to achieve for children of primary school age. A cognitive model of children's reporting of food intake was proposed by Baranowski and Domel[10]. This model includes three structural components: sensory register, short-term memory, and long-term memory. In the 7–8 year age group, there seems to be a fairly rapid increase in children's ability to participate in unassisted recalls for foods eaten in the immediate past[11]. However, children between 7 and 10 years old often need some help from parents or other adults, especially for providing details about types and quantities of consumed food[11]. Twenty-four-hour dietary recalls (24hDR) are logistically simple, applicable for cross-cultural surveys and not too burdensome for respondents, and would be the method of choice (especially when assisted by parents) for assessing food intake among school-age children[12, 13]. Furthermore, computers appear to be useful for this task since they (a) are seen as enjoyable devices for children, (b) reduce the costs of both collecting and processing dietary intake information due to the quantity and complexity of data usually involved, (c) enhance consistency of interviewing, due to standardization of the probes used to query details of consumed foods and respective portions, and (d) minimize the burden of respondents compared to other diet assessment systems[14,15].

In Portugal, data on food consumption are scarce for all age levels, and especially for children. There are few reliable data sources. The Food Balance Sheets[16] and the few national monitoring surveys[17], conducted on representative population samples, do not provide reliable estimates at the individual level, which are essential for identifying groups at risk and studying causal relationships between diet and disease[18].

A new method for assessing food and nutrition intake of Portuguese school-age children is currently being developed: the Portuguese self-administered computerized 24hDR (PAC24). In order to design this web-based questionnaire, it would be helpful to (a) identify and select an extensive list of food items for PAC24, (b) better understand how children organize their previous day's food intake when trying to report this information, and (c) identify different meanings and labels children give to certain food items. To obtain such information, we followed a qualitative approach with a sample of second, third and fourth-grade Portuguese school-age children.

METHODS

This study follows a qualitative approach, with data collection carried out using focus groups (FGs) between March and September 2011. FGs allow more abstract and in-depth exploration of food and nutrition issues than is possible with less interactive data collection tools such as structured questionnaires. They also enable the gathering of a considerable amount of information in a short data-collection timeframe, and of several individuals' perspectives as well. This data-collection methodology thus maximizes the opportunity of gaining insight into how children refer to and speak about food-related habits and consumption[19, 20].

Study population and design

The study included students from the second to the fourth grade. They were selected from seven schools

in the seven regions of Portugal (including the islands): North, Centre, Lisbon and Tagus Valley (LTV), Alentejo, Algarve, Madeira and the Azores. Schools were selected on the basis of a convenience sampling process, with the authorization and active collaboration of the Portuguese Ministry of Education. The criteria for the inclusion of schools were: regional location, presence of second to fourth grades, and willingness to participate. Within each school, participants were selected from class lists according to theoretical criteria (purposive sampling). In accordance with these purposive criteria, FGs were constructed to ensure homogeneity for school grade and area of residence, and heterogeneity of gender and social-economic status. The study was approved by the Ethics Committee of the Faculty of Medicine of Lisbon. Parents completed informed consent forms, and assent was obtained from children before they participated.

All FGs were conducted at school, in private classrooms. In each school, three FG sessions were conducted, one each with children from the second, third and fourth grade (a mean of 10 children per FG). Most FGs were conducted during the morning (90.5%). This was because greater accuracy has been reported with interviews conducted in the morning when the target period is the previous day [21]. The FGs, each lasting between 40 and 60 minutes, were conducted and moderated by nutritionists and one psychologist. The same nutritionist conducted the FGs in all regions, except in Madeira and Azores, where the FGs were conducted by local nutritionists. Each nutritionist was trained in administering the same standardized questions and was also informed of the objectives of the study. The psychologist conducted the first three sessions with the nutritionist and gave assistance with methodological issues concerning qualitative approaches for child subjects.

Focus group questions

FG questions were developed by the research team on the basis of a previous review of the literature. The discussion followed an enjoyable game format. Topics for discussion were:

a) Previous day's food consumption

Data on the previous day's food consumption were obtained by simulating a multiple pass 24hDR, developed by the US Department of Agriculture[22]. The multiple pass method guides the respondent through a 24-hour reference period of food intake, providing different opportunities for the respondent to remember food details and also additional foods (Table 1). It has been validated and shown to accurately estimate mean total energy and protein intakes. In the US, it has been used in the National Health and Nutrition Examination Survey (NHANES), and in Europe, a similar program, EPIC-SOFT, has been developed for use in the European Prospective Investigation into Cancer and Nutrition.

Children were asked to verbally report intake in any order they wished in response to the initial instruction "Tell me everything you had to eat and drink yesterday, from when you woke up until when you went to bed" *("Diz-me tudo aquilo que comeste e tudo aquilo que bebeste ontem, desde que acordaste até ao momento em que foste dormir.")*. They were then asked about items that might have been forgotten, including water, soft drinks, biscuits, sweets and ice cream. These forgotten food items were based on commonly forgotten categories of foods described previously[22]. After that, the children were asked about the time and occasion of each food, and for further information (details, amounts and place where each food was eaten). They were asked to report quantities of food in terms of units (e.g. number of biscuits, number of slices of toast, number of slices of pizza) and/or household measures (e.g. spoons of sugar, glasses of water). In a final review, the children were asked if they had consumed anything else (the moderator repeated what they had reported and gave a prompt like "Did you eat anything yesterday that I didn't mention?"*)*. Responses were obtained from each child during FGs. But interaction between children frequently prompted additional food items to be recalled (e.g., one child reminding another that she/he also ate a birthday cake). This possible bias was useful and informative for the main purpose of the data collection (i.e., recording food items as they are remembered and reported by children of this age).

b) Individual meanings and labelling of food items

We asked children if they could identify and differentiate wholegrain from white bread, commonly consumed low fat or reduced fat foods (e.g. milk), and also if they knew what ice tea is made from (Table 2). The reason for these questions for meaning assessment was that in the first FGs it became clear that the meanings for such items were not universal among these age-groups.

Data analysis

The FGs were audiotaped and transcribed to ensure proper thematic content analysis. Each FG was transcribed by the researchers who participated as FG moderators. The recorded content of all the FGs (full corpus) was merged and included in the analysis. Content analysis followed a thematic coding process. Each unit of meaning was considered as important as any other, no matter the frequency of its verbalization. This was because the main goal was to gather terms and meaning about food items. The analysis was performed entirely by one of the researchers, and was

subsequently validated by the other researcher. After the coding process, the coded transcripts were sorted, each piece of material relevant to a particular issue or theme being cut and pasted so that all material relevant to a particular topic was placed in the same category. As the data were qualitative in nature, only frequencies are used for food item selection purposes (Table 1) and no formal statistical tests were applied in the study.

RESULTS

A total of 21 FGs were conducted. Overall, 204 children participated in the study. The age distribution was: 7-8 years (second grade; n=70); 8-9 years (third grade; n=61), and 9-10 years (fourth grade; n=73). With respect to geographical distribution, 29 children lived in the North region, 37 in the Centre region, 19 in LTV, 34 in the Alentejo, 29 in the Algarve, 27 in the Azores, and 29 in Madeira.

Analyses of the data were based on three key themes: 1) the previous day's food consumption; 2) the way children reported on the previous day's food consumption; and 3) meaning and labelling of specific food items.

Previous day's food consumption

Overall, 3959 food items were identified by children when asked about their previous day's food intake. These food items were classified by researchers (rather than by the children themselves) into the following food groups (Table 1): 1) cereals, cereal products and potatoes (920 items);

Table 1. Food items included in the 12 food categories

Food Groups	Description	Food items reported	
		n	%
1) Cereals, cereal products and potatoes	All types of bread made with different types of flour (wheat, whole wheat, rye) including toasted bread; all types of pasta; baby cereals; all types of rice; potatoes; sweet potatoes; potato crisps; mashed potatoes; breakfast cereals; crackers; biscuits without cream or chocolate; sweet corn	920	23.2
2) Fruit	Fresh fruit; 100% fruit juice; nuts; seeds; olives	326	8.2
3) Vegetables	Raw and cooked vegetables; vegetable soup	376	9.5
4) Milk and dairy products	All types of milk (whole, semi-skimmed, skimmed, flavoured); yoghurt; cheese	591	14.9
5) Meat, fish and eggs	Beef; pork; hamburgers; chicken; poultry; raw, canned and cooked fish; fish products; crustaceans and molluscs; eggs (fried, boiled, scrambled, omelettes); ham; sausage; snails	546	13.8
6) Pulses, fresh and processed	All types of beans; lentils; peas; lupin seeds	30	0.8
7) Oils and fats	Butter; olive oil and other vegetable oils; margarine; cream; mayonnaise; peanut butter	150	3.8
8) Beverages	Tap water; bottled water; fruit juice with added sugar; soft drinks; black coffee; tea; alcohol; other hot drinks (cocoa or chocolate beverages; white coffee), fruit drinks	449	11.3
9) Sweet products	Chocolate and chocolate products; ice cream; biscuits (chocolate biscuits, butter biscuits); cakes; sweet snacks; sugar; jelly; milk-based desserts; sweets; jam; marmalade; honey; sweet breakfast cereals; sweet cereal-based snacks (e.g. bars); pancakes; waffles; brioches; milk bread rolls; croissants; croissants with chocolate filling	445	11.2
10) Snacks and fast food	Pizza; hot dogs; quiches; savoury pies; pastry	35	0.9
11) Mixed dishes	Meat-based dishes; fish-based dishes; pasta-based dishes	84	2.1
12) Miscellaneous	Vinegar, ketchup, mustard sauce	7	0.2

2) fruit (326 items); 3) vegetables (376 items); 4) milk and dairy products (591 items); 5) meat, fish and eggs (546 items); 6) pulses (30 items); 7) oils and fats (150 items); 8) beverages (449 items); 9) sweet food (445 items); 10) snacks (non-sweet) and fast food (35 items); 11) mixed dishes (84 items); and 12) miscellaneous (7 items). The FGs were run during spring and summer, which may explain the high reported consumption of ice cream.

The most popular breakfast choices were: chocolate cereals, honey cereals, toast, milk and bread with butter, cheese, ham or jam. Common to all children was the fact that their parents prepared breakfast for them whether they (the parents) were present at the meal or not (e.g., when breakfast was taken out of home). A wide variety of foods were reported as being eaten as snacks, such as sandwiches, biscuits, cakes, yoghurt, flavoured milk, fruit and ice cream. Snacks were most commonly eaten during school break-time and at home, straight after school. Snacks in school were typically brought from home, with the exception of the flavoured milk (usually with chocolate) that was offered by the school.

The majority of children had lunch in the school canteen and the reporting of lunch food consumption was more collective (involving all participants of each FG) than individual. All the lunches included vegetable soup, meat or fish with potatoes, pasta or rice. Salad and fruit were optional, and so some children did not report the consumption of those food items.

There were considerable differences in food composition of dinner between children. By contrast, the consumption of beverages was common during dinner, particularly soft drinks, especially ice tea. Of the total consumption of beverages reported by children, 56.6% were soft drinks. Finally, few children reported an additional snack before going to bed. When they did, it consisted of cake, sweets, milk or tea.

How children reported on the previous day's food consumption

In general terms, children reported foods chronologically (from the first item eaten in the morning to the last item at night), but some foods, such as beverages (e.g. water) were routinely reported non-chronologically. Most children reported three main meals (breakfast, lunch and dinner). Without prompts for snacks (Table 2) participants did not spontaneously report the consumption of foods between breakfast and lunch, lunch and dinner, and/or after dinner. They reported food items using the time of day and other contexts, such as where they were, who they were with, and what they were doing as methods of remembering which foods they had consumed. Individual children differed in the effort they made trying to remember what they ate during the previous day. A number verbalized having difficulties reporting what they ate and in reporting the quantities of those foods remembered. This was more evident among children in the second grade (7-8 years old), and was also more evident when children were asked about quantities of sugar, chocolate, honey or coffee added to beverages (Table 2). Regarding water consumption, children reported different sources, including glasses of water, bottled water and drinking fountains. Most children reported the consumption of sweets and cakes that other pupils brought to school (especially on birthdays to share with their peers), after they were asked for forgotten foods (Table 2).

Meaning and labelling of specific food items

With regard to wholegrain bread, some children thought that it was a special type of bread for people who are trying to lose weight; other children understood it to be toasted bread (Table 2). Most children differentiated whole, semi-skimmed and skimmed milk on the basis of the colour of the bottle (Table 2).

When children were asked "What is ice tea made from?", a considerable percentage (15.8%) who reported consuming this soft drink said that it is made from water with a small quantity of sugar (Table 2).

Regional or culture-specific terms were also identified for some of the food items.

DISCUSSION

There is a need to develop tools for assessing food intake among Portuguese children. This study was undertaken in order to identify and select food items that will comprise a computer-based, self-administered 24hDR for second-fourth grade Portuguese children. It also aimed to gain a better understanding of the way that children of this age report their previous day's food consumption, through FG methodology that enabled a more in-depth exploration of food consumption issues than is possible with less interactive data collection tools such as structured questionnaires. The results could also be used to better understand how to ask children about their recent food intake through a computerized food recall, such as PAC24.

Usually, qualitative methods aim to capture the ways and processes in which people think and behave. In this study, the main goal was to gather an extensive list of words, terms and expressions used by Portuguese second to fourth grade children to refer to food items. So, rather than conducting a phenomenological or interpretative analysis of the content, analysis of the

corpus (i.e., transcripts of the FGs) was mainly targeted at identifying those food words and terms.

Although the FG technique has significant advantages in gathering data, it also has some limitations. For instance, the results cannot be used quantitatively, and the quality of the data obtained relies to a large extent on the skills of the researcher(s) in charge of the FGs. This should be taken into account when reviewing the results of qualitative research such as this and when considering how they can, and should, be used. Another limitation is that we have no way of knowing whether what children said was really what they had eaten on the previous day, because the

Table 2. Major reporting issues regarding previous day's food consumption and individual meanings and labelling of some food items

Food reporting issues	Typical comments
Children reported the three main meals first (breakfast, lunch and dinner) and then snacks, after specific prompting for snacks.	**Moderator** I'd like to know what you ate yesterday from when you woke up until you went to bed. **Child** I ate bread with butter and a glass of milk with Nesquik[1]. **Moderator** And then? **Child** I ate cabbage soup and cod with potato. **Moderator** And that was your lunch? **Child** Yes. **Moderator** And then what? **Child** Pizza. **Moderator** And then? **Child** Then is the next day. **Moderator** You told me that in the morning, you ate bread with butter and milk with Nesquik[1]. And between breakfast and lunch, did you eat or drink anything? **Child** Ah, I drank milk and I ate a *chipicao*[2].
Description of food quantities was difficult for some children, especially for sugar, chocolate, honey or coffee added to beverages.	**Moderator** Ok. And if I ask you about how much sugar was in your milk, can you tell me? **Child** No. **Moderator** How many spoons of chocolate did you add to milk? **Child** I don't know. My mother puts sugar in my milk every day.
The majority of children reported sweets and cakes that children brought to school on birthdays after prompting for forgotten food items.	**Moderator** One thing that surprises me is that nobody besides these two girls ate chocolate or sweets yesterday. **Child** I did. **Child** I think I did the day before yesterday. **Child** I had a croissant. **Child** Yesterday I drank a juice. **Child** I only have them on birthdays. **Child** Every day I eat at least two chocolate biscuits. **Child** I eat more on Sundays, that's the day I go to my grandmother's house and she gives me pastries. **Child** Yesterday I ate a *pastel de nata*[3]. **Moderator** So, I think that's better, at the end of the game that I'm developing, to add a question like this: "Did you eat sweets yesterday?" What do you think about that? **Children** Good.
Individual meanings and labelling of some food items	**Typical comments**
Some children thought that wholegrain bread was a special type of bread for people who are trying to lose weight; for other children it was like toast.	**Moderator** That bread *[you said you ate yesterday]*... was it very white or rather dark? **Child** Dark. **Moderator** Who eats white bread? **Children** Me. **Moderator** And dark? **Child** Just him. **Moderator** Ok, but before the bread went to the toaster, what colour was it? **Child** White. It was normal bread. It was dark outside but inside it was white. **Moderator** Who can say what "wholegrain bread"is? **Child** Wholegrain bread is for people who are trying to lose weight. (...) **Child** It's something that helps you lose weight and it also has little brown dots.
The majority of children classified ice tea as flavoured water with no or little added sugar.	**Moderator** And you? Tell me what do you think what ice tea is. **Child** It's a bit like tea. **Moderator** It's a bit like tea. And do you think it has a little or a lot of added sugar? **Child** A little.

[1]Nesquik: chocolate powder for milk; [2]Chipicao: a sweet filled 'croissant', [3]Pastel de nata: a traditional portuguese cake.

data were not validated with a method such as face-to-face 24hDR or direct meal observations. Furthermore, since the objective of this study was not to analyze children's dietary reporting accuracy, the results should not be interpreted as such. Another potential limitation of this study is the generic nature of the authors' questions in the FGs regarding quantities of food consumed. Future research should use more appropriate tools for assisting children in this estimation, such as food photographs. Finally, it is also possible that some children were unwilling to talk about their food consumption in a group setting because of the sensitivity of these issues.

In this study, children from second to fourth grade (7 to 10-year-olds) were asked to report their previous day's food consumption, without assistance from parents or teachers. This is important, because literature suggests that parents lack first-hand knowledge of their children's intake at school and also because there is evidence that children of this age are able to respond adequately to self-report methods such as dietary recalls[11]. Answers regarding food items were grouped by researchers (when analyzing the collected data) into 12 food groups. The categorization of these groups was based on a combination of findings from international dietary surveys[23-27].

When asked about what they had eaten the previous day, children generally reported foods chronologically (from the first item eaten in the morning to the last item at night). But some foods, such as beverages (e.g. water) were routinely reported non-chronologically. Subar *et al*[28] found the same results in formative research on a 'quick list' for a computerized dietary recall. Regarding the interview format (open or structured by main meals), Baxter *et al*[29] found that although more items were reported as being eaten in a structured meal interview format than in an open interview format, accuracy was better with open format interviews, with lower intrusion and total inaccuracy rates. We found that children did not report the consumption of snacks spontaneously, but in the majority of cases only when specific meal/snack name prompts were used. Subar *et al* [28] and Foster *et al*[30], after testing two versions of a 'quick list' for remembering foods consumed on the previous day (open format versus meal format), found that participants showed a strong preference for the meal-based format. Further studies should be carried out before deciding on the interview format for PAC24.

Students used a wide variety of retrieval categories when reporting consumption[31]. FG participants from this study used the time of day and other contexts as cues for remembering which foods they had consumed. According to Baxter *et al*[32], food category prompting slightly improves recall accuracy among fourth graders, but only in half of the children who received it. We found that most children reported the consumption of sweets only after specific prompting for forgotten foods. This suggests that asking children about easily forgotten foods (e.g., foods that are usually taken outside main meals) may have an important role in increasing the accuracy of self-administered automated recalls. Further research should thus be conducted in order to validate the food prompts that will be included in PAC24.

Furthermore, not all children were able to report foods without a significant effort; both descriptions and quantities of food were difficult for some children to recall. Research indicates that children have considerable difficulties in accurately estimating quantities eaten[33].

We identified some regional or culture-specific names attributed by children to some food items that will be taken into account for the software development. The FGs also showed that the majority of children did not understand the nutritional composition of some food items (e.g., ice tea and wholegrain bread). This highlights the need to increase the nutritional literacy of this age-group.

In summary, a new method for assessing food and nutrition intake of Portuguese school-age children is currently being developed: PAC24. In order to design this web-based questionnaire, a qualitative approach was followed, with data collection carried out using FGs. This study enriched the pool of food items that had been developed based on a literature review and also revealed the main ways in which children report their previous day's food consumption, as well as different meanings and labelling of some specific food items, that should be taken into account in the development of PAC24. Future research, particularly content validation by experts, usability tests and criteria validation, should be carried out in order to validate PAC24 for use in Portuguese school-age children.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

FUNDING

This research received no specific grant from any funding agency from the public, commercial or not-for-profit sectors.

ACKNOWLEDGEMENTS

The authors thank Carla Jardim, Marta Perro Domingues and Sara Ferreira for their assistance in the development of the focus groups in schools. The authors especially thank the schools and children who participated in the study.

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Recebido: 02/01/2014
Aceite: 24/04/2014

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Appendix II:

Validation of the Portuguese self-administered computerised 24-hour Dietary Recall (PAC24) among second-, third- and fourth-grade children

BDA The Association of UK Dietitians
THE OFFICIAL JOURNAL OF THE BRITISH DIETETIC ASSOCIATION
Journal of Human Nutrition and Dietetics

RESEARCH PAPER

Validation of the Portuguese self-administered computerised 24-hour dietary recall among second-, third- and fourth-grade children

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Keywords
24-h dietary recall, children, computer, dietary assessment, lunch observations.

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How to cite this article
Carvalho M.A., Baranowski T., Foster E., Santos O., Cardoso B., Rito A., Pereira Miguel J. (2014) Validation of the Portuguese self-administered, computerised, 24-h dietary recall among second-, third- and fourth-grade children. *J Hum Nutr Diet*.
doi:10.1111/jhn.12280

Abstract

Background: Current methods for assessing children's dietary intake, such as interviewer-administered 24-h dietary recall (24-h DR), are time consuming and resource intensive. Self-administered instruments offer a low-cost diet assessment method for use with children. The present study assessed the validity of the Portuguese self-administered, computerised, 24-h DR (PAC24) against the observation of school lunch.
Methods: Forty-one, 7–10-year-old children from two elementary schools, in Lisbon, were observed during school lunch followed by completion of the PAC24 the next day. Accuracy for reporting items was measured in terms of matches, intrusions and omissions; accuracy for reporting amounts was measured in terms of arithmetic and absolute differences for matches and amounts for omissions and intrusions; and accuracy for reporting items and amounts combined was measured in terms of total inaccuracy. The ratio of the estimated weight of food consumed with the actual weight consumed was calculated along with the limits of agreement using the method of Bland and Altman.
Results: Comparison of PAC24 against observations at the food level resulted in values of 67.0% for matches, 11.5% for intrusions and 21.5% for omissions. The mean for total inaccuracy was 3.44 servings. For amounts, accuracy was high for matches (−0.17 and 0.23 servings for arithmetic and absolute differences, respectively) and lower for omissions (0.61 servings) and intrusions (0.55 servings). PAC24 was found to under-estimate the weight of food on average by 32% of actual intake.
Conclusions: PAC24 is a lower-burden procedure for both respondents and researchers and, with slight modification, comprises a promising method for assessing diet among children.

Introduction

Valid methods of assessing dietary intake are required to better understand what children are eating, what correlates with intake, and to evaluate dietary change intervention programmes (Livingstone *et al.*, 2004). The interviewer-administered 24-h dietary recall (24-h DR) is the most commonly used method for dietary surveys and is often used to collect information from children, despite self-report being prone to errors (McPherson *et al.*, 2000; Andersen *et al.*, 2011). Moreover, interviewer-administered 24-h DRs are expensive because of the need for highly-trained interviewers, multiple days of assessment to attain acceptable reliability, and specialised software to

elict and record the foods consumed, and to convert this detailed information into servings and nutrients consumed (Baranowski *et al.*, 2002). Interactive multimedia provides potentially powerful tools for assessing diet by capturing children's attention, graphically displaying foods and manipulating images to estimate portion size (Baranowski *et al.*, 2002). Computerised 24-h DRs have been developed and used successfully with adults and children in the USA (Baranowski *et al.*, 2002, 2012b; Subar *et al.*, 2012) and in children and adolescents in Europe (Vereecken *et al.*, 2005; Moore *et al.*, 2008; Foster *et al.*, 2013a). Although 8–9-year-old children tended to have more difficulty with food-categorisation tasks and took more time to complete these tasks (Baranowski *et al.*, 2010), there appears to be a fairly rapid increase in the ability of children to participate in unassisted recalls for foods eaten in the immediate past at approximately 7–8 years of age (Livingstone *et al.*, 2004).

The school environment provides a unique opportunity to validate parts of children's 24-h DR through lunch observations. Foods eaten at school are important because a significant percentage of a child's total daily intake is consumed at school. Reference information in most validation studies in which children have provided diet recalls without parental assistance has been obtained by observing one or two school meals (Simons-Morton & Baranowski, 1991; Domel *et al.*, 1994; Baxter *et al.*, 2000, 2001, 2002; Baranowski *et al.*, 2002, 2012a; Paxton *et al.*, 2011; Richter *et al.*, 2012). Direct observation of meals is often considered the 'Gold standard' by which dietary assessment tools are validated (Simons-Morton & Baranowski, 1991) because it is practical and economical in school/institutional settings, independent of the subject's memory, and can provide accurate unbiased information about the subject's actual intake.

The present study validated a new multimedia dietary assessment programme – the Portuguese self-administered computerised 24-h DR (PAC24) – completed directly by second-, third- or fourth-grade children (7–10 years old) on a computer against observation of consumption at school lunch. Validation of the PAC24 is critical because it will be used to monitor the dietary intake of Portuguese school-age children, which will provide the basis for epidemiological studies on the links between diet and health, in turn contributing to public health policy and the design of national health programmes.

Materials and methods

The Ethics Committee of the Faculty of Medicine of Lisbon approved the present study. Second-, third- or fourth-grade students (7–10 years old) from two elementary schools in 2013 were asked to participate. Schools were selected using a purposive sampling with authorisation and active collaboration from the Portuguese Ministry of Education. School inclusion criteria were: located in Lisbon and Tagus Valley region, covering second to fourth grades, and being a school with Internet access, with computers/laptops available to children. The Portuguese Ministry of Education identified three schools according to these inclusion criteria. Two agreed to participate (one of which was located in a lower income neighborhood). In each school, children from the second, third and fourth grades were randomly selected. Written informed consent was obtained from parents. Data were collected by school lunch observations and the PAC24 the day after. The target reference period for the study was midnight to midnight of the previous day. No incentives were provided to students for participating.

Portuguese self-administered computerised 24-h dietary recall

The PAC24 comprises software, designed for use with second-, third- or fourth-grade Portuguese children, which uses interactive multimedia to facilitate a child's self-report of diet by simulating a multiple pass 24-h DR. The system automatically records and stores the appropriate food composition code and gramme-weight of each item selected with portion size assesment based on a system developed specifically for use with children (Foster *et al.*, 2013b). Multiple food images are presented in progressively larger amounts on the same screen to enable children to quickly report food portion size (Islam *et al.*, 2013).

The first stage is the 'child identity card', where children provide their personal data (name, age, school grade). The second stage is the 'food list', where the user is queried about what meals and snacks were eaten on the previous day (first, the system asks for breakfast, then lunch, dinner and, finally, snacks). A search system (including spell check with many common misspellings of food names) then locates and displays foods automatically when matches are detected. Each meal has a box where children type in all of the foods and drinks that they remember consuming the previous day. Next, the user is presented with an 'incomplete food list', which contains food items requiring further information on the types and portion sizes of food/drink consumed. Clicking on an item in the 'incomplete food list' results in a request for portion size information. For the majority of foods recorded, the child is asked to identify the amount of food served using seven food images (ranging from the 5th to 95th centile of weight served to children in the UK National Diet and Nutrition Survey (Gregory *et al.*, 2000)

and the amount of food left over, if any, using a selection form with seven food images (from the 5th centile to the smallest presentable portion) to reflect the amount consumed. For foods that are usually served in predetermined amounts, a range of commonly consumed portion sizes is displayed in one photograph and the child is asked to select one portion size and then is asked about how many servings they ate. If no image is available for a specific food item, a description of the amount served and left over is entered manually. Once all details for consumed foods have been entered, the system prompts the user to provide the approximate time and place where each meal or snack was consumed. As a final check, the user is shown a summary of all items of food and drink recorded throughout the day. A button allows the user to return to the incomplete food list at any time during the process to add a forgotten item. In a nutshell, the PAC24 is a web application developed in PHP (Hypertext Preprocessor; http://php.net) and backed by a MySQL database (http://www.mysql.com/). User data are collected through a web interface, rendered on any JavaScript enabled browser and, subsequently, exported to EXCEL format (Microsoft Corp., Redmond, WA, USA).

Measures: school lunch observations and the Portuguese self-administered, computerised, 24-h dietary recall

One trained nutritionist and four trained nutrition science students conducted observations in the school cafeteria during usual school lunchtime. Two children were observed at the same table by one observer. Observers had school menus but walked through the lunch line before the children arrived to assess whether what was served corresponded to what was on the menu and also to weigh the foods that would be served to children. School lunches had several components: (i) soup as the first course; (ii) meat or fish with rice, pasta, potatoes and/or pulses as the main course; (iii) vegetables (lettuce, tomato or carrot); (iv) fruit/dessert; (v) bread; and (vi) water. All children had access to the same first and main course. Vegetables, fruit/dessert, bread and water were optional for all children because cooks only served these food items if children asked for them. Children received the same food portion size of each food because food was served to children by the cooks. Each child under observation was identified unobtrusively by their teacher at the beginning of the lunch period. As the child left the school service line, the observer recorded the number and amount of each item on the child's tray. The observer then positioned herself to clearly observe both children. During the meal, the observer recorded the amounts of all foods traded (i.e. food obtained from or given to other children at the table) and any food spilled or dropped on the floor. At the end of the meal, the observer recorded the amount of each food left on the tray using kitchen scales (Vitalia, BC-200, Fagor, Mondragon, Spain). Standard observation training procedures were employed (Simons-Morton & Baranowski, 1991). Eaten foods and respective amounts were recorded and correlated with later student response options on the PAC24. Using inter-observer realibility (IOR) procedures (Baglio *et al.*, 2004), during training and data collection, observations for the same student were compared across pairs of observers. IOR was calculated as the percentage of agreement between two observers (amount of food/beverage items served and amount of food/beverage eaten). IOR had to exceed 85% (IOR = 86.9%) for data collection to proceed.

The PAC24 was conducted the day after lunch observations in a private location at school on a computer or laptop computer with Internet access (most PAC24s were conducted in the morning before lunch to enable observation of school lunch for the next day's PAC24). The PAC24 was completed by children who were observed the day before. During the PAC24 administration, assistance was provided by one nutritionist to children who presented with questions such as: (i) how to spell a word; (ii) what to do when the system did not recognise more than one food per line at the second stage; (iii) what to do when the system did not present exactly the same food in the portion size image as the child had reported consuming; and (iv) what to do if they did not know what time they ate meals.

Statistical analysis

Lunch observations were used to validate the PAC24. The PAC24 covered a full 24-h period, whereas school lunch observation only covered the previous day's lunch consumption. Statistical weights were assigned to meal components to reflect their importance: combination entree (e.g. hamburger on bun) multiplied by 2, and remaining components (e.g. chicken, milk, apple, peas) multiplied by 1, so that errors in reporting entrees counted more than errors in reported sides and drinks (Baxter *et al.*, 2000, 2002, 2003; Baxter, 2009). Condiments were not assessed because condiments were not available to children during the lunch period. Nutritionists compared the sets of data by hand and assigned all foods by meal into the categories: matches (reported in both records being compared), intrusions (reported in the PAC24 but not by the validator) or omissions (reported in the validator but not in the PAC24) for each individual separately. Because foods can be reported in many ways, items were scored as matches unless it was clear that the child's recall did not describe an observed food. Examples of items

observed and reported as matches were all types of milk (e.g. skim, semi-skim) and all types of vegetable soup (pea soup, spinach soup). Fruit, vegetables and breads that differed were not considered matches. Rates per student for each lunch were calculated for each of the three categories (Table 1).

In addition, to evaluate children's accuracy of reported amounts, observed and reported amounts were scored in servings (0.0 = none, 0.1 = taste, 0.25 = little bit, 0.5 = half, 0.75 = most, 1 = all, or the actual number of servings if more than 1) (Baxter *et al.*, 2000). Total innaccuracy [total inaccuracy = (absolute difference between amounts reported and observed eaten for each match × statistical weight) + (each omitted amount × statistical weight) + (each intruded amount × statistical weight) summed over all items at school lunch for each child] was calculated as a measure that combined accuracy for reporting of items and amounts, although it fails to indicate whether errors are the result of omissions, intrusions or incorrectly reported amounts. A total inaccuracy score of zero indicated a perfect recall compared to observation (Baxter *et al.*, 2002).

To analyse accuracy for reported amounts (in servings) for matches, arithmetic differences for matches [arithmetic differences for matches = {sum [(amount reported − amount observed for each match) × weight]}/(weighted number of matches)] and absolute differences for matches [absolute differences for matches = {sum [(absolute difference between amounts reported and observed for each match) × weight]}/(weighted number of matches)] were calculated; amounts for omissions [amounts for omissions = {sum [(amount observed but not reported for each omission) × weight]}/(weighted number of omissions)] and intrusions [amounts for intrusions = {sum [(amount not observed but reported for each intrusion) × weight]}/(weighted number of intrusions)] were also calculated to assess whether these errors in reporting involved small or large amounts of servings (Baxter *et al.*, 2009a). Values close to zero for arithmetic and absolute differences for matches, and amounts for omissions and intrusions, represented high accuracy.

For those food items that were correctly reported (matches), the method of Bland & Altman, (1986) was used to assess the accuracy of estimates of food weight reported using the PAC24 by calculating the ratio of estimated food weight (by the PAC24) to actual food weight intake as measured by the lunch observations (Table 2).

After cleaning and validation, data were converted and exported to a database for statistical analysis in SPSS, version 21 (IBM Corp., Armonk, NY, USA). Differences between groups (gender and grade) were examined for the percentage of foods matched, omitted and intruded, and, for total inaccuracy, arithmetic differences for matches, absolute differences for matches, amounts for omissions, and amounts for instrusions (Table 1). Variables were tested by gender and grade for normality. Percentages of foods omitted and intruded, and also total inaccuracy, amounts for omissions, and amounts for instrusions were found to be highly positively skewed. The mean value between two independent samples was calculated using an independent sample *t*-test. The nonparametric alternative was the Mann–Whitney *U*-test. Analysis of variance was used to compare the mean values between more than two independent samples after testing for normality and homogeneity. The nonparametric alternative test was the Kruskal–Wallis test. $P < 0.05$ was considered statistically significant.

Log transformations were applied to approximate normality. Accuracy of estimates of food weight using the PAC24 was assessed by calculating the mean ratio of estimated weight to actual weight (1 indicated an exact agreement of the two methods at the group level) and the limits of agreement were calculated as the mean ratio (±1.96 SD) to give a measure of precision (Table 2).

Results

In total, 44 students returned the signed assent and parental consent forms indicating their agreement to participate. However, PAC24 data from three students were lost. Accordingly, data collection included 41 students (24 girls corresponding to 58.5% of the sample). Most children were 10 years old (34.1%), with some being 9 years (31.7%), 8 years (24.4%) and 7 years (9.8%). The mean (SD) age was 8.9 (1.0) years.

Sixty-seven percent of foods reported were matches of specific foods, 21.5% were omissions and 11.5% were intrusions (Table 1). Items that were most often omitted were vegetables (39.7%) and sweets (15.1%). Items with the highest percentage of intrusions were beverages (38.2%).

Table 1 also shows the results for total inaccuracy, amounts for matches, omissions and intrusions by gender and grade. The total inaccuracy measure for each recall, based on all items observed and recalled across lunch, captured the total error, in servings, of the dietary recall. Total inaccuracy (3.44 servings) was low. For matches, mean arithmetic difference per serving in amounts reported was −0.17, indicating an overall slight tendency to under-report amounts of items actually eaten; the mean absolute difference per serving was 0.23. Mean amounts of omitted and intruded items per serving were 0.61 and 0.55, respectively. There were no statistically significant differences by gender or grade ($P > 0.05$).

Table 1 Mean (SD) frequencies for outcome variables comparing the Portuguese self-administered, computerised, 24-h dietary recall (PAC24) to lunch observations among children ages 7–10 (n = 41) by gender and school grade

Characteristic	*n* (%)	% Foods matched at food level (SD)*,†	% Foods omitted at food level (SD)*,‡	% Foods intruded at food level (SD)*,§	Total inaccuracy (in servings)*,¶	Arithmetic differences for matches (in servings)*,**	Absolute differences for matches (in servings)*,††	Amounts for omissions (in servings)*,‡‡	Amounts for intrusions (in servings)*,§§
Gender									
Boy	17 (41.5)	65.0 (27.1)	21.2 (23.8)	13.8 (11.6)	3.46 (2.72)	0.16 (0.14)	0.19 (0.17)	0.46 (0.48)	0.66 (0.51)
Girl	24 (58.5)	68.4 (18.9)	21.7 (16.8)	10.0 (12.4)	3.43 (2.05)	0.18 (0.25)	0.26 (0.20)	0.71 (0.43)	0.47 (0.52)
P-value		0.639¶¶	0.565***	0.219***	0.740***	0.796¶¶	0.210¶¶	0.075***	0.315***
Grade									
Second	12 (29.3)	69.7 (21.2)	18.7 (14.5)	11.7 (10.9)	2.76 (2.08)	0.11 (0.13)	0.16 (0.18)	0.67 (0.49)	0.58 (0.51)
Third	15 (36.6)	60.3 (27.3)	29.7 (24.9)	10 (12.9)	4.28 (2.79)	0.18 (0.27)	0.28 (0.18)	0.64 (0.41)	0.47 (0.52)
Fourth	14 (34.1)	71.9 (16.8)	15.1 (13.8)	13.1 (12.9)	3.13 (1.79)	0.21 (0.19)	0.24 (0.20)	0.52 (0.50)	0.61 (0.56)
P-value		0.350†††	0.248‡‡‡	0.586‡‡‡	0.163‡‡‡	0.450†††	0.252†††	0.254‡‡‡	0.554‡‡‡
Total	41 (100.0)	67.0 (22.4)	21.5 (19.5)	11.5 (12.1)	3.44 (2.32)	0.23 (0.19)	0.17 (0.21)	0.61 (0.46)	0.55 (0.52)

*A statistical weight was assigned to each item by meal component with combination entree = 2 and meal components = 1.

†% Foods matched at food level = [sum of weighted matches/(sum of weighted matches + sum of weighted omissions + sum of weighted intrusions)] × 100.

‡% Foods omitted at food level = [sum of weighted omissions/(sum of weighted matches + sum of weighted omissions + sum of weighted intrusions)] × 100.

§% Foods intruded at food level = [sum of weighted intrusions/(sum of weighted matches + sum of weighted omissions + sum of weighted intrusions)] × 100.

¶Total inaccuracy = (absolute difference between amounts reported and observed eaten for each match × statistical weight) + (each omitted amount × statistical weight) + (each intruded amount × statistical weight) summed over all items at school lunch for each child.

**Arithmetic differences for matches = {sum [(amount reported − amount observed for each match) × weight]}/(weighted number of matches).

††Absolute differences for matches = {sum [(absolute difference between amounts reported and observed for each match) × weight]}/(weighted number of matches).

‡‡Amounts for omissions = {sum [(amount observed but not reported for each omission) × weight]}/(weighted number of omissions).

§§Amounts for intrusions = {sum [(amount not observed but reported for each intrusion) × weight]}/(weighted number of intrusions).

¶¶*t*-test.

***Mann–Whitney *U*-test.

†††One-way analysis of variance.

‡‡‡Kruskal–Wallis test.

Table 2 Accuracy of estimates of intakes using the Portuguese self-administered, computerised, 24-h dietary recall (PAC24) compared to lunch observations among children ages 7–10 (n = 41)

Food categories	Mean ratio	Limits of agreement	
		Lower	Upper
Beverages	0.66	0.21	2.05
Cereals and potatoes	0.68	0.11	4.30
Fruit	0.47	0.10	2.28
Meat, fish and eggs	0.61	0.10	3.66
Milk products	1.23	0.59	2.58
Pulses	0.51	0.06	4.59
Sweet products	0.77	0.39	1.53
Vegetables	0.74	0.19	2.91

Use of the PAC24 led to underestimates of the weight of food on average by 32% of the actual intake. The limits of agreement for food consumption ranged from an under-estimation of 85% to an over-estimation of 218%. Accuracy of estimates of intake using the PAC24 were lower for the intake of pulses with wide limits of agreement (from an under-estimate of 94% to an over-estimate of 359%) (Table 2). Sweet products and vegetables were the most accurately estimated foods (Table 2).

Observers indicated some problems occurred in completing the PAC24. Younger children (second grade) experienced more difficulty in completing the PAC24 than third- and fourth-grade children. Other problems included: (i) instruction boxes were frequently ignored and sometimes children were unable to understand their meaning; (ii) misspelled search terms and more than one food item per line at the second stage resulted in search failures; (iii) in some cases, the food images shown at the third stage did not correspond to the food item written by the children at the second stage (e.g. children write mackerel and the image shown is salmon filets); (iv) unintentional clicking of buttons (e.g. instead of clicking on the 'back' button of the PAC24 to return to the previous page, some children clicked on the Internet 'back' button, which meant they had to start over again); (v) unable to understand what to do at a specific stage, particulary in the third stage regarding food type and portion sizes, and in the fourth stage where younger children were unable to give information about what time they ate the meals (Table 3).

Table 3 Problems and suggestions for simplifying and modifying the Portuguese self-administered, computerised, 24-h dietary recall (PAC24) among children ages 7–10 (n = 41)

Problems detected	Suggestions for simplifying (1) and modifying (2) PAC24
Instruction boxes were frequently ignored and sometimes children were unable to understand their meaning	(1) Give assistance to children
	(2) Replace the instruction boxes with an audio tutor and/or an interactive avatar explaining what to do before each specific stage
Misspelled search terms and more than one food item per line resulted in search failures	(1) Give assistance to children
	(2) Improve the spell check system by adding more misspellings of food names
Some food images did not correspond to the food item written by the children	(1) Give assistance to children
	(2) Increase the food images database
Unintentional clicking of buttons	(1) Give assistance to children
Some children were unable to understand what to do at specific stages	(1) Give assistance to children
	(2) Use an interactive avatar

Discussion

Use of the PAC24 attained a high match rate (67.0%) and a low level of intrusions (11.5%) and omissions (21.5%), although there was substantial variability, especially for omissions (±19.5%) and intrusions (±12.1%). Mean match values were somewhat higher than previously reported for FIRSSt (8–13-year-old children) (Baranowski *et al.*, 2002) and an early version of ASA24, both of which employed observation of school lunch as the criterion measure (Baranowski *et al.*, 2012a). Food items were scored as matches unless it was clear that the child's recall did not describe an observed food. This broad interpretation maximised the score correctness of the child's recall; this may contribute to the high match rate found in the present study. Although some studies have reported higher accuracy matches for girls (Baxter *et al.*, 2006), others did not (Baxter *et al.*, 2009b); in our sample, there were no statistically significant differences by gender or grade. Similar to our findings, other studies reported that sweets were frequently omitted (Vereecken *et al.*, 2008) and beverages were the most frequently intruded item at lunch (Smith *et al.*, 2008). Accuracy of estimates of intake using the PAC24 were lower for pulses because the food images for pulses often did not match the way in which pulses were served to children: pulses were mostly served with pasta or potatoes, and so it was very difficult for children to estimate the quantity of food served and left over.

Mean arithmetic differences for matches indicates a slight tendency overall to underreport amounts of items observed eaten (−0.17). This is similar to results from previous studies with fourth-graders (Baxter *et al.*, 2002, 2003, 2009b). When children failed to report items observed eaten, the average amount per omission was 0.61 servings and, when children falsely reported items that were not observed eaten, the average amount per intrusion was a half serving (0.55).

The weight of food was under-estimated by 32% on average using the PAC24 compared to lunch observations. Although wide limits of agreement were found in the present study (from an underestimation of 85% to an overestimation of 218%), Foster *et al.* (2013b) also showed wide limits of agreement ranging from an under-estimate of 41% to an over-estimate of 72%. These may reflect the small sample size and indicate that, on an individual level, considerable differences between both methods are possible. Other factors possibly contributing to the under-estimation of weight of food are that the food photographs in the PAC24 did not include some of the foods served at lunch in school canteens and/or the presentation of food on the plate was not the same. This happens because there are no national data available in Portugal regarding school-age children's food consumption and so we had to use food photographs from another country. We developed focus groups sessions in the seven regions of Portugal before developing the PAC24 to identify food items reported specifically by Portuguese school-age children. However, although this qualitative methodology enriched the food-items pool that was originally developed by a literature review and also identified some regional specific names attributed by children to some food items, it did not allow us to know how food was presented to children in the school canteens (e.g. the presentation of pulses and fish differs from the presentation in the food photographs). Thus, it might be difficult for children to estimate the quantity of food served and left over for some food items. Future research is necessary to adapt the PAC24 to include food photographs more appropriate for portuguese children.

Although no statistically significant differences were detected by grade, observers reported second-graders experienced more difficulty in completing the PAC24, than third-and fourth-grade children, perhaps as a result of their cognitive immaturity (Baxter, 2009), which was not assessed. Therefore, the children, especially the younger children, required assistance to complete the PAC24. The problems that observers detected in the PAC24 administration might be addressed by training nutritionists to assist the children. In the present validation study, a single nutritionist was able to provide assistance in completion of the PAC24 for up to 10 children.

The limitations of the present study include the small sample size ($n = 41$), primarily because of the limited time and financial support to collect data; the sample of children was limited to the Lisbon region, reflecting local and regional educational and food practices. It is not clear how these procedures may work in other cities or regions.

Success in using the tool with this population suggests its usefulness with similar populations; however, the tool must be validated for use in each specific population to analyse differences in the accuracy of dietary reporting by socioeconomic and racial/ethnic groups among children. To redress the problems detected, and to improve accuracy of the PAC24, system improvements need to be made, including: (i) replacing the instructions boxes by an audio tutor and/or an avatar to guide the user through the system; (ii) increasing the food image database; and (iii) developing and testing additional prompts based on data on the types of foods that were more frequently omitted during this validation study. Further validation research, usability testing and experience will also direct future development.

The PAC24 requires less professional labour than other interview-administered methods. In the present study, conducted in a small sample of children, the PAC24 was found to have a higher validity compared to lunch observations than comparable tools reported in the literature. Children were able to complete the PAC24, although most required assistance. Future research will need to determine how to adapt and simplify the PAC24 to better meet children's abilities and preferences.

Acknowledgments

The authors thank Ana Lúcia Silva, Sofia Tomás, Emília Alves, Marisa Costa and Rita Garcia for their assistance in the development of the field work. We especially thank the schools and children who participated in the study.

Conflict of interests, source of funding and authorship

The authors declare that they have no conflicts of interest.
No funding declared.
MAC conceived and designed the study, analysed and interpreted the data, and drafted and wrote the manuscript. All authors critically reviewed the manuscript and approved the final version submitted for publication.

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Appendix III:

Parent Inform Consent used for the accuracy study of PAC24

Universidade de Lisboa
Faculdade de Medicina
Grande Oficial da Ordem de S. Tiago de Espada

Instituto de Medicina Preventiva
(Director: Prof. Doutor J. Pereira Miguel)

Lisboa, 20 de Maio de 2013

Assunto: Pedido de autorização para participação no estudo *"Consumo alimentar de crianças portuguesas em idade escolar: desenvolvimento e ensaio de um novo instrumento de avaliação"*.

Estimado(a) Encarregado(a) de Educação,

O Projeto "Consumo alimentar de crianças portuguesas em idade escolar: desenvolvimento e ensaio de um novo instrumento de avaliação" é um projeto de doutoramento que está a ser desenvolvido no Instituto de Medicina Preventiva da Faculdade de Medicina da Universidade de Lisboa (FMUL). Este projeto tem como objetivo principal desenvolver, validar e ensaiar um questionário *online* de avaliação do consumo alimentar em crianças Portuguesas do 1º ciclo do Ensino Básico. O projeto obteve o consentimento favorável da Comissão de Ética da FMUL.

Durante a primeira fase do projeto foram seleccionados os itens alimentares que compreendem o questionário, através de uma revisão da bibliografia e da realização de sessões de focus groups com crianças nas sete regiões de Portugal (NUTS II). Posteriormente, o questionário foi desenvolvido, tendo sido validado por um painel de peritos em Fevereiro de 2013 e testada a sua utilização em crianças durante o mês de Abril de 2013.

Neste momento, vamos iniciar o estudo da validade do questionário em epígrafe e neste contexto, a escola que a sua criança frequenta foi uma das escolas seleccionadas para o estudo. Assim, vimos por este meio pedir-lhe autorização para que o/a seu/sua filho/a participe no estudo. Nesta etapa, que irá decorrer no período de 28 de Maio a 14 de Junho de 2013, iremos observar o que o/a seu/sua filho/a consome durante o almoço escolar e posteriormente iremos solicitar o preenchimento do questionário *online*. Esta fase do estudo vai incluir outros colegas de escola do/a seu/sua filho/a. O anonimato das informações recolhidas será assegurado, sendo os dados recolhidos utilizados apenas no contexto deste estudo, não sendo acessíveis a pessoas que não pertençam à equipa de investigação.

Caso concorde com a participação do/a seu/sua filho/a no estudo, agradecemos que nos devolva a folha anexa a esta carta, devidamente assinada.

A sua colaboração é fundamental para o sucesso deste projeto! O/a seu/sua filho/a não poderá participar no estudo sem a sua autorização. Para quaisquer esclarecimentos adicionais, pode contactar-me, enquanto responsável principal pelo projeto de investigação (mariaanacarvalho@gmail.com).

Desde já agradecida e com os melhores cumprimentos,

Maria Ana Carvalho

Maria Ana Carvalho
(Investigadora Principal do Projeto)

Universidade de Lisboa
Faculdade de Medicina
Grande Oficial da Ordem de S. Tiago de Espada

Instituto de Medicina Preventiva
(Director: Prof. Doutor J. Pereira Miguel)

Consentimento Informado

Nome do Encarregado de Educação:

_____

Nome da Criança:

_____

Data de Nascimento da Criança: _____/_____/_____

Código-Postal da Residência: _____:_____

Freguesia: _____ Cidade/Localidade: _____

Ano de Escolaridade da Criança: _____

Na qualidade de Encarregado de Educação, tendo lido e compreendido os objetivos do Projeto de Avaliação do Consumo Alimentar em Crianças Portuguesas em Idade Escolar, autorizo o/a meu/minha filho/a a participar neste projeto e que os dados recolhidos sejam utilizados apenas e exclusivamente no contexto do estudo.

Assinatura do Encarregado de Educação

_____

Appendix IV:

Lunch Observation Record Sheet used in the accuracy study of PAC24

Nome do Observador:

Data da observação (dd/mm/aaaa):

Código da Criança:

Ano de Escolaridade:

Alimentos servidos ao almoço	**1) Presença no tabuleiro/prato (assinale com um X)**		**2) Quantidade servida no prato**			**3) A criança deu alimentos a um colega?**		**4) A criança recebeu alimentos de um colega?**		**5) Quantidade deixada no prato**	**6) A criança repetiu? (assinale com um X)**	
	Sim	**Não**	**porção caseira***	**nº de porções****	**g/ml*****	**Quais? (assinale com um X)**	**Quantidade estimada**	**Quais? (assinale com um X)**	**Quantidade estimada**	**g/ml*****	**Sim (se sim repetir perguntas de 1 a 5)**	**Não**
Creme de cenoura e couve ripada												
Granadeiro de tomatada												
Arroz branco												
Salada de alface												
Salada de frutas												
Água												
Outros alimentos (especifique por favor nas linhas abaixo):												

*concha de sopa, colher de servir, colher de sopa, colher de sobremesa; **1/2;1;1+1/2;2;2+1/2; etc; ***pesar em balança (retirar tara)