Year : 2018

Dietary intake and nutritional status in Switzerland: a population perspective

Chatelan Angeline

UNIL | Université de Lausanne
Faculté de biologie
et de médecine

Institute of Social and Preventive Medicine (IUMSP)

Dietary intake and nutritional status in Switzerland: a population perspective

Thesis of Doctorate in Life Sciences (PhD)

Presented at the

Faculty of Biology and Medicine
of the University of Lausanne

by

Angéline CHATELAN

Registered Dietitian, University of Applied Sciences, Geneva, Switzerland
Master of Science in Public Health Nutrition, University of Southampton, United Kingdom

Jury

Thesis supervisor:	Prof. Murielle BOCHUD
President:	Prof. Jean-Pierre HORNUNG
Expert:	Prof. Olivier BONNY
Expert:	Prof. Sabine ROHRMANN

Lausanne 2018

UNIL | Université de Lausanne
Faculté de biologie
et de médecine

Institut Universitaire de Médecine Sociale et Préventive (IUMSP)

Apports alimentaires et statut nutritionnel en Suisse: une perspective populationnelle

Thèse de doctorat ès sciences de la vie (PhD)

présentée à la

Faculté de biologie et de médecine
de l'Université de Lausanne

par

Angéline CHATELAN

Diététicienne diplômée HES, Haute école de santé Genève
Master of Science en santé publique nutrition, Université de Southampton, Grande-Bretagne

Jury

Directrice de thèse:	Prof. Murielle BOCHUD
Président:	Prof. Jean-Pierre HORNUNG
Expert:	Prof. Olivier BONNY
Experte:	Prof. Sabine ROHRMANN

Lausanne 2018

UNIL | Université de Lausanne
Faculté de biologie
et de médecine

Ecole Doctorale
Doctorat ès sciences de la vie

Imprimatur

Vu le rapport présenté par le jury d'examen, composé de

Président·e	Monsieur	Prof.	Jean-Pierre	**Hornung**
Directeur·rice de thèse	Madame	Prof.	Murielle	**Bochud**
Experts·es	Monsieur	Prof.	Olivier	**Bonny**
	Madame	Dre	Sabine	**Rohrmann**

le Conseil de Faculté autorise l'impression de la thèse de

Madame Angéline Chatelan

Msc in Public Health Nutrition University of Southampton, Royaume-Uni

intitulée

Dietary intake and nutritional status in Switzerland: a population perspective

Lausanne, le 8 mars 2019

pour le Doyen
de la Faculté de biologie et de médecine

Prof. Jean-Pierre Hornung

Remark

The PhD lasted for three years (from February 2016 to March 2019). Before that, the PhD student took part in the data collection of the first national nutrition survey, menuCH.

This thesis was completed as part of the PhD Program in Public Health from the Swiss School of Public Health (SSPH+; www.ssphplus-phd.ch).

The PhD thesis was funded by the Federal Food Safety and Veterinary Office. They financed the PhD in exchange of specific analyses of menuCH data, and of recommendations for the next national nutrition survey after conducting a feasibility study among children.

Affiliations of the Jury

Prof. Murielle Bochud	Institute of Social and Preventive Medicine (IUMSP), University of Lausanne (UNIL), Lausanne, Switzerland.
Prof. Jean-Pierre Hornung	Faculty of Biology and Medicine, University of Lausanne (UNIL), Lausanne, Switzerland.
Prof. Olivier Bonny	Nephrology Unit, Lausanne University Hospital (CHUV), University of Lausanne (UNIL), Lausanne, Switzerland.
Prof. Sabine Rohrmann	Epidemiology, Biostatistics and Prevention Institute, University of Zürich, Zürich, Switzerland.

'It is better to be healthy than ill or dead. That is the beginning and the end of the only real argument for preventive medicine. It is sufficient.'

Geoffrey Rose

'Health and health inequalities tell us a great deal about the good and bad effects of social policies.'

Michael Marmot

Acknowledgements

For the last three years I have worked with passion on this thesis thanks to all who have guided and supported me. Of whom some I would like to thank in particular.

I thank my supervisor, Murielle Bochud, for her expertise, trust, and support. Her dedication and knowledge is an inspiration to me.

My gratitude also goes to Kate Frohlich for her invitation at the University of Montreal. Her support and teaching was very insightful to me. I thank Arnaud Chioléro and Magali Leyvraz for giving me the opportunity to work on a systematic review with them.

I am thankful to my colleagues, especially Sandrine Estoppey, Cristian Carmeli, Dusan Petrovic, Saman Khalatbari-Soltani, Fabiën Belle, Carlos de Mestral, Yara Barrense-Dias, Sina Rüeger, Silvia Stringhini, Christina Akré, Alex Randriamiharisoa, Juan-Manuel Blanco, and Pascal Bovet, for making every day a resourceful and delightful place to work.

I am grateful to the Federal Food Safety and Veterinary Office for funding my PhD and giving me the opportunity to pursue research on data of the first national nutrition survey.

I would like to thank all the co-authors of the papers.

Finally and most importantly, I thank my parents, Fabienne and Bernard, my partner, Sylvain, and my closest friends, Marion and Marie, for believing in me, supporting me, and acknowledging my career choices despite their relative inconveniences!

Summary

Nutrition is a major modifiable determinant of health. National nutrition surveys are essential tools to monitor the population nutritional status and guide nutrition policies. Switzerland conducted its first national survey, menuCH, in 2014-2015. A total of 2 086 Swiss residents aged 18 to 75 years old were interviewed and their diet assessed using two 24-hour dietary recalls. This thesis aimed at 1) describing dietary intake of Swiss adult population using menuCH data, and 2) developing recommendations for the next national nutrition surveys and future nutrition policies.

menuCH data indicated that the vast majority of the Swiss adult population poorly adhered to the national dietary guidelines. The population consumed insufficient plant-based products, and excessive ultra-processed and/or animal-based foods. Moreover, food consumption patterns substantially differed between the German, French and Italian-speaking parts of Switzerland. Finally, we showed that regularly consuming a breakfast rich in fruit, unsweetened cereal flakes, nuts and yogurt was associated with reduced abdominal obesity.

Since menuCH did not survey children nor collect bio-samples, we tested child-specific dietary assessment methods and evaluated acceptability of bio-sample collection in a feasibility study to prepare the next national nutrition survey. We recruited a population-based sample of 53 children aged 3 to 17 years in Lausanne. The developed dietary assessment tools (*e.g.*, 24-hour food diary, food questionnaire) were well accepted by participants and their caregiver(s). Compliance with the collection of spot urine, venous and capillary blood, and toenails was high in the different age groups.

As shown above, dietary behaviours in Switzerland are not optimal. Classically, public health can propose two types of interventions to improve the situation: 1) provide information to encourage behavioural modifications (individual level), or 2) change the environment to reduce exposition (population level). I wrote an essay about a novel instrument designed to improve diet, *i.e.,* precision nutrition. I concluded that providing personalized advice at a large scale via smartphones (individual level) might have a limited effect on dietary behaviours and obesity, if environments promoting unhealthy food are not modified in parallel (population level).

We have shown that Switzerland needs public health interventions to improve dietary behaviours. We suggest that these interventions target in priority the food environments to facilitate access to healthy foods. Furthermore, the next national nutrition surveys should include children, strengthen dietary assessment methods, and collect bio-samples for relying on objective nutritional biomarkers. We believe that this will improve the assessment of dietary intake and nutritional status at both individual and population levels to further fine-tune national dietary guidelines and guide future nutrition policies.

Résumé

L’alimentation joue un rôle majeur dans la promotion de la santé. Les enquêtes nationales sur l’alimentation sont des outils indispensables pour surveiller l’état nutritionnel de la population et orienter les politiques nutritionnelles. La Suisse a mené sa première enquête nationale, menuCH, en 2014-5. L’alimentation de 2 086 personnes âgées de 18 à 75 ans a été évaluée à l'aide de deux rappels de 24h. Cette thèse visait à décrire les apports alimentaires de la population adulte suisse grâce aux données menuCH, et à élaborer des recommandations pour les prochaines enquêtes nationales ainsi que pour les futures politiques nutritionnelles.

Les données menuCH ont montré que la grande majorité de la population adulte suisse ne respectait pas les recommandations alimentaires. La population consommait une quantité insuffisante de produits d’origine végétale et un excès d’aliments ultra-transformés et/ou d'origine animale. De plus, les habitudes alimentaires différaient considérablement entre la Suisse alémanique, romande et italienne. Enfin, nous avons constaté que la consommation régulière d’un petit-déjeuner riche en fruits, flocons de céréales non sucrés, oléagineux et en yogourt était associée à une réduction de l’obésité abdominale.

Puisque menuCH n'a pas interrogé d’enfants ni prélevé d’échantillons biologiques, nous avons testé des méthodes spécifiques aux enfants et évalué l'acceptabilité de la collecte d’échantillons biologiques lors d'une étude de faisabilité afin de préparer la prochaine enquête. Nous avons recruté 53 enfants issus de la population lausannoise (3 à 17 ans). Les outils de recueil alimentaire (p.ex. carnet alimentaire de 24h) ont été bien acceptés par les participants. L’acceptabilité à la récolte d'urine (spot), de sang veineux et capillaire et d'ongles était élevée.

Comme indiqué, l’alimentation des Suisses n’est pas idéale. La santé publique peut proposer deux types d’interventions pour y remédier: fournir de l’information pour améliorer les comportements (niveau individuel) ou modifier l'environnement pour réduire l'exposition (niveau populationnel). J’ai rédigé un essai sur un nouvel instrument conçu pour améliorer les habitudes alimentaires: la nutrition de précision. J’ai conclu que donner des conseils personnalisés à grande échelle via des smartphones (individuel) aurait probablement un effet limité sur l'épidémie d'obésité, si l’environnement promouvant une alimentation peu équilibrée n’était pas modifié en parallèle (populationnel).

Cette thèse montre que des interventions pour améliorer l’alimentation sont nécessaires en Suisse. Nous suggérons que ces interventions ciblent en priorité l’environnement alimentaire. En outre, les prochaines enquêtes nationales sur l’alimentation devraient inclure les enfants, renforcer les méthodes de recueil alimentaire et collecter des échantillons biologiques pour avoir des biomarqueurs nutritionnels objectifs. Nous pensons que ceci améliorera l'évaluation de l’état nutritionnel tant des individus que de la population, afin d'affiner les recommandations alimentaires nationales ainsi que d'orienter les futures politiques nutritionnelles.

Glossary

Biomarker	A characteristic that is objectively measured and evaluated as an indicator of normal or pathogenic biological processes.
Bio-sample	Biological material (*e.g.*, tissue, blood or urine) taken from a study participant or patient at a specific time.
Diet	Foods usually eaten or drunk by a person.
Diet history	A retrospective structured interview to capture detailed information on habitual food intake or food intake at a specific life stage/time period.
Food	Solid and liquid nourishing material/substances that people eat to sustain life, provide energy, promote growth, *etc*.
Food consumption occasion	Moment in the day when foods and/or beverages are consumed. Synonym of meals and snacks.
Imbalanced diet	Diet poor in fruits, nuts, seeds, beans, vegetables, whole grains, plant oils, yogurt, fish and rich in ultra-processed foods, sugar, trans-fat and sodium. Synonym of unhealthy eating.
Malnutrition	Inadequate nutritional status of any forms: over-nutrition/consumption, under-nutrition or micronutrient deficiencies.
menuCH	First national nutrition survey in Switzerland.
Nutrient	A molecule the human body needs to acquire from food to make energy, grow, develop, and reproduce. Macronutrients are consumed in relatively large quantities and include proteins, carbohydrates, fats, fibres and water. Micronutrients - vitamins and minerals - are consumed in relatively smaller quantities, but are essential to body processes.
Nutrition	Intake of foods and nutrients considered in relation to the body’s dietary requirements.
Nutrition policy	Decisions and actions that are undertaken to achieve specific nutrition goals within a population.
Precision nutrition	Tailored nutritional dietary advice based on individuals’ dietary behaviours and individuals’ biomarkers, including genetics. Sometimes used as a synonym of personalized nutrition.

List of abbreviations

24HDR	24-Hour Dietary Recall
BMI	Body Mass Index
BUAS	Bern University of Applied Sciences
CATI	Computer-Assisted Telephone Interview
CER-VD	‘Commission cantonale d'Ethique de la Recherche sur l'être humain du canton de Vaud’, Cantonal Ethics Committee of Vaud
CHUV	‘Centre Hospitalier Universitaire Vaudois’, Lausanne University Hospital
CTU	Clinical Trial Unit in Lausanne University Hospital
EFSA	European Food Safety Authority
EPIC	European Prospective Investigation into Cancer and Nutrition
FFQ	Food Frequency Questionnaire
FPQ	Food Propensity Questionnaire
FOPH	Federal Office for Public Health (OFSP in French or BAG in German)
FSO	Federal Statistical Office (OFS in French or BFS in German)
FSVO	Federal Food Safety and Veterinary Office (OSAV in French or BLV in German)
GD	GloboDiet®
IARC	International Agency for Research on Cancer
IPAQ	International Physical Activity Questionnaire
ISPM	Institute of Social and Preventive Medicine in Bern
IUMSP	Institute of Social and Preventive Medicine in Lausanne
MET-min	Metabolic Equivalent of Task minutes per week
MSM	Multiple Source Method
NCD	Non-Communicable Disease
NHANES	National Health And Nutrition Examination Survey
PCA	Principal Component Analysis

PN	Precision Nutrition
SES	Socio-Economic Status
SPADE	Statistical Program to Assess Dietary Exposure
SVI	Swiss Vitamin Institute
T	Tertile
U.S.	United States
WC	Waist Circumference
WHtR	Waist-to-Height Ratio
WHO	World Health Organization
WHR	Waist-to-Hip Ratio

Table of content

1. Introduction

1.1. Why do diet and nutrition matter?

1.1.1. Global nutrition crisis

Today the world faces a nutrition crisis [1]. Eighty-eight per cent of countries experience the double or triple burden of malnutrition [2-4]. Over-nutrition/consumption, under-nutrition and micronutrient deficiencies coexist within the same populations, households, and individuals across the life course or even simultaneously [3]. Globally obesity has almost tripled since 1975 [5]: in 2018 about 2.3 billion children and adults are overweight or obese (*i.e.,* nearly one in three) [5]. At the same time, the Food and Agriculture Organization estimates that 815 million people in the world (*i.e.,* one in nine) are chronically undernourished [6]. Finally, two billion people are estimated to be deficient in key vitamins and minerals, in particular iron, zinc, vitamin A, and iodine [2]. **Figure 1** summarizes the nutritional situation among children under five in the world: 25% are stunted, 8% wasted, and 6% overweight or obese [7].

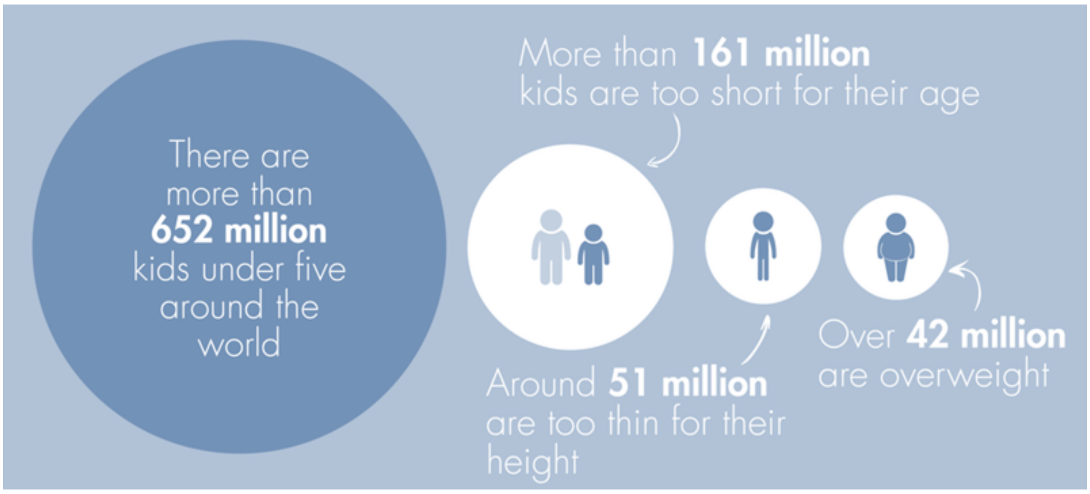


Figure 1. Overview of worldwide malnutrition in children under five in 2015 (adapted from [7]).

Nutrition is a major concern for public health but also for social and economic development, environment/ecology and geopolitics due to its close interplay with agriculture, water and land use, climate change, sustainability, and food systems. The latter play a substantial and complex role on diet quantity and quality.

In response to this global nutrition crisis, the United Nations launched the Decade of Action on Nutrition 2016-2025 [8]. Member States committed to undertake ten years of comprehensive, sustained and coherent implementation of policies and programmes and enlarged investments to eradicate all forms of malnutrition [8]. Commitments relate to strengthening nutrition governance and accountability, and increasing investments for nutrition education, sustainable food systems and food environments promoting healthy eating [8].

1.1.2. A major determinant of health

Nutrition is a major determinant of health. According to the 2016 Global Burden of Disease, child and maternal malnutrition (*i.e.,* under-nutrition and micronutrient deficiencies) and an imbalanced diet are the two world leading risk factors for morbidity and mortality. They account for 11.5%, and 9.6% of all disability-adjusted life-year (DALYs), respectively [9]. In high-income countries, including Switzerland, where non-communicable diseases (NCD) are responsible for nine in ten deaths [10-12] and for large costs [13, 14], an imbalanced diet is the second risk factor, after tobacco [9]. Unhealthy eating increases in particular the risk of cancer, cardiovascular disease, diabetes mellitus, and obesity, as summarized in **Table 1** [9, 15-17].

Table 1. Health consequences of an imbalanced diet (x = strong and consistent evidence of a causal relationship according to [9, 15-17]).

		Cancer	**Cardiovascular disease**	**Type 2 diabetes**	**Obesity**
Foods	Diet low in fruits	x (several sites)	x (ischemic heart disease and stroke)	x	
	Diet low in vegetables	x (oesophagi)	x (ischemic heart disease and stroke)	x	
	Diet low in legumes		x (ischemic heart disease)		
	Diet low in whole grains	x (colon and rectum)	x (ischemic heart disease and stroke)	x	x
	Diet low in nuts and seeds		x (ischemic heart disease and stroke)	x	
	Diet low in dairy products	x (colon and rectum)[1]	x (stroke)	x (only yogurt)	
	Diet high in red meat	x (colon and rectum)	x (stroke)	x	
	Diet high in processed meat	x (colon and rectum)	x (ischemic heart disease)	x	
	Diet high in sugar-sweetened beverages		x (ischemic heart disease)		x

		Cancer	Cardiovascular disease	Type 2 diabetes	Obesity
Nutrients	Diet high in calories				x
	Diet low in fibre	x (colon and rectum)	x (ischemic heart disease)		
	Diet low in calcium	x (colon and rectum)			
	Diet low in fish and seafood omega 3 fatty acids		x (ischemic heart disease)		
	Diet low in poly-unsaturated fatty acids		x (ischemic heart disease and stroke)		
	Diet high in trans fatty acids		x (ischemic heart disease)		
	Diet low in mono-unsaturated fat		x (stroke)		
	Diet high in sodium	x (stomach)	x (hypertension, ischemic heart disease and stroke)		
	Diet low in potassium		x (hypertension, stroke)		
	Diet with high glycaemic index/load	x (endometrial)	x (ischemic heart disease and stroke)	x	
	Diet high in ultra-processed/fast food				x

[1] *Consumption of dairy products might increase the risk of prostate cancer [15].*

1.2. Developing dietary guidelines and nutrition policies

Since diet is modifiable, most countries have generated dietary guidelines to inform their population about the optimal diet and to guide policies aiming at reducing the different forms of malnutrition. Dietary guidelines have evolved over time. The first guidelines in the 1940s were nutrient-based and intended to address the risk of vitamin and mineral deficiencies. After 1970s, guidelines were still mainly nutrient-based but aimed at reducing NCD [18].

Since 2000s, advances in nutritional epidemiological research and corresponding new evidence have suggested food-based dietary guidelines. National recommendations and guides, such as MyPlate in the United States [19] or the Food Pyramid in Switzerland [20, 21], are now oriented towards food groups (*e.g.*,'5 portions of fruit and vegetable a day') and dietary patterns (*e.g.*, Mediterranean diet) [18, 22, 23]. Dietary guidelines emphasis has gradually shifted from diet quantity to diet quality and sustainability [18, 22]. In 2018, Mozaffarian and Forouhi stated that there is a consensus on general dietary priorities for cardio-metabolic health. It could be summarized as follows: ‘Eat minimally processed, bioactive rich foods (fruits, nuts, seeds, beans, vegetables, whole grains, plant oils, yogurt, fish) and avoid ultra-processed foods rich in refined starch sugars, and industrial additives such as trans-fat and sodium’ [24].

To develop dietary guidelines and nutrition policies, countries review the available evidence from nutritional epidemiology [25, 26]. Countries also consider the domestic context, such as traditionally consumed foods, local food systems, main public health concerns, socio-economic and political contexts, *etc*. [20, 22, 25]. Thus, countries greatly rely on international nutrition research and their national nutrition surveys.

1.3. Nutrition as a research challenge

Despite advances in nutrition science, nutritional epidemiology suffers from controversies and challenges [24, 27-29]. The main concerns are as follows:

- Precise assessment of individuals' food and nutrient intake is technically difficult, especially in the long-term, and data are often based on self-reported information from food frequency questionnaires (FFQ) or 24-hour dietary recalls (24HDR) [30, 31].
- Scientific evidence relies mainly on observational studies with complementary evidence from short-term experimental studies [24, 27, 32],
- Vested interests, coming from both food industry and researchers themselves (*i.e.,* white hat bias), have led to biased research and has greatly influenced messages to the public [24, 28, 33-35].

Whereas vested interests could be tackled with more transparency in research and public messaging, the problem of over-reliance on observational studies is difficult to overcome. Indeed, long-term randomized control trials are attractive [27] but complex to conduct, if not unfeasible [24]. First, blinding is impossible, except with vitamin and mineral supplements. Second, long-term adherence to an unfamiliar controlled diet is hard, even more in large samples from the general population. This increases the risk of attrition bias. Third, the interventions are complex to design: Which foods and/or nutrients should be changed in the intervention group? Does the intervention affect total energy intake or other food or nutrient intake? Which dose(s) should be prescribed? Finally, trials would have to be long enough to reliably detect effects on diseases, and therefore expensive and probably unethical if new science supersedes the tested intervention by the time the trial is completed [24]. The next chapter presents the different dietary assessment methods and a potential way to overcome their limitations with objective nutritional biomarkers.

1.3.1. Dietary assessment methods

There are three traditional methods to measure dietary intake: *i.e.,* food questionnaires, 24-hour dietary recalls (24HDR) and food diaries/records. All have strengths and limitations as shown in **Table 2** [36-40].

Table 2. Traditional dietary assessment tools, their strengths and limitations [36-40].

Tool	Food questionnaire	24-hour dietary recall	Food diaries/records
Method	Self-administered retrospective questionnaire based on a food list to assess usual diet over a reference period (month/year). Food Propensity Questionnaire (FPQ) assesses consumption frequency [37, 38]. Food Frequency Questionnaire (FFQ) assesses frequency and portion sizes (semi-quantitative).	In-depth interview by a trained interviewer to assess in detail everything the participant has eaten over the past 24 hours (previous day).	Prospective food diary in which participant records food and beverages consumed at the time of consumption for several days, usually 3 to 7 days. Portion sizes can be estimated or weighted (scale provided to participants).
Strengths	• Low participant burden. • Captures usual intake and foods not consumed on a regular basis. • Relative low costs, computerized processing. • Useful to repeat dietary assessment over a number of years.	• Captures diet in detail (*e.g.*, cooking methods, use of fats and oils, meal patterns, *etc.*). • Participant does not know moment of recall, less prone for altering eating behaviour. • Sensitive to ethnicity-specific eating behaviours. • Suits erratic lifestyle habits (eating outside home).	• Does not require recall. • Captures diet in detail (*e.g.,* cooking methods, use of fats and oils, meal patterns, *etc.*). • Suits erratic lifestyle habits (eating outside home). • Precise portion sizes (weighted food diaries).
Limitations	• Reported intake is limited to the foods items in the list. • Requires literacy and numeracy of participant. • Population specific. • Estimated portion sizes. • Misreporting. • Recall bias.	• Requires well-trained interviewers. • Single recall gives poor individual measurement. • Irregular eaten food are not well captured. • Expensive. • Misreporting. • Recall bias.	• High participant burden. • Non-response bias. • Requires literacy, numeracy, and motivation of participant. • Erratic lifestyle habits can be difficult with weighing and recording away from home. • Irregular eaten food are not well captured. • Expensive. • Misreporting.

Traditional dietary assessment methods can integrate novel digital technologies. For example, dietary information can be collected with a smartphone application via online food questionnaire [41], electronic food diary [42], which can be complemented with digital photography of consumed foods and beverages [43]. The main benefits of these novel methods are threefold: 1) increasing standardisation and quality of assessment in an attempt to limit errors of participant/interviewer (*e.g.,* better portion size estimation), and 2) reducing burden related to data collection and entry, and therefore 3) decreasing costs [39, 40, 43, 44]. However, these technology-assisted dietary assessment methods cannot overcome the recurring problems of 1) non-response bias in relation to the complex tasks of comprehensive reporting, 2) misreporting in relation to social desirability bias, and 3) recall bias (*i.e.,* forgetting entering a snack or taking pictures) [39, 40, 43, 44]. In addition, they have their own drawbacks, such as need for Internet access and computer literacy, and high development costs [39, 40, 43, 44].

1.3.2. Nutritional biomarkers

Biomarkers represent core objective indicators of diet and nutrition [45]. Biomarkers can be classified in two main categories: recovery and concentration biomarkers [39]. Recovery biomarkers are mainly used as reference measures to validate and calibrate self-reported intakes thanks to their strong dose-response relationship with intakes [39, 46]. There are only a few known recovery biomarkers: *e.g.,* urinary potassium and nitrogen to estimate total daily potassium or protein intake, respectively. Concentration biomarkers correlate with dietary intake, but are affected by metabolism and personal characteristics such as age, gender, and/or obesity [39, 47]. Concentration biomarkers can be used in studies assessing the relationship between tissue concentrations and health outcomes (*e.g.*, serum vitamin D and osteoporosis, fatty acids measured in adipose tissue and cardiovascular disease). In that sense, they are proxies for assessing nutritional status [39, 48].

Biomarkers ease and enrich the interpretation of dietary intake data [47, 49-51], even if a lot remains to be done to understand and define the optimal set of biomarkers for assessing dietary intake (in particular overall dietary patterns) and nutritional status, especially in children and adolescents. Biomarkers have also their own limitations. They can be expensive to measure and are often less well accepted by the general free-living population, leading to non-response bias. Finally, biomarkers can be influenced by poor manipulation in the collection, storage, and/or laboratory analyses of bio-samples.

Nowadays, there is growing interest in metabolomics, coupled with bioinformatics and pathway analysis as well as computational modelling, to identify novel dietary biomarkers [50, 52-54]. Metabolomics aims to identify and quantify small metabolites in biological samples: plasma, urine, skin cells, hair, *etc*. [52]. Metabolomics-based approaches have identified markers of single food intake including salmon, broccoli, wholegrain wheat cereal, raspberry [55], cruciferous vegetables [56], citrus fruits [57], coffee [58, 59], sugar-sweetened beverages [60], red onions [61] and meat [62]. Metabolomics profiling has also been used to classify individuals into dietary patterns in observational studies [53, 63] or assess compliance to dietary intervention in clinical trials [64, 65]. Finally, this methodology may help elucidate mechanistic pathways linking diet to chronic disease risk [53, 54, 66]. However, further research (*e.g.,* molecule identification, standardization of laboratory analyses) is needed before using metabolomics data as standard dietary assessment tools in nutrition research.

1.4. National nutrition surveys

1.4.1. Conceptual framework

National nutrition surveys have three purposes in public health as shown in **Figure 2**: 1) population monitoring and surveillance, 2) epidemiological research, and 3) policy-making.

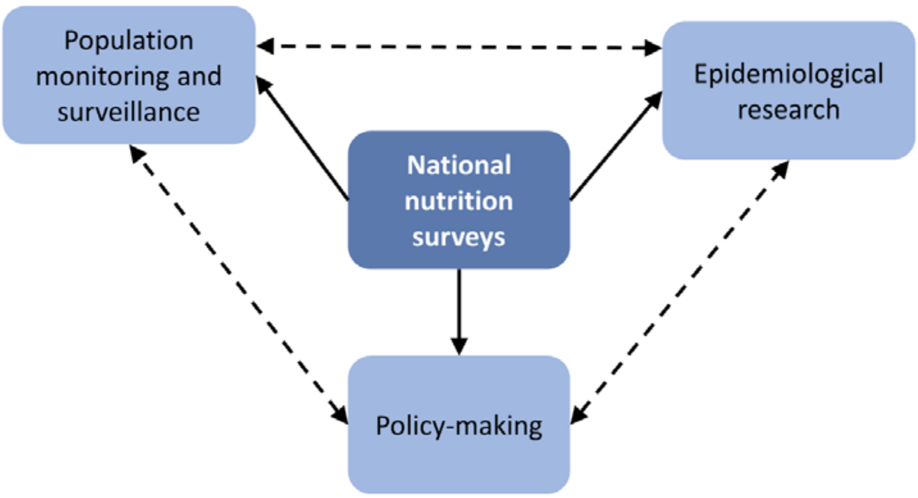


Figure 2. Conceptual framework: the three main purposes of national nutrition surveys in public health.

First, they estimate food and nutrient intakes to assess nutritional status at the population level: they are essential tools for food and nutrition monitoring and surveillance in the country [67]. They allow determination of what, where, when and how much people eat in order to identify the groups of individuals who are the most vulnerable to unhealthy diet (*i.e.,* descriptive epidemiology) [68, 69]. Second, national nutrition surveys provide data for nutritional epidemiology research, studying the relations between diet and health/disease. In complement with other observational (*e.g.*, prospective cohorts) and experimental studies (*e.g.*, randomized controlled trials), they provide insights into the optimal dietary intake and potential solutions to improve population diet (*i.e.,* analytical epidemiology). Third, results from national nutrition surveys are part of scientific evidence for the establishment of policies and strategies because they inform about the overall nutritional situation and main dietary risks in the country. Finally, periodically conducting these surveys allow assessing the evolution in food and nutrition intake over time and therefore evaluate the impact of the different implemented policies in the population (*i.e.,* evaluative epidemiology) [68, 70].

Of note, national nutrition surveys are also important tools in public health for food safety and biomonitoring. They allow estimating population exposure to beneficial or harmful diet-related substances or toxics, and therefore evaluate the risk of contamination. Biomarkers are also essential tools for chemical exposure risk assessments [71, 72]. However, in this thesis, we will focus mainly on the importance of national nutrition surveys for nutrition purposes.

1.4.2. Design and methodology used in other high-income countries

In 2009 and later in 2014, the European Food Safety Authority (EFSA) provided recommendations on how to collect food consumption information at the national level [73, 74]. It is the reference document in Europe for conducting national nutrition surveys and harmonising design and methodology across countries. EFSA recommends measuring dietary intake on two non-consecutive days, using software with a multiple-pass method. In adults, 24HDR can be part of a personal or phone interview. For children aged 3 months to 9 years (possibly up to 15 years), EFSA suggests using 24-hour food diaries, followed by face-to-face or phone interview. These food consumption data should be complemented with measured height and weight, and a targeted food questionnaire, such as a FPQ. EFSA provides no recommendations for the collection of bio-samples and the analyses of specific nutritional biomarkers. **Table 3** provides an overview of the different designs and methods used for national nutrition surveys in seven high-income countries. All presented countries had completed at least one national nutrition survey, and all, except Germany, included children in the same survey.

Table 3. Overview of national nutrition surveys in seven high-income countries.

Country	Latest survey	Year	Participants	Dietary assessment	Biomarkers	Others measures
USA [75, 76]	What We Eat in America (WWEA), part of National Health and Nutrition Examination Survey (NHANES)	Since 2001 (continuous program)	All ages (N=about 5000/year)	24HDR: 2 non-consecutive days (1st in the mobile examination centre, 2nd by phone)	Blood and spot urine collection	• General questionnaire • Measured height, weight and weight history • Use of dietary supplements • Oral glucose test and several other tests
Canada [77]	Canadian Community Health Survey (CCHS) - Nutrition	2015	Aged >1y (N=20 487)	24HDR: 1-2 non-consecutive days (1st at home, 2nd by phone in a subsample)	No biomarkers taken	• General questionnaire • Measured height and weight • Use of dietary supplements
UK [78]	National Diet and Nutrition Survey (NDNS)	Since 2008 (continuous program)	Aged >1.5y (N=1 000/ year)	Food diary: 4 consecutive days (home visit)	Blood sample and spot urine collection	• General questionnaire • Food propensity questionnaire • Measured height, weight, waist and hip circumferences • Blood pressure • Use of dietary supplements
Germany [79-81]	Nationale Verzehrsstudie II (NVS II)	2005-2007	Aged 14-80y (N=19 329)	Diet-history of the last 4 weeks (in a study centre) + 24HDR: 2 non-consecutive days (by phone) For a subsample (N=975): weighted food diary: 2x 4 days	No biomarkers taken	• General questionnaire • Measured height and weight • Use of dietary supplements
France [82]	Étude Individuelle Nationale des Consommations Alimentaires 3 (INCA 3)	2014-2015	Aged 0-14y Aged 15-79y (N=5 855)	24-hour food diary followed by phone interview: 3 non-consecutive days 24HDR: 3 non-consecutive days (by phone)	No biomarkers taken	• General questionnaire • Food propensity questionnaire • Measured height and weight (home visit) • Use of dietary supplements
Italy [83, 84]	Studio sui Consumi Alimentari in Italia (INRAN-SCAI)	2005-2006	Aged 0-97y (N=3 323)	Food diary: 3 consecutive days (home visit)	No biomarkers taken	• General questionnaire • Measured height and weight • Use of dietary supplements
Netherlands [85]	Dutch National Food Consumption Survey (DNFCS)	2012-2016	Aged 1-8y Aged 9-79y (N=4 340)	24-hour food diary: 2 non-consecutive days (1st at home, 2nd by phone) 24HDR: 2 non-consecutive days (by phone or home visit after if aged <16y or >70y)	No biomarkers taken	• General questionnaire • Measured height and weight • Use of dietary supplements

1.5. Nutrition situation in Switzerland

1.5.1. Available data in 2016

When starting my PhD in 2016, there were no nationally representative data on individual dietary intake in Switzerland. Scientists and policy makers assessed diet quality and its evolution relying on:

- National agricultural statistics [86, 87],
- Local epidemiological studies, including
  - Bus Santé (since 1993): population-based repeated cross-sectional surveys in middle-aged adults living in the canton of Geneva using a FFQ and measuring a few biomarkers [88, 89],
  - CoLaus (since 2009): a population-based prospective cohort study in middle-aged adults living in Lausanne using the same FFQ as in Bus Santé and measuring several biomarkers [90],
  - FAN (in 2010): a population-based cross-sectional survey in children aged 6 to 12 years living in Ticino, using a seven-day food diary [91], and
- National surveys on single nutrition-related items, including
  - Swiss Study on Salt (in 2010-2011): a national population-based cross-sectional survey with sodium urinary excretion, anthropometric markers and a few biomarkers [92, 93], and
  - Swiss Health Survey (since 1981): national population-based repeated cross-sectional surveys every five years with limited information on dietary habits, self-reported weight and height [94, 95].

Therefore, Switzerland was one of the few high-income countries unable to base its nutrition policies on national representative data on food consumption and eating behaviours. This shortcoming was one of the main messages of the 6th Swiss Nutrition Report [96, 97].

1.5.2. Diet and nutritional status of the Swiss population

Based on the available data in 2012, the 6th Swiss Nutrition Report [96] summarized the nutrition situation in the adult population as follows. Over-nutrition/consumption is the main nutrition concern [96]. The prevalence of overweight and obesity was respectively 31% (*i.e.,* 40% in men and 23% in women) and 10% (*i.e.,* 11% in men and 9% in women) [95]. Regarding dietary intake, consumption of plant-based oils had grown in the last 20 years, while animal fats (*e.g.*, butter or lard) had declined [96]. Fish consumption had grown by about 50% over the last 30 years [96]. Twenty-one per cent of men and 38% of women consumed five portions of fruit and vegetables a day [98]. Average daily salt intake was estimated at 11g for men and 8g for women [92], nearly double the World Health Organization recommendations of less than 5 g/day.

Imbalance between energy intake and expenditure is also a public health issue in Swiss children and adolescents [99-102]. There are also specific concerns regarding deficits in macro-and micronutrients [100, 103, 104], but data regarding nutritional status and dietary intake of children and adolescents are very scarce (Chapter 1.5.1). The Swiss government acknowledged, however, the priority to target this age group in the 2008-2012 National Programme on Diet and Physical Activity [105] (extended up to 2016) and its recent 2017-2024 Swiss Nutrition Policy [106].

1.6. National nutrition surveys in Switzerland

In 2006, the Swiss Federal Office of Public Health (FOPH) initiated the first steps for a national nutrition survey. The FOPH decided in 2009 to follow the EFSA's guidance regarding design and methodology [73]. FOPH opted for repeated 24HDR using the software EPIC-SOFT (currently renamed GloboDiet®) provided by the International Agency for Research on Cancer (IARC) in Lyon.

In 2012, on the bases of an open call for tenders, the Food Safety division of the FOPH (FSVO/FOPH)[1] contracted the Institutes of Social and Preventive Medicine in Lausanne (IUMSP) and Bern (ISPM) in collaboration with Bern University of Applied Sciences to develop and conduct the first national nutrition survey, menuCH. A pilot study was conducted in 2013. Data collection of the main study started in January 2014 and was completed in February 2015. It included two non-consecutive 24HDR, anthropometric measurements, as well as a questionnaire mainly on dietary behaviours and physical in more than 2,000 adults.

Results of this first national nutrition survey considerably increase the knowledge about the diet of the Swiss population, as you will see below. Yet, a gap remains unfilled for children and adolescents because menuCH did not include these age groups. In addition, menuCH did not collect any bio-samples, which limits the assessment of the population's nutritional status.

[1] As of January 1st 2014 the Food Safety Division of the FOPH merged with the former Federal Veterinary Office to build the new Federal Food Safety and Veterinary Office (FSVO).

1.7. References

1. Mozaffarian, D. A history of nutrition science: Implications for current research, dietary guidelines and food policy. In: Food for thought: the science and politics of nutrition. 2018. Zurich, Switzerland: Swiss Re Institute / The BMJ.
2. Development Initiatives, Global Nutrition Report 2017: Nourishing the SDGs. 2017, Development Initiatives: Bristol, United Kingdom.
3. World Health Organization (WHO), The double burden of malnutrition. Policy brief. 2017, WHO: Geneva, Switzerland.
4. Pinstrup-Andersen, P., Agricultural Research and Policy for Better Health and Nutrition in Developing Countries: A Food Systems Approach. Agricultural Economics, 2007. 37(S1): p. 187- 198.
5. World Health Organization. Obesity and overweight. Key facts. [cited 2018 Apr 5]; Available from: http://www.who.int/mediacentre/factsheets/fs311/en/.
6. Food and Agriculture Organization (FAO), The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security. 2017, FAO: Rome, Italy.
7. International Food Policy Research Institute (IFPRI), Global Nutrition Report 2015: Actions and accountability to advance nutrition and sustainable development. 2015, IFPRI: Washington DC, United States of America.
8. United Nations. United Nations Decade of Action on Nutrition. [cited 2018 Sep 4]; Available from: https://www.un.org/nutrition/home.
9. G. B. D. Risk Factors Collaborators, Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet, 2017. 390(10100): p. 1345-1422.
10. Federal Office of Public Health (FOPH), Swiss Nutrition Policy 2013-2016. Based on the Main Findings of the 6th Swiss Nutrition Report. 2012, FOPH: Bern.
11. G. B. D. Causes of Death Collaborators, Global, regional, and national age-sex specific mortality for 264 causes of death, 1980-2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet, 2017. 390(10100): p. 1151-1210.
12. World Health Organization (WHO), World Health Organization - Noncommunicable Diseases (NCD) Country Profiles. 2014, WHO: Geneva, Switzerland.
13. World Economic Forum (WEF) and the Harvard School of Public Health, The Global Economic Burden of Noncommunicable Diseases. 2011, WEF: Geneva, Switzerland.

14. Peytremann-Bridevaux, I. and B. Burnand, Prévention et prise en charge des maladies chroniques: une approche applicable en Suisse (Prevention and management of chronic diseases: an approach for Switzerland). Bulletin des médecins suisses, 2009. 90(32).

15. World Cancer Research Fund International (WCRF) / American Institute of Cancer Research (AICR), Diet, Nutrition, Physical Activity and Cancer: a Global Perspective (the Third Expert Report). 2018, WCRF: London, United Kingdom.

16. Mozaffarian, D., Dietary and Policy Priorities for Cardiovascular Disease, Diabetes, and Obesity: A Comprehensive Review. Circulation, 2016. 133(2): p. 187-225.

17. Harvard T.H. Chan School of Public Health. Obesity causes. Food and Diet. [cited 2018 Sep 18]; Available from: https://www.hsph.harvard.edu/obesity-prevention-source/obesity-causes/diet-and-weight/.

18. Mozaffarian, D., I. Rosenberg, and R. Uauy, History of modern nutrition science-implications for current research, dietary guidelines, and food policy. BMJ, 2018. 361: p. k2392.

19. United States Department of Agriculture. 2015-2020 Dietary Guidelines for Americans. [cited 2018 Apr 5]; Available from: https://www.choosemyplate.gov/dietary-guidelines.

20. Walter, P., E. Infanger, and P. Mühlemann, Food Pyramid of the Swiss Society for Nutrition. Ann Nutr Metab, 2007. 51(suppl 2): p. 15–20.

21. Swiss Society for Nutrition / Federal Food Safety and Veterinary Office. Pyramide alimentaire suisse 2011 (Swiss Food Pyramid 2011). [cited 2017 Jul 16]; Available from: http://www.sge-ssn.ch/fr/toi-et-moi/boire-et-manger/equilibre-alimentaire/pyramide-alimentaire-suisse/.

22. Food and Agriculture Organization (FAO). Plates, pyramids, planet. Developments in national healthy and sustainable dietary guidelines: a state of play assessment. [cited 2018 Sep 4]; Available from: https://www.un.org/nutrition/home.

23. Public Health England. The Eatwell Guide. [cited 2018 Apr 5]; Available from: https://www.gov.uk/government/publications/the-eatwell-guide.

24. Mozaffarian, D. and N.G. Forouhi, Dietary guidelines and health-is nutrition science up to the task? BMJ, 2018. 360: p. k822.

25. World Health Organization (WHO). Development of WHO nutrition guidelines. [cited 2018 Sep 5]; Available from: http://www.who.int/elena/about/guidelines_process/en/.

26. United States Department of Health and Human Services (HHS) / Human Services and Department of Agriculture (USDA). 2015–2020 Dietary Guidelines for Americans. 8th ed. [cited 2018 Sep 5]; Available from: http://health.gov/dietaryguidelines/2015/guidelines/.

27. Ioannidis, J.A., The challenge of reforming nutritional epidemiologic research. JAMA, 2018.

28. Ioannidis, J.A. and J.F. Trepanowski, Disclosures in nutrition research: Why it is different. JAMA, 2018. 319(6): p. 547-548.

29. Archer, E., M.L. Marlow, and R.A. Williams, Government Dietary Guidelines: Uncertain Science Leads to Questionable Public Health Policy. Mercatus Working Paper. 2017, Mercatus Center at George Mason University: Arlington, United States of America.

30. Archer, E., G.A. Hand, and S.N. Blair, Validity of U.S. nutritional surveillance: National Health and Nutrition Examination Survey caloric energy intake data, 1971-2010. PLoS One, 2013. 8(10): p. e76632.

31. Archer, E., M.L. Marlow, and C.J. Lavie, Controversy and Debate: Memory based Methods Paper 1: The Fatal Flaws of Food Frequency Questionnaires and other Memory-Based Dietary Assessment Methods. J Clin Epidemiol, 2018.

32. Ioannidis, J.P., Implausible results in human nutrition research. BMJ, 2013. 347: p. f6698.

33. Bes-Rastrollo, M., et al., Financial conflicts of interest and reporting bias regarding the association between sugar-sweetened beverages and weight gain: a systematic review of systematic reviews. PLoS Med, 2013. 10(12): p. e1001578.

34. Cope, M.B. and D.B. Allison, White hat bias: examples of its presence in obesity research and a call for renewed commitment to faithfulness in research reporting. Int J Obes (Lond), 2010. 34(1): p. 84-8.

35. Kearns, C.E., L.A. Schmidt, and S.A. Glantz, Sugar Industry and Coronary Heart Disease Research: A Historical Analysis of Internal Industry Documents. JAMA Intern Med, 2016. 176(11): p. 1680-1685.

36. Willett, W., ed. Nutritional epidemiology. 2nd ed. 1998, Oxford University Press: New York, United States of America.

37. Subar, A.F., et al., The food propensity questionnaire: concept, development, and validation for use as a covariate in a model to estimate usual food intake. J Am Diet Assoc, 2006. 106(10): p. 1556-63.

38. European Food Safety Authority (EFSA), Guidance on the EU Menu methodology. Appendix 5.3.5. Example of a protocol for application of the Food Propensity Questionnaire (FPQ) based on the PANCAKE and the PILOT-PANEU projects. EFSA Journal 2014. 12(12): p. 3944.

39. Naska, A., A. Lagiou, and P. Lagiou, Dietary assessment methods in epidemiological research: current state of the art and future prospects. F1000Res, 2017. 6: p. 926.

40. University of Cambridge. DAPA Measurement Toolkit. Dietary assessment. [cited 2018 Sep 30]; Available from: http://dapa-toolkit.mrc.ac.uk/diet/diet-splash.

41. Fallaize, R., et al., Online dietary intake estimation: reproducibility and validity of the Food4Me food frequency questionnaire against a 4-day weighed food record. J Med Internet Res, 2014. 16(8): p. e190.

42. Rangan, A.M., et al., Electronic Dietary Intake Assessment (e-DIA): Comparison of a Mobile Phone Digital Entry App for Dietary Data Collection With 24-Hour Dietary Recalls. JMIR Mhealth Uhealth, 2015. 3(4): p. e98.

43. Martin, C.K., et al., Measuring food intake with digital photography. J Hum Nutr Diet, 2014. 27 Suppl 1: p. 72-81.

44. McClung, H.L., et al., Dietary Intake and Physical Activity Assessment: Current Tools, Techniques, and Technologies for Use in Adult Populations. Am J Prev Med, 2018. 55(4): p. e93-e104.

45. Hunter, D., Biochemical indicators of dietary intake. In: Nutritional epidemiology. 2nd ed., W. Willett, ed. 1998, Oxford University Press: New York, United States of America.

46. Neuhouser, M.L., et al., Use of Recovery Biomarkers to Calibrate Nutrient Consumption Self-Reports in the Women's Health Initiative. American Journal of Epidemiology, 2008. 167(10): p. 1247-1259.

47. Corella, D. and J.M. Ordovas, Biomarkers: background, classification and guidelines for applications in nutritional epidemiology. Nutr Hosp, 2015. 31 Suppl 3: p. 177-88.

48. Vandevijvere, S., et al., Evaluation of food and nutrient intake assessment using concentration biomarkers in European adolescents from the Healthy Lifestyle in Europe by Nutrition in Adolescence study. Br J Nutr, 2013. 109(4): p. 736-47.

49. Hambidge, M., Biomarkers of trace mineral intake and status. J Nutr, 2003. 133 Suppl 3: p. 948S-955S.

50. Hedrick, V.E., et al., Dietary biomarkers: advances, limitations and future directions. Nutr J, 2012. 11: p. 109.

51. Raiten, D.J., et al., Executive summary--Biomarkers of Nutrition for Development: Building a Consensus. Am J Clin Nutr, 2011. 94(2): p. 633S-50S.

52. O'Gorman, A., H. Gibbons, and L. Brennan, Metabolomics in the identification of biomarkers of dietary intake. Comput Struct Biotechnol J, 2013. 4: p. e201301004.

53. Brennan, L. and F.B. Hu, Metabolomics-Based Dietary Biomarkers in Nutritional Epidemiology-Current Status and Future Opportunities. Mol Nutr Food Res, 2018: p. e1701064.

54. Sebedio, J.L., Metabolomics, Nutrition, and Potential Biomarkers of Food Quality, Intake, and Health Status. Adv Food Nutr Res, 2017. 82: p. 83-116.

55. Lloyd, A.J., et al., Use of mass spectrometry fingerprinting to identify urinary metabolites after consumption of specific foods. Am J Clin Nutr, 2011. 94(4): p. 981-91.

56. Edmands, W.M., et al., Identification of human urinary biomarkers of cruciferous vegetable consumption by metabonomic profiling. J Proteome Res, 2011. 10(10): p. 4513-21.

57. Heinzmann, S.S., et al., Metabolic profiling strategy for discovery of nutritional biomarkers: proline betaine as a marker of citrus consumption. Am J Clin Nutr, 2010. 92(2): p. 436-43.

58. Altmaier, E., et al., Variation in the human lipidome associated with coffee consumption as revealed by quantitative targeted metabolomics. Mol Nutr Food Res, 2009. 53(11): p. 1357-65.

59. Stalmach, A., et al., Metabolite profiling of hydroxycinnamate derivatives in plasma and urine after the ingestion of coffee by humans: identification of biomarkers of coffee consumption. Drug Metab Dispos, 2009. 37(8): p. 1749-58.

60. Gibbons, H., et al., A metabolomics approach to the identification of biomarkers of sugar-sweetened beverage intake. Am J Clin Nutr, 2015. 101(3): p. 471-7.

61. Mullen, W., et al., Flavonoid metabolites in human plasma and urine after the consumption of red onions: analysis by liquid chromatography with photodiode array and full scan tandem mass spectrometric detection. J Chromatogr A, 2004. 1058(1-2): p. 163-8.

62. Cross, A.J., J.M. Major, and R. Sinha, Urinary biomarkers of meat consumption. Cancer Epidemiol Biomarkers Prev, 2011. 20(6): p. 1107-11.

63. Imamura, F., et al., A combination of plasma phospholipid fatty acids and its association with incidence of type 2 diabetes: The EPIC-InterAct case-cohort study. PLoS Med, 2017. 14(10): p. e1002409.

64. Esko, T., et al., Metabolomic profiles as reliable biomarkers of dietary composition. Am J Clin Nutr, 2017. 105(3): p. 547-554.

65. Zheng, J.S., et al., Serum metabolomics profiles in response to n-3 fatty acids in Chinese patients with type 2 diabetes: a double-blind randomised controlled trial. Sci Rep, 2016. 6: p. 29522.

66. Wittenbecher, C., et al., Amino acids, lipid metabolites, and ferritin as potential mediators linking red meat consumption to type 2 diabetes. Am J Clin Nutr, 2015. 101(6): p. 1241-50.

67. Briefel, R.R., Assessment of the US diet in national nutrition surveys: national collaborative efforts and NHANES. Am J Clin Nutr, 1994. 59(1 Suppl): p. 164S-167S.

68. Byers, T., Nutrition monitoring and surveillance. In: Nutritional epidemiology. 2nd ed., W. Willett, ed. 1998, Oxford University Press: New York, United States of America.

69. National Research Council / Committee on Diet and Health, Dietary Intake and Nutritional Status: Trends and Assessment. In: Diet and Health: Implications for Reducing Chronic Disease Risk. 1989, National Academies Press: Washington DC, United States of America.

70. Mukuria, A.G., Using national health and nutrition surveys for policy and programs: experiences from the demographic and health surveys. Forum Nutr, 2003. 56: p. 207-8.

71. Timbrell, J.A., Biomarkers in toxicology. Toxicology, 1998. 129(1): p. 1-12.

72. Fowler, B.A., Biomarkers in toxicology and risk assessment. EXS, 2012. 101: p. 459-70.

73. European Food Safety Authority (EFSA), General principles for the collection of national food consumption data in the view of a pan-European dietary survey. EFSA Journal, 2009. 7(12): p. 1435.

74. European Food Safety Authority (EFSA), Guidance on the EU Menu methodology. EFSA Journal, 2014. 12(12): p. 3944.

75. United States Department of Agriculture (USDA). What We Eat in America. NHANES 2015-2016. [cited 2018 Sep 5]; Available from: https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/food-surveys-research-group/docs/wweianhanes-overview/.

76. Center for Disease Control and Prevention (CDC) / National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey (NHANES). [cited 2018 Sep 5]; Available from: https://www.cdc.gov/nchs/nhanes/index.htm.

77. Health Canada, 2015 Canadian Community Health Survey - Nutrition. Reference Guide to Understanding and Using the Data. 2017, Health Canada: Ottawa, Canada.

78. Roberts, C., et al., National Diet and Nutrition Survey. Results from Years 7-8 (combined) of the Rolling Programme (2014/15 to 2015/16). 2018, Public Health England: London, United Kingdom.

79. Max Rubner-Institut (MRI), Nationale Verzehrsstudie II - Ergebnisbericht Teil 1 (2nd German Food Consumption Survey, Part 1). 2008, MRI: Karlsruhe, Germany.

80. Max Rubner-Institut (MRI), Nationale Verzehrsstudie II - Ergebnisbericht Teil 2 (2nd German Food Consumption Survey, Part 2). 2008, MRI: Karlsruhe, Germany.

81. Heuer, T., et al., Food consumption of adults in Germany: results of the German National Nutrition Survey II based on diet history interviews. Br J Nutr, 2015. 113(10): p. 1603-14.

82. Agence nationale de sécurité sanitaire de l'alimentation de l'environnement et du travail (ANSES), Étude individuelle nationale des consommations alimentaires 3 (INCA 3) (3rd French Food Consumption Survey). 2017, ANSES: Maisons-Alfort, France.

83. Leclercq, C., et al., The Italian National Food Consumption Survey INRAN-SCAI 2005-06: main results in terms of food consumption. Public Health Nutr, 2009. 12(12): p. 2504-32.

84. Sette, S., et al., The third Italian National Food Consumption Survey, INRAN-SCAI 2005-06--part 1: nutrient intakes in Italy. Nutr Metab Cardiovasc Dis, 2011. 21(12): p. 922-32.

85. van Rossum, C.T.M., et al., The diet of the Dutch: Results of the first two years of the Dutch National Food Consumption Survey 2012-2016. 2017, National Institute for Public Health and the Environment (RIVM): Bilthoven, The Netherlands.

86. Federal Office of Public Health (FOPH), ed. Swiss Nutrition Policy 2013-2016. Based on the main findings of the 6th Swiss Nutrition Report. 2012, FOPH: Bern, Switzerland.

87. Federal Office of Public Health (FOPH), ed. Sixième rapport sur la nutrition en Suisse (6th Swiss Nutrition Report). 2012, FOPH: Bern, Switzerland.

88. de Abreu, D., et al., Compliance with the Swiss Society for Nutrition's dietary recommendations in the population of Geneva, Switzerland: a 10-year trend study (1999-2009). J Acad Nutr Diet, 2014. 114(5): p. 774-80.

89. Schneid Schuh, D., et al., Twenty-four-year trends and determinants of change in compliance with Swiss dietary guidelines. Eur J Clin Nutr, 2018.

90. de Abreu, D., et al., Low compliance with dietary recommendations for food intake among adults. Clin Nutr, 2013. 32(5): p. 783-8.

91. Suggs, L.S., S. Della Bella, and P. Marques-Vidal, Low adherence of Swiss children to national dietary guidelines. Prev Med Rep, 2016. 3: p. 244-9.

92. Chappuis, A., et al., Swiss survey on salt intake: main results. 2011, Service de Néphrologie et Institut Universitaire de Médecine Sociale et Préventive, Centre Hospitalier Universitaire Vaudois (CHUV): Lausanne, Switzerland.

93. Guessous, I., et al., Vitamin D levels and associated factors: a population-based study in Switzerland. Swiss Med Wkly, 2012. 142: p. 0.

94. de Mestral, C., et al., Fifteen-year trends in the prevalence of barriers to healthy eating in a high-income country. Am J Clin Nutr, 2017. 105(3): p. 660-668.

95. Federal Statistical Office (FSO), ed. Swiss Health Survey 2012. Overview. 2013, FSO: Neuchatel, Switzerland.

96. Federal Office of Public Health (FOPH), ed. Sixième rapport sur la nutrition en Suisse (6th Swiss Nutrition Report). 2012, FOPH: Bern, Switzerland.

97. Federal Office of Public Health (FOPH), ed. Swiss Nutrition Policy 2013-2016 based on the main findings of the 6th Swiss Nutrition Report. 2012, FOPH: Bern, Switzerland.

98. Eichholzer, M., et al., Daten zum Übergewicht und zu Ernährungsgewohnheiten aus der Schweizerischen Gesundheitsbefragung 2007 (Data on overweight and eating habits from the Swiss Health Survey 2007). Praxis, 2010. 99: p. 17-25.

99. Schneider, H., W. Venetz, and C. Gallani Berard, Overweight and obesity in Switzerland. Part 2: Overweight and obesity trends in children. 2009, Federal Office of Public Health: Basel.

100. European Food Safety Authority (EFSA), Scientific Opinion on nutrient requirements and dietary intakes of infants and young children in the European Union. EFSA Journal, 2013. 11(10): p. 3408.

101. Lasserre, A.M., et al., Overweight in Swiss children and associations with children's and parents' characteristics. Obesity (Silver Spring), 2007. 15(12): p. 2912-9.

102. Aeberli, I., et al., Stabilization of the prevalence of childhood obesity in Switzerland. Swiss Med Wkly, 2010. 140: p. w13046.

103. Federal Commission for Nutrition (FCN), Iodine supply in Switzerland: Current Status and Recommendations. Expert report of the FCN. 2013, Federal Office of Public Health: Zurich, Switzerland.

104. Zimmermann, M.B., et al., Increasing the iodine concentration in the Swiss iodized salt program markedly improved iodine status in pregnant women and children: a 5-y prospective national study. Am J Clin Nutr, 2005. 82(2): p. 388-92.

105. Federal Office of Public Health (FOPH), ed. National Programme on Diet and Physical Activity 2008-2012. 2008, FOPH: Bern, Switzerland.

106. Federal Food Safety and Veterinary Office (FSVO), Swiss Nutrition Policy 2017–2024. 2017, FSVO: Bern, Switzerland.

2. Aims, objectives and outline

2.1. Aims and objectives

The aims of the thesis were 1) to describe dietary intake and nutritional status of the Swiss adult population, using menuCH data, and 2) develop recommendations for future national nutrition-related research and policies. The PhD thesis focuses on national nutrition surveys in Switzerland. Following the conceptual framework presented in Chapter 1.4.1, the objectives were:

- To monitor dietary intake and nutritional status in Switzerland *(population monitoring and surveillance),*
- To create new evidence for the prevention of obesity (*epidemiological research),*
- To provide recommendations to conduct the next national nutrition surveys (*policy-making*), and
- To guide future nutrition policies *(policy-making*).

2.2. Thesis outline

This thesis is composed of several distinct projects in relation to the three dimensions of the conceptual framework: population monitoring and surveillance, epidemiological research, policy-making (**Figure 1**).

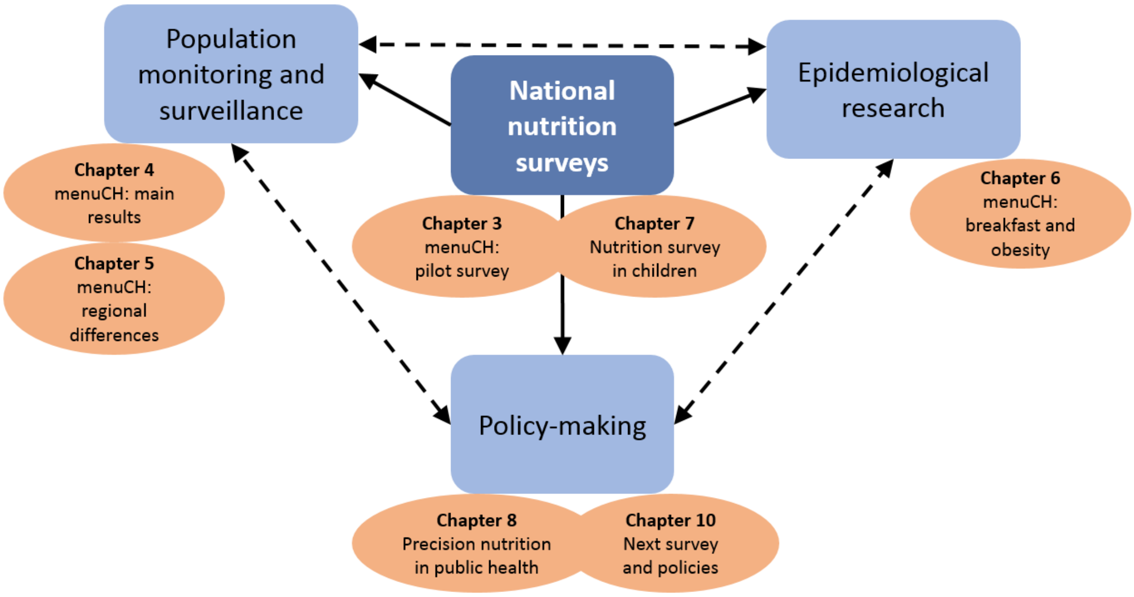


Figure 1. Overview of the thesis chapters classified according to the conceptual framework. *Chapter 9 is not presented in this figure because its presents very diverse projects.*

Chapter 3 describes lessons learnt from menuCH pilot survey. **Chapter 4** introduced menuCH main results presented to the public (work in collaboration with FSVO and IUMSP co-workers). **Chapter 5** assesses the differences in food consumption and compliance to national food-based dietary guidelines between the German-, French-, and Italian-speaking regions of Switzerland using menuCH data. **Chapter 6** evaluates the association between breakfast composition and abdominal obesity among regular breakfast eaters in menuCH. **Chapter 7** presents the design and the conduction of a feasibility study in a small population-based sample of children and adolescents. It also provides recommendations in terms of age-specific dietary assessment methods and bio-sample collection for the next national nutrition survey. **Chapter 8** discusses the potential opportunities and risks for public health to use precision nutrition, which is a novel instrument designed to improve dietary behaviours of large numbers of individuals via smart-phone applications. **Chapter 9** presents other projects conducted in parallel of the thesis. **Chapter 10** discusses the main findings and provides suggestions for the next national nutritional survey and for nutrition policies in Switzerland.

3. menuCH pilot survey

Title of the manuscript: Lessons learnt about conducting a multilingual nutrition survey in Switzerland: results from menuCH pilot survey.

Authors: Angeline Chatelan[1], Pedro Marques-Vidal[2], Sabine Bucher[3], Stefan Siegenthaler[4], Nathalie Metzger[1], Christine Anne Zuberbuehler[5], Esther Camenzind-Frey[5], Andrea Renggli[5], Murielle Bochud[1], Sigrid Beer-Borst[3,4].

Affiliations: [1] Institute of Social and Preventive Medicine (IUMSP), Lausanne University Hospital (CHUV), Lausanne, Switzerland, [2] Department of Medicine, Internal Medicine, Lausanne University Hospital (CHUV), Lausanne, Switzerland, [3] Institute of Social and Preventive Medicine (ISPM), University of Bern, Bern, Switzerland, [4] Health Division, Bern University of Applied Sciences, Bern, Switzerland, [5] Risk Assessment Division, Scientific Evaluation Sector, Federal Food Safety and Veterinary Office (FSVO), Bern, Switzerland.

Author contributions: AC, SBB and MB drafted the manuscript, based on analyses performed by AC and MB. All co-authors critically reviewed the manuscript and approved the final version. AR coordinated the open call for tenders. The survey protocol was prepared by SBB and PMV. ECF and CZ established the trilingual Swiss version of GloboDiet® with the menuCH picture book and helped in project coordination. SB directed the recruitment centre and team. SBB, AC, NM, StS, CZ and ECF trained field dietitians. AC, NM, and SBB defined and conducted quality controls. StS carried out GloboDiet® data cleaning. SBB was responsible for survey implementation. PMV was in charge of data management. MB directed the survey.

Publication status: Manuscript published in International Journal for Vitamin and Nutrition Research.

3.1. Abstract

The manuscript informs about the implementation of the first trilingual Swiss nutrition pilot survey and lessons learnt in terms of recruitment, participation, data collection feasibility, and data management. The population-based cross-sectional nutrition pilot survey took place between June and November 2013. Six trained dietitians interviewed 276 adults aged 18-75 years residing in the cantons of Bern (German), Vaud (French) or Ticino (Italian). Food consumption was assessed with two non-consecutive computer-assisted 24-Hour Dietary Recalls (24HDR), applying a trilingual version of GloboDiet® adapted to specific requirements of Switzerland. The first interview was face-to-face and included anthropometric measurements while the second was by phone. Quality controls consisted mainly in the descriptive analysis of data at food level, and the observation and rating of 21 interviews (4%) by coordinators. Net participation rate was 29%. Participants and non-participants were similar: mean [±SD] age was 49±16 and 47±16 years, and women proportion 49.6% and 49.8%, respectively. Training and data collection proved feasible and deliverable in the six months using the newly developed survey instruments. Dietitians followed the standard operating procedures. Quality controls on food consumption data showed comparable results between face-to-face and phone 24HDR, and across dietitians (median number of reported food items per 24HDR: 27). Procedures to transfer and clean food consumption data were developed. The implementation concept proved applicable in the trilingual Swiss context. Additional resources were planned for increasing participation rate and facilitating data cleaning.

3.2. Introduction

So far Switzerland lacked nationally representative information to evaluate food consumption patterns and the country's situation in terms of diet, nutrition and food safety [1, 2]. To fill the gap and comply with European standards, the government initiated in the mid-2000s the planning of the first national nutrition survey. Key elements were to assess food consumption and provide measured anthropometric data of a population-based representative sample of Swiss adult residents.

The Institutes of Social and Preventive Medicine in Lausanne (IUMSP) and Bern (ISPM) in cooperation with Bern University of Applied Sciences (BUAS) were contracted to develop and conduct the first Swiss national nutrition survey - menuCH - on the bases of an open call for tenders by the Food Safety division of the Federal Office of Public Health (FSVO/FOPH). The tripartite mandate asked for an approved implementation concept as well as the successful completion of a pilot survey prior to the launch of the main survey.

Switzerland had no previous experience in collecting nationally representative food consumption/nutrition data across the major Swiss linguistic regions. The survey had to be developed in three languages (German, French, and Italian) and piloted across these regions. The main objective of the present pilot survey was to test the overall survey organization defined in a specifically established implementation concept. More specifically the trilingual pilot survey aimed at 1) testing recruiter training, recruitment procedures and estimating participation rate, 2) testing data collection practicability using the various survey instruments, 3) examining field dietitians' training and refining quality control measures, as well as 4) establishing applicable data management structures and cleaning procedures using real data. This paper focuses on the lessons learnt from the implementation of this pilot survey.

3.3. Methods

The cross-sectional multi-centric pilot survey lasted from June to November 2013. **Table 1** shows the survey implementation phases with related tasks/procedures, applied instruments and responsible institutions. Recruitment and interviews with participants were conducted in German, French and Italian whereas the common administrative language was English.

Table 1. Pilot survey implementation phases with related tasks/procedures, applied instruments and involved institutions.

Phases	Tasks/procedures	Instruments	Institutions[2]
Recruitment	Provide a population-based sample with contact details		FSO
	Invite people to participate	• Invitation letter[1] + response card[1]	IUMSP FSVO/FOPH
	Train recruiters	• Training program/manual	ISPM
	Recruit participants and fix appointment in a study centre	• Computer-assisted telephone interview (CATI)-system • Central web-based scheduling tool[1] • 5-item non-respondent questionnaire[1]	ISPM
Data collection	Train dietitians	• Training program and survey manual	ISPM, IUMSP, BUAS, FSVO/FOPH
	Apply methods following standard operating procedures (SOP)	• Participant information[1] + consent form[1] • GloboDiet® (GD)[1] + set of household measures + picture book[1] • 49-item dietary behaviour and physical activity questionnaire[1] • Anthropometric tools + a form to note measured values	Dietitians, IUMSP
Data management	Transfer GD data from field to central data centre	• FileZilla© - password protected online File Transfer Protocol server	IUMSP
	Enter questionnaire and anthropometric data	• Sphinx©[1] - web-based survey database	Dietitians
	Control, merge and analyse data	• SQL Server Management Studio Express - useful to modify GD files • R - classical statistical software	IUMSP
	Evaluate and clean GD data to inform software updates and to prepare for data linkage	• GD[1] and Microsoft Excel©	BUAS, FSVO/FOPH, IARC
Quality controls	Identify questions or issues from the field (*e.g.,* in survey instruments)	• Bi-weekly electronic logbooks	Dietitians, BUAS, IUMSP, ISPM, FSVO/FOPH
	Assess interview quality on site	• 47-indicator checklist	IUMSP, ISPM
	Assess GD data quality, following IARC's protocol	• R and STATA - classical statistical software	IUMSP

[1] Available in German, French and Italian. [2]FSO: Federal Statistical Office. IUMSP: Institute of Social and Preventive Medicine, Lausanne. FSVO/FOPH: Food Safety division of the Federal Office of Public Health. ISPM: Institute of Social and Preventive Medicine, Bern. BUAS: Bern University of Applied Sciences. IARC: International Agency for Research on Cancer, Lyon, France.

Sampling and recruitment

Target pilot survey sample size was 300 adults living in three cantons and linguistic regions: Bern (mainly German), Vaud (French), and Ticino (Italian). The Federal Statistical Office (FSO) provided a population-based random sample of 1200 individuals aged 18-75 years from the sample frame for person and household surveys [3]. Due to the unexpectedly low rate of available phone numbers, this original sample was extended to a total sample of 2016 individuals. Between June and August 2013, every subject was mailed a personal pre-tested invitation letter in German, French, or Italian, announcing a phone call from the central recruitment centre (ISPM, CATI-laboratory). The letter included a prepaid response card to indicate contact details and best availability for a call in case of interest to participate. It was directly returned to the recruitment centre. The mailing was organized in six waves sent every two weeks. Latest one month after mailing, people with known phone number were called by trained recruiters using a computer-assisted telephone (CATI)-system. Recruiters explained participation details and informed about compensation payment of CHF 100 to cover participation related expenses. For people who agreed to participate recruiters fixed the first appointment using a survey specific web-based scheduling tool. Refusals were asked to answer a 5-item non-respondent questionnaire (CATI) to allow for comparative characterization of responders and non-responders.

The first interview took place in one of three centrally located study centres in Bern, Lausanne and Lugano; the second interview was conducted by phone two to six weeks later, in general on a different weekday. Interview days were Mondays to Saturdays. Recruiters were instructed to distribute appointments evenly across weekdays. However, with no appointments on Sunday, Mondays had to be overrepresented to be able to cover food consumption on either Saturday or Sunday. The scheduling tool served to centrally book appointments, issue confirmation letters and send E-Mail reminders to participants, and to monitor recruitment pace and patterns across centres in real time. Responders were mailed a participant’s information sheet, a consent form, a confirmation of appointment, a study centre access map and a dietary behaviour and physical activity questionnaire.

Data collection procedures

Trained dietitians/nutritionists (field dietitians) conducted two interviews per participant. Key elements were the repeated 24-Hour Dietary Recalls (24HDR) and the realization of objective anthropometric measurements. The structure and timing of the face-to-face interview was established based on European Food Safety Authority’s recommendations [4], international health and nutrition survey reports [5, 6] and previous experience from survey investigators. The face-to-face interview was expected to take between 75 and 90 minutes, consisting of six elements: (a) introduction and consent; (b) completeness check of the dietary behaviour and physical activity questionnaire; (c) anthropometry; (d) 24HDR (40-60 minutes); (e) schedule of the second phone-administrated 24HDR, and (f) closure. The duration of the phone interview (only elements d and f) was expected to take between 45 and 65 minutes. Table 1 details all applied survey instruments related to data collection.

Food consumption

Following European guidelines [4], food consumption information was collected through two non-consecutive 24HDR. All consumed foods and beverages were recorded using a computerized 24HDR program (multiple-pass approach). The software, called GloboDiet® (GD, formerly EPIC-Soft®), had been developed and validated by the International Agency for Research on Cancer (IARC), Lyon, France [7-10]. For menuCH, the software had been adapted to comply with the Swiss specific food market and specific national requirements defined by FSVO/FOPH, research and public health actors. It was provided in German, French and Italian. The GD software was complemented with a comprehensive menuCH Swiss picture book [11]. It was adapted by FSVO/FOPH from the EPIC-Soft picture book [12] to meet Swiss requirements and thus support survey participants in quantifying amounts of consumed foods [13, 14]. The picture book comprised 119 series of graduated portion-size pictures of common food items, of which 49 (41%) displayed typical Swiss foods such as Roesti, Birchermuesli, and Raclette cheese. In addition, real-size two-dimensional drawings of geometrical models (circles, wedges) as well as standard bread and cake shapes were displayed combined with a thickness scale. Twelve picture series of different household measures (glasses, cups, bowls, ladles, *etc*.) completed the picture book to estimate portion size. A set of about 60 real dishes was on display in all study centres.

Anthropometry

Body weight and height were measured to the nearest 0.1 kg and cm, respectively following World Health Organization guidelines [15] using a calibrated Seca 701 scale, equipped with a Seca 220 telescopic measuring rod (Seca GmbH, Hamburg, Germany). Mean waist and hip circumferences were calculated out of three measures [15] to the nearest 0.5 cm using a Gulick I unstretchable tape, equipped with a dynamometer (North Coast Medical, CA, USA). In pregnant and lactating women, only height was measured. Field dietitians controlled daily the functionality of all instruments prior to use. Data were entered in a centrally managed secured web-based database.

Dietary behaviour and physical activity questionnaire

Participants completed a pre-tested self-administered 49-item paper questionnaire, compiled by FSVO/FOPH from existing and newly developed questions. It included questions about cooking and eating habits, nutrition knowledge, and physical activity (short form IPAQ [16-18]), complemented with a set of questions about socio-economic and demographic characteristics. The questionnaire was returned in person, controlled during the face-to-face interview and data entered in a centrally managed secured web-based database after interview closure.

Quality control concept

Quality control at all stages of a survey is crucial for high data quality [19-21]. A quality control concept was established and tested, covering the period before, during and after data collection.

Before data collection - Training

Recruitment interviewers and field dietitians were separately trained in June/July 2013. The director of the CATI-laboratory trained during at least two half days and supervised three recruiters covering the three survey languages plus English. The focus was on communication with concurrent use of the CATI-system and the scheduling tool software, followed by practice calls with specifically instructed volunteers. In parallel, the field dietitians (two per linguistic region) were trained by the survey coordinators during the three-step training program. Firstly, during a 3.5 day central baseline training, field dietitians were informed about the survey specific standard operating procedures (SOP) and intensively trained to perform 24HDR using GD following IARC training standards [22], take anthropometric measures, check the dietary behaviour and physical activity questionnaire for completeness and get accustomed with data entry and management. Secondly, dietitians conducted at least five face-to-face and phone interviews each with fake participants at their local study centre. These volunteers had been recruited as described above as part of the recruiters' training. Interviews were supervised by two regional coordinators. Thirdly, a 1.5-day central consolidation training was held: field dietitians were tested by survey investigators and coordinators for their competencies to conduct standardized interviews in their local language with invited volunteers. Field dietitians completed an evaluation form after baseline and consolidation training. They were asked to evaluate received information (*e.g.*, 'I feel well informed about ...') and their use of survey tools (*e.g.,* 'I feel ready to perform …') on a six-point rating scale, indicate graphically their satisfaction with the training format/method and content, and provide any suggestions.

During data collection - Field work quality control

On-site quality controls were performed using an internally developed 47-indicator checklist to rate (++ / + / - / - -) field dietitians' interview and work quality. Checklist indicators were based on survey specific SOP, including anthropometry (*e.g.*, implementation of the single measurements in compliance with protocol, error-free data entry), IARC's international recommendations about how to conduct a 24HDR [22], an existing tool [23] and literature [20, 24]. The quality control checklist was completed by coordinators while attending interviews at the study centres and was followed by a personal evaluation with the field dietician.

Field dietitians reviewed their daily work in keeping electronic logbooks and informed coordinators every two weeks about questions or issues raised during fieldwork and potentially influencing data quality. Logbooks concerned the overall survey organization including data transfer/management issues, the GD software (*e.g.*, description of complex foods, calculation of portion size from food dimensions, new foods and recipes), the picture book, the household measures (*e.g.*, desirable new food pictures or bread shapes), the dietary behaviour and physical activity questionnaire and its data entry, and the scheduling tool. Investigators, supported by FSVO/FOPH, merged and evaluated all incoming thematic logbooks and provided standardized written answers/solutions to the entire survey team for subsequent implementation.

After data collection - Central data collection quality control

The 24HDR data collection quality was evaluated using mostly the criteria/indicators recommended by IARC [8]: number of food consumption occasions (*i.e.,* meals and snacks) and foods reported per recall; consumed quantity of 18 food groups per recall; recall duration; number of recalls by weekday; use frequency of pre-coded generic food items (*e.g.,* berries, not specified), unknown and non-specified descriptors (*e.g.*, cooked with fat, not specified); outliers in energy intake to identify typing errors in portion size entry or incomplete 24HDR interviews (very low: <1 000 kcal/day and very high: >4 000 kcal/day). Data from the dietary behaviour and physical activity questionnaire and anthropometric measurements were analysed for inconsistencies, unexpected results compared to literature, and missing values.

Data management, cleaning and analysis

Data from the dietary behaviour and physical activity questionnaire and anthropometric measures were directly entered and managed in a central web-based Sphinx© database (Sphinx Development, London, UK). GD files stored at study centres were transferred on a weekly basis to the secured centralized database at IUMSP. For safety reasons, field dietitians also made a daily back-up on a password protected USB stick. After central GD data quality control, a specifically trained dietitian (data cleaner) prioritized the cleaning of dietitians' notes following IARC internal recommendations, and established on this basis a standardized GD data cleaning protocol. New foods and recipes, that could not be selected from the given GD food and recipe lists, could thus be identified and reported to FSVO/FOPH for updating GD prior to the main survey.

GD data analysis was restricted to food level. It primarily aimed at supporting data cleaning by analysing the number and types of notes taken during dietary interviews, and assessing variability within 24HDR by interview administration mode and across dietitians for quality control purposes. Descriptive statistics, without adjustments or weighting factors, were applied. Categorical data are presented as absolute or relative frequencies. Continuous data are presented as mean ± standard deviation when distribution tended to be normal, or with box-plots when skewed. Group comparisons were performed using chi-square or two-sample t test (two-sided significance set at $p<0.05$).

Ethical issues

The pilot survey protocol was approved by the three cantonal ethics committees of Vaud (lead committee, Protocol 26/13, accepted on Feb 21st 2013), Bern and Ticino.

3.4. Results

Sampling and participation

For 1 310 out of 2 016 address data sets (65%), a landline phone number was provided. This rate was lower in the French and Italian parts, but could be slightly complemented with 383 returned response cards. Still, for 47% of the gross sample no contact was possible (**Figure 1**). Overall, 276 people took part in the pilot survey which corresponded to 13.7% gross and 28.8% net participation rates. Net participation rate among people with response card was 70%. Six people dropped out before the second interview. The remaining 270 participants had complete dataset: *i.e.,* two 24HDR, a complete dietary behaviour and physical activity questionnaire, and all anthropometric measures. Uniform distribution of 24HDR across all weekdays was not fully achieved (**Figure 2**). Recalls assessing food consumption at the end of the week were less frequent than recalls reporting diet from Monday to Wednesday. This was especially the case for phone interviews. Out of 684 people who refused participation, 337 (49%) accepted to answer the non-respondent questionnaire (Figure 1). They stated lack of time (55%) and no interest (26%) as the main reasons for refusal. Twenty-five percent of refusals reported being regular smokers.

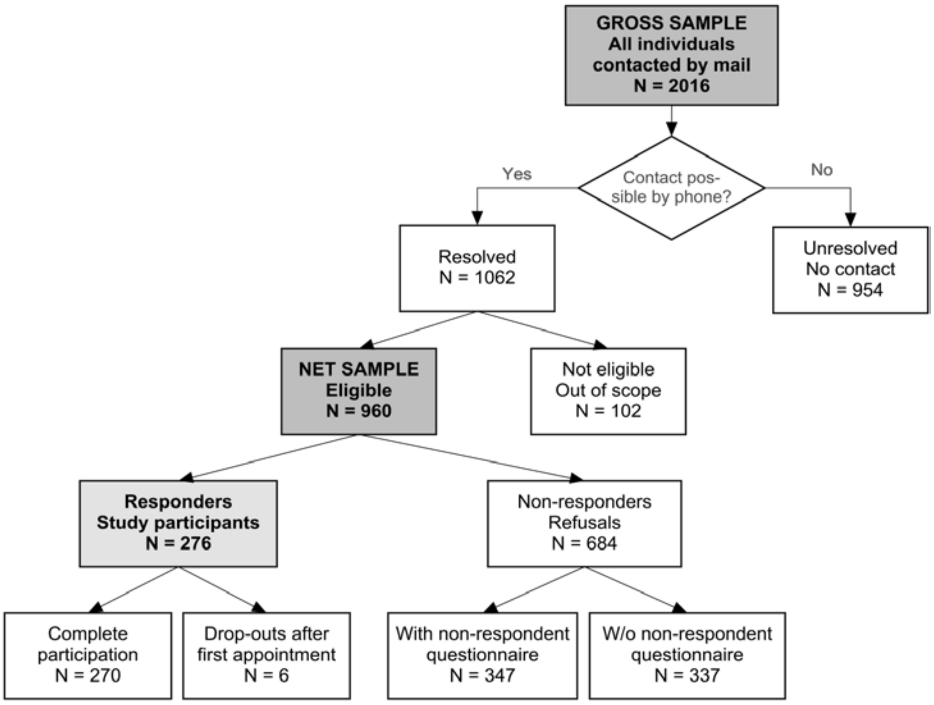


Figure 1. Participation classification, following 2014 European Food Safety Authority's classification recommendations [35]. *Complete participation implies the entire dataset is available: two 24HDR, a complete dietary behaviour and physical activity questionnaire, and all anthropometric measures.*

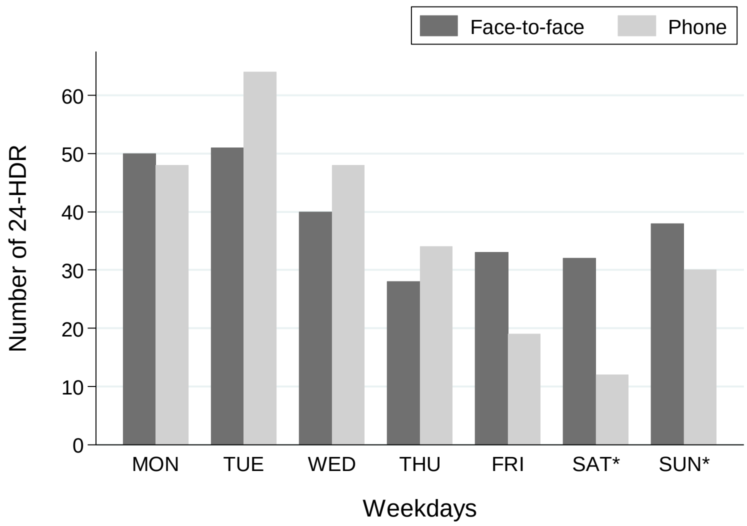


Figure 2. Distribution of the 24HDR interviews (N=527) over weekdays per recall day, and by administration mode (face-to-face vs. phone). Appointments (interview days) were possible from Mondays to Saturdays.**Participants interviewed on Mondays having an odd identification code were asked to report their dietary intake from Sunday, respectively from Saturday when even*.

Table 2 shows that pilot survey participants and non-participants (*i.e.,* non-responders, ineligible and never phone-contacted people) were similar regarding age (48.7±15.5 vs. 47.0±15.6 years) and gender proportion (49.6% vs. 49.8% of women). However, significantly more Swiss than non-Swiss accepted to participate (*P* < 0.001). The prevalence of overweight and obesity in pilot survey participants was respectively 36% and 15% and smoking rate 25%.

Table 2. Characteristics of selected people from gross sample and by participation status (data provided by Federal Statistical Office, Switzerland, 2013).

Characteristics	Gross sample	Participants	Non-participants	P-value[1]
	N (%) or mean (±SD)			
Sample size	2 016 (100.0)	276 (13.7)	1 740 (86.3)	
Sex				0.967
Men	1 013 (50.3)	139 (50.4)	874 (50.2)	
Women	1 003 (49.8)	137 (49.6)	866 (49.8)	
Age	47.2 (±15.6)	48.7 (±15.5)	47.0 (±15.6)	0.092
Communication language				0.300
German	638 (31.7)	97 (35.1)	541 (31.1)	
French	701 (34.8)	96 (34.8)	605 (34.8)	
Italian	677 (33.6)	83 (30.1)	594 (34.1)	
Marital status				0.062
Single	599 (29.7)	87 (31.5)	512 (29.4)	
Married	1 135 (56.3)	163 (59.1)	972 (55.9)	
Widowed - Divorced	282 (14.0)	26 (9.4)	256 (14.7)	
Household size				0.048
1 person	325 (16.1)	35 (12.7)	290 (16.7)	
2 people	690 (34.2)	106 (38.4)	584 (33.6)	
3 people	396 (19.6)	42 (15.2)	354 (20.3)	
4 people	384 (19.1)	63 (22.8)	321 (18.5)	
5 or more	221 (11.0)	30 (10.9)	191 (11.0)	
Nationality				<0.001
Swiss	1 538 (76.3)	247 (89.5)	1 291 (74.2)	
Non-Swiss	478 (23.7)	29 (10.5)	449 (25.8)	

[1] *Between the two groups (participants vs. non-participants) using chi-square tests,* respectively *two-sample t test for age.*

Data collection procedures and instruments

The structure and allocated time per appointment was considered as sufficient by field dietitians and coordinators, except if recruiters and field dietitians had to book all available time slots of a day for face-to-face and phone interviews, allowing for no rest periods. The median duration of the 24HDR was slightly shorter than the expected minimum duration of 40 minutes: 37 minutes (P25: 29 minutes and P75: 48). Face-to-face 24HDR lasted for 39 minutes (39, 37 and 38 minutes in the German, French and Italian areas, respectively) whereas 35 minutes was needed for phone 24HDR (respectively 39, 33 and 36 minutes).

No technical problems occurred with any of the applied devices or IT-solutions. Logbook entries related to GD-software and subsequent evaluation of notes served to identify 36 typing errors and imprecisions in food and recipe names; 65 new foods and 27 new recipes were added in the food/recipe lists. A few new recipes (N=4) were considered as international or nationally available, but most were added at the request of German, French and Italian speaking dietitians (9, 6, and 8, respectively). The dietary behaviour and physical activity questionnaire was generally completed in comprehensive and correct ways, and field dietitians properly identified and clarified participants' missing or inappropriate answers.

Quality control concept

The quality control concept proved reliable and useful to detect shortcomings and inform about improvements needed for the main survey as well as in quality control instruments.

Before data collection - Training

The main challenge for recruiters was the simultaneous use of the CATI-system to manage recruitment and the scheduling tool to set up appointments with dietitians. Oral and written evaluation showed that field dietitians' training was appropriate to allow conducting real-life interviews. They felt very well informed and ready to collect data after the consolidation training. All rated themselves between 1 and 2 out of 6, 1 being the best grade and 6 the worst. Learning and concurrent use of different software applications and associated materials during recruitment/interview situations was experienced challenging and training-intensive. Time for in-depth (self-) reflection and feedback was short.

During data collection - Field work quality control

Regional coordinators visited each field dietitian at least twice during the 4-month data collection; they attended 21 interviews (4%) applying the quality control checklist. Checklist analyses showed that all field dietitians followed the defined interview structure and SOP. Even though standardization of anthropometric measurements (*e.g.*, precision for waist circumference) and GD data entry regarding complex foods or recipes was challenging, no indicators were rated as insufficient by coordinators. Comparison between regional coordinators showed that both jointly attended interviews were rated very similarly but the interpretation of '++' vs. '+' in the four-point rating scale (++ / + / - / - -) slightly differed between coordinators. The rating was subsequently reduced to a concrete three-point scale of 'adequate/acceptable/insufficient'. Further, separate checklists for the more extensive face-to-face and shorter phone interview were prepared (available on request). Electronic logbooks were submitted and evaluated as planned. Number of entries reduced over time for all issues in every linguistic region but those concerning the 24HDR using GD. The standardized description of certain foods and recipes challenged dietitians due to different possibilities to interpret some facets (*e.g.,* ‘After which level of preparation a commercial food becomes a homemade preparation?’). The data cleaner established a common question and answer document (in English) with additional separate sections for language-specific matters. It was continuously updated in cooperation with FSVO/FOPH and sent to field dietitians as a reference to complement the GD manual for the main survey.

After data collection - Central data collection quality control

Evaluation of 24HDR quality at food level showed that data collection was similar across dietitians, centres and independent of the administration mode. The total number of conducted interviews per dietitian varied between 71 and 112. The median number of meals and snacks and of reported foods per recall day were similar across dietitians and between face-to-face and phone interviews (**Figure 3**). For the 18 food groups predefined by GD, the median consumption per 24HDR was comparable between face-to-face and phone interviews (*data not shown*). On average, 3.5 pre-coded generic food items were used per recall, *i.e.,* 15% of all food items reported (17% in the German and French-speaking parts, and 12% in the Italian). No major differences were seen between face-to-face (3.6 items per recall) and phone (3.4) 24HDR. The pre-coded unknown or non-specified descriptors for food and recipe facets were seldom used: 8% and 9% of all descriptors, respectively. No differences were observed between linguistic regions and administration mode. Outliers in energy intake (N=29 low and N=13 high intakes) could often be explained by consulting indications concerning special days (*e.g.,* being sick or feast day) and diets (*e.g.,* weight management).

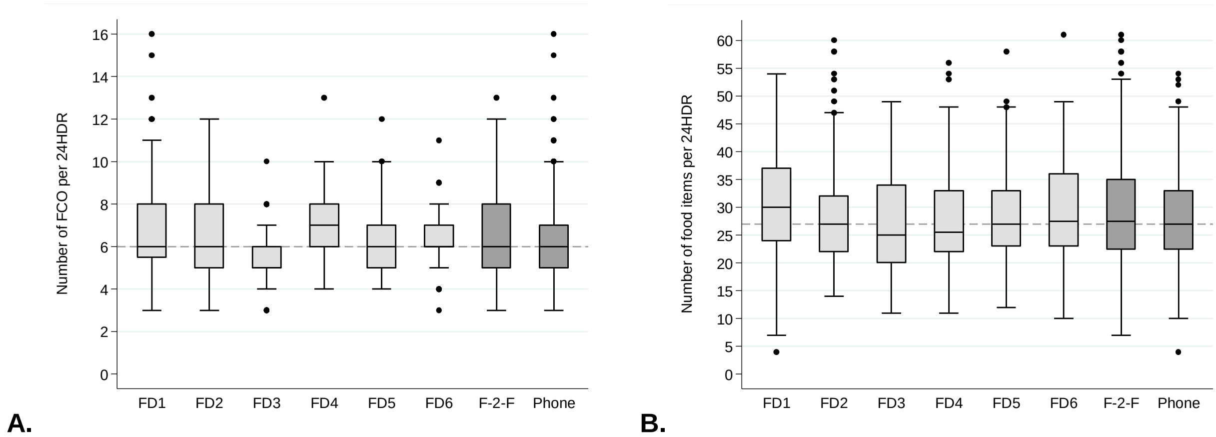


Figure 3. Number of reported food consumption occasions (*i.e.,* meals and snacks) **(A)** and number of consumed food items per 24HDR (**B**) by field dietitian (FD) and, in darker grey, by administration mode (face-to-face vs. phone). *The horizontal dashed line shows the median considering all 24HDR interviews.*

Data management and cleaning

The established data management structure was step-wise refined during pilot survey. The management of the complex GD file transfer needed particular attention. Field dietitians requested additional support in proper implementation. The procedure to back-up, transfer and centrally store GD files was revised immediately after identification of a problem that caused the loss of 19 24HDR files. GD file evaluation and data cleaning procedures were clarified and related workload estimated. The cleaning of 527 pilot 24HDR implied checking and cleaning 660 notes from field dietitians plus 1221 notes automatically generated by GD (3.6 notes per 24HDR). About 10 minutes were needed to clean a single 24HDR. Time spent to clean notes was directly related to their quality. The cleaning was finalised in parallel to the main survey phase.

3.5. Discussion

The present pilot survey tested the feasibility of the nutrition survey implementation concept based on the given specifications by the open call of tenders. The overall implementation concept was feasible in terms of sampling, participants' recruitment, data collection in three languages, standard operating and quality control procedures. Basic data management structures and data cleaning procedures were tested. Descriptive data analysis served quality control purposes only. The pilot survey highlighted details that needed improvement for the larger scale main survey that started in December 2013.

Sampling and participation

Sampling by the FSO was based on community registry data that are regularly updated. Still, almost half of the sample remained unresolved and were lost to recruitment because no contact was possible (Figure 1). A major limitation was the lack of phone numbers for about one third of the gross sample. The returned response card allowed contacting people without initially provided phone number. However, these people may have been more nutrition and health conscious than the remaining sample and thus may have introduced a selection bias. Still, participants and non-participants did not differ in most selected socio-demographic characteristics. In addition, the prevalence of overweight (36%) and obesity (15%) was comparable to other national surveys. For example, in the 2010-2011 Swiss survey on salt intake, respectively 32% and 13% were overweight and obese [25]. Based on self-reported weight and height, 41% of participants in the 2012 Swiss Health Survey were considered overweight or obese (BMI ≥ 25 kg/m2) [26].

A gross participation rate of 14% was achieved compared to the expected 25%. The latter was based on reports from other European surveys [5, 6, 27, 28] and the Swiss Health Surveys 2007 (66%) [29] and 2012 (54%) [26], both phone-administrated. However, comparability of response rates is limited due to differences in sampling strategies across Europe (community registry vs. phone registry), the way of expressing/calculating response rates, and the applied interview administration mode (face-to-face vs. phone). Other factors may be the population's appreciation of the survey topic (nutrition vs. general health) and a seasonal effect. The present pilot survey was conducted in summer and fall, both typical Swiss vacation periods. Furthermore, the need for two appointments, of which one required dislocation to a study centre, was a probable reason for refusal. Compensation payment could cover travel costs but not entirely time investment. It was not experienced as a decisive leverage by recruiters.

Recruiters were well trained but it was difficult to anticipate the full range of reactions of a population sample invited to participate in a first national nutrition survey. With time, recruiters refined strategies to convince participants and recruitment became increasingly successful. However, the main reasons for refusal, *i.e.,* lack of time and interest, were still difficult to overcome. In this view, an improved practice-informed peer-supported recruiter training for the main survey was elaborated to benefit from the lessons learnt during the pilot survey. The observed distribution of interviews across weekdays reflected a combination of responders' favourite availabilities, study centres' opening hours and conflicting bookings by recruiters (face-to-face) and field dietitians (phone). This is a known phenomenon in food consumption surveys and is making application of statistical weighting strategies necessary [5, 30-32].

Based on these experiences, the gross sample for the main survey was corrected upwards in order to reach the target sample size of 2000 participants across Switzerland in 12 months. The invitation letter with response card was kept unchanged. Additional resources were allocated to the recruitment centre, which was the key step to reach the anticipated 25% gross participation rate and *de facto* maximize representativeness of the main survey participants. A monthly lottery (CHF 300) was also introduced to boost motivation for participation. The scheduling tool was improved to gain time at recruitment, survey coordination and field dietitian levels.

Data collection procedures and instruments

Data collection procedures could be implemented as planned. Offering responders a choice of interview dates and time slots required sufficient presence and flexibility of field dietitians. Based on the pilot experience, it was decided to plan five interviews per eight hour working day. The available time per appointment was extended by 15 minutes for both face-to-face and phone interviews to ensure enough time for preparatory and follow-up work as well as regulated work breaks, independent of booking status.

Quality control concept

The multilevel quality control concept was successfully implemented and resulted in some changes in the field dietitians training and supervision. The three-part training of field dietitians was sufficient to guarantee good to high quality face-to-face and phone interviews. However, training evaluation results and repeated on-site quality controls highlighted the need for better standardization of anthropometric measures, as reported for other health professionals [33]. Additionally, 24HDR related information and question-answer sessions were recognized to be a key issue requesting more time. Consequently, for the main survey the training was extended to 4.5 days for baseline and two days for consolidation. The field dietitians' logbook entries and newly established 24HDR's question and answer document showed that food consumption across Switzerland varies and will require continuous extension of the trilingual Swiss version of GD. More structured guidance on when a specific note was needed and which information should be included was necessary. Individual feedback regarding notes was also asked by dietitians. Thus, the main survey training concept and material were adapted to consider cases that are more realistic, and to integrate pilot field dietitians as peer-co-trainers.

Central data collection quality control showed that the trilingual Swiss GD software application provided reasonable and comparable results at food level, across dietitians and administration mode. Changes in GD, namely addition of new foods and recipes as well as correction of errors were expected [7], but their implementation by FSVO/FOPH and IARC was more time consuming than usual because of the three languages. Availability of an updated Swiss version of GD was thus slightly delayed, without hampering preparation and start of the main survey. Finally, an international group of experts in dietary assessment methods and nutrition surveys from Germany, France and the Netherlands, IARC, FSO, and the menuCH team was established to discuss data handling and analyses in the main survey.

Data management and cleaning

The experiences gained by the pilot survey allowed a practice-based time estimate for the cleaning of 4000 24HDR planned for the main survey, considering IARC's recommendations on note prioritization and defined the need for additional human resources. GD file management was improved by introducing additional backup strategies. Original 24HDR files had to be kept secured until the end of the survey at three levels: the field dietitian that conducted the interview, the senior dietitian responsible for data cleaning and at the central data management centre.

Strengths and limitations

Overall, the pilot survey implementation concept of the first national nutrition survey in Switzerland proved applicable. A direct comparison with other national surveys is difficult, since to our knowledge no other country published in peer-reviewed journals information about their pilot national nutrition survey. As Switzerland is characterized by three linguistic regions, where dietary patterns are expected to differ, a representative nutrition survey of the Swiss population thus required a complex structure and logistic organization, which we could pilot only in limited ways.

First, the pilot survey was restricted to three cantons. However, despite a slightly different sampling frame the limitations of the community-registry sample data were recognized and measures were taken to increase participation in the main survey. Second, the multilingual approach required personnel with strong language skills. Dietitians had to speak the local language to interview the participants plus English to communicate with the menuCH team. This requirement could only be partially met in the professional group of dietitians and turned overall communication during training and fieldwork difficult and time-consuming. However, the complexity of the dietary assessment requires nutrition professionals, as confirmed by the positive results from the quality controls and also stated earlier [34]. Third, the core instrument, the Swiss adaptation of GD was still under construction when preparing the pilot survey. Fourth, due to timely constraints, investigators only focused on the field test of organization, recruitment and interview methods, operational reliability of instruments including quality control procedures, and the set-up of efficient and secure data management and data cleaning structures. Prior to the main survey, no extensive analyses (*e.g.*, using survey weights) of these pilot survey data were conducted; hence no detailed information on food or nutrient consumption could be provided. Time thus was recognized as the largest limitation, balanced by the strength of an experienced/knowledgeable and efficient investigator team.

Conclusion

The pilot survey was particularly important and valuable to prepare the first trilingual national nutrition survey. It allowed identifying bottlenecks and improving procedures and survey instruments. Investigators could establish an implementation concept complying with the requirements of the FSVO/FOPH and building on international nutrition survey models. The concept's comprehensive pilot application in the specific Swiss context confirmed to be the only mean to realistically estimate the investments and needs at structural, human, timely, communication, instrumental and monetary levels. On this basis, the conduct of the main survey applying a tested and slightly amended implementation concept was justified.

3.6. References

1. Federal Office of Public Health (FOPH), ed. Swiss Nutrition Policy 2013-2016. Based on the main findings of the 6th Swiss Nutrition Report. 2012, FOPH: Bern, Switzerland.
2. Federal Office of Public Health (FOPH), ed. National Programme on Diet and Physical Activity 2008-2012. 2008, FOPH: Bern, Switzerland.
3. Federal Statistical Office (FSO). Stichprobenrahmen für Personen- und Haushaltserhebungen (Swiss persons and households registry). [cited 2016 Aug 31]; Available from: http://www.bfs.admin.ch/bfs/portal/de/index/news/00/08.html.
4. European Food Safety Authority (EFSA), General principles for the collection of national food consumption data in the view of a pan-European dietary survey. EFSA Journal, 2009. 7(12): p. 1435.
5. vanRossum, C.T.M., et al., Dutch National Food Consumption Survey 2007-2010. Diet of children and adults aged 7 to 69 years. 2011, National Institute for Public Health and the Environment (RIVM): Bilthoven, The Netherlands.
6. Max Rubner-Institut (MRI), Nationale Verzehrsstudie II - Ergebnisbericht Teil 1 (2nd German Food Consumption Survey, Part 1). 2008, MRI: Karlsruhe, Germany.
7. Slimani, N., et al., The standardized computerized 24-h dietary recall method EPIC-Soft adapted for pan-European dietary monitoring. Eur J Clin Nutr, 2011. 65 Suppl 1: p. S5-15.
8. Crispim, S.P., et al., Quality assurance of the international computerised 24 h dietary recall method (EPIC-Soft). Br J Nutr, 2014. 111(3): p. 506-15.
9. Crispim, S.P., et al., Two non-consecutive 24 h recalls using EPIC-Soft software are sufficiently valid for comparing protein and potassium intake between five European centres--results from the European Food Consumption Validation (EFCOVAL) study. Br J Nutr, 2011. 105(3): p. 447-58.
10. Slimani, N., et al., Structure of the standardized computerized 24-h diet recall interview used as reference method in the 22 centers participating in the EPIC project. European Prospective Investigation into Cancer and Nutrition. Comput Methods Programs Biomed, 1999. 58(3): p. 251-66.
11. Camenzind-Frey, E. and C. Zuberbühler, menuCH - Schweizerisches Fotobuch / Livre Photo Suisse / Manuale Fotografico Svizzero (Picture book for menuCH). 2013, Bern, Switzerland: Federal Office of Public Health / Federal Food Safety and Veterinary Office.
12. Kappel, A.L., J. Amoyel, and N. Slimani, EPIC-Soft picture book for estimation of food portion sizes. 1995, Lyon, France: International Agency for Research on Cancer.
13. Gibson, R.S., Measuring food consumption of individuals. In: Gibson R.S. Principles of nutritional assessment. 2nd ed. 2005, New York, United States of America: Oxford University Press.

14. Nelson, M. and J. Haraldsdottir, Food photographs: practical guidelines II. Development and use of photographic atlases for assessing food portion size. Public Health Nutr, 1998. 1(4): p. 231-7.

15. World Health Organization. MONICA Manual, Part III: Population Survey. Section 1: Population Survey Data Component. 4.6 Height, weight, waist and hip measurement. [cited 2016 Sep 30]; Available from: http://www.thl.fi/publications/monica/manual/part3/iii-1.htm#s4-6.

16. International Physical Activity Questionnaire (IPAQ). Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire (IPAQ) - Short and Long Forms. 2005 [cited 2016 Sep 2]; Available from: http://www.academia.edu/5346814/Guidelines_for_Data_Processing_and_Analysis_of_the_International_Physical_Activity_Questionnaire_IPAQ_Short_and_Long_Forms_Contents.

17. Hagstromer, M., P. Oja, and M. Sjostrom, The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. Public Health Nutr, 2006. 9(6): p. 755-62.

18. Craig, C.L., et al., International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc, 2003. 35(8): p. 1381-95.

19. Millen, B.E. and J.A. Vernarelli, ed. Survey Research Planning and Questionnaire Design. In: Monsen E.R. and Van Horn L. Research: Successful Approaches. 3rd ed. 2008, American Dietetic Association: Chicago, United States of America.

20. Shaffer, N.M., et al., Quality control for interviews to obtain dietary recalls from children for research studies. J Am Diet Assoc, 2004. 104(10): p. 1577-85.

21. Üstun, T.B., et al., Quality assurance in surveys: standards, guidelines and procedures. In: United Nations. Household Sample Surveys in Developing and Transition Countries. 2005, World Health Organization: Geneva, Switzerland.

22. International Agency for Research on Cancer (IARC), Internal EPIC-Soft/GloboDiet training documents: Concepts & definitions / General interview techniques / Overall internal structure / Interview steps / Step-by-step Interview / Recipes / Telephone interviews 2013, IARC: Lyon, France.

23. Drijvers, J., et al., Quality Control dietary monitoring. Experiences in the Dutch National Food Consumption Survey 2007-2011. In: ICDAM 8. 2012: Rome, Italy.

24. Edwards, S., et al., Objective system for interviewer performance evaluation for use in epidemiologic studies. Am J Epidemiol, 1994. 140(11): p. 1020-8.

25. Chappuis, A., et al., Swiss survey on salt intake: main results. 2011, Service de Néphrologie et Institut Universitaire de Médecine Sociale et Préventive, Centre Hospitalier Universitaire Vaudois (CHUV): Lausanne, Switzerland.

26. Federal Statistical Office (FSO), Swiss Health Survey 2012. 2013, FSO: Neuchatel, Switzerland.

27. Lafay, L., et al., Étude Individuelle Nationale des Consommations Alimentaires 2 (INCA 2) 2006-2007 (2nd French Consumption Survey). 2009, Agence Francaise de Sécurité Sanitaire des Aliments (AFSSA): Maisons-Alfort, France.

28. Bates, B., et al., National Diet and Nutrition Survey: Results from Years 1-4 (combined) of the Rolling Programme (2008/2009 - 2011/12): Executive summary. 2014, Department of Health and the Food Standards Agency: London, United Kingdom.

29. Federal Statistical Office (FSO), Swiss Health Survey 2007. First findings. 2008, FSO: Neuchatel, Switzerland.

30. Verret, F. and S. Thomas, Effects of Uncontrolled Factors at the Collection Stage on the Canadian Community Health Survey on Nutrition. ASA Section on Survey Research Methods, 2006: p. 3801-8.

31. Danyliw, A.D., et al., Beverage intake patterns of Canadian children and adolescents. Public Health Nutr, 2011. 14(11): p. 1961-9.

32. Bailey, R.L., et al., Estimation of total usual calcium and vitamin D intakes in the United States. J Nutr, 2010. 140(4): p. 817-22.

33. Sebo, P., et al., Reliability of doctors' anthropometric measurements to detect obesity. Prev Med, 2008. 47(4): p. 389-93.

34. Schaub, A. and C. Palladino. Schlussbericht NANUSS Pilot: Ernährungsverhalten (Final report of NANUSS pilot study: Nutritional behavior). [cited 2016 Jun 7]; Available from: http://www.bag.admin.ch/themen/ernaehrung_bewegung/05192/05943/index.html?lang=de.

35. European Food Safety Authority (EFSA), Guidance on the EU Menu methodology. EFSA Journal 2014. 12(12): p. 3944.

4. menuCH public results

Title of a webpage: Food consumption. Results from menuCH 2014-2015 [German, French and Italian].

Authors: Federal Food Safety and Veterinary Office (FSVO)[1] in collaboration with Angeline Chatelan[2], Juan Manual Blanco[2], Murielle Bochud[2], Sigrid Beer-Borst[3]

Affiliations: [1] Federal Food Safety and Veterinary Office (FSVO), Bern, Switzerland, [2] Institute of Social and Preventive Medicine (IUMSP), Lausanne University Hospital (CHUV), Lausanne, Switzerland, [3] Institute of Social and Preventive Medicine (ISPM), University of Bern, Bern, Switzerland

Author contributions: FSVO conceived and translated the webpage. AC defined the food grouping in collaboration with three other nutrition experts (including SBB and members of FSVO). AC, JMB, MB conducted part of data analyses.

Publication status: Webpage published on 16.03.2017 (www.menuch.ch).

4.1. Abstract

The first national survey on food, menuCH, interviewed 2 086 adults aged 18-75 year living in Switzerland. It revealed that dietary intake of the Swiss population did not comply with the guidelines from the Swiss Food Pyramid. Sweet products and salty snacks were consumed in a much higher proportion than the recommendations. If the portions of oils, fats and nuts corresponds, to some extent, to the recommended values, those of dairy products were too low. Meat intake was threefold too large. The Swiss do not consume enough legumes, fruits and vegetables. However, they drink water, coffee and tea in sufficient quantities.

4.2. FSVO website presenting menuCH results to the public

This project, conducted in collaboration with FSVO, aimed at presenting menuCH food consumption data to the public. My tasks were to establish food group definition and to classify all consumed foods and beverages into the 75 defined food groups and calculated the average amount consumed per day per participant. In this process, I supervised other registered dietitians speaking German to proofread definitions and classifications. Results are presented on www.menuch.ch (available in German, French and Italian, see **Figures 1 and 2**). Results of the first national nutrition survey, menuCH, were announced to the public by FSVO through two press releases on 03.11.2016 (primary results) and 16.03.2017 (complete results).

Figure 1. Illustration designed by the FSVO showing the Swiss food-based dietary guidelines (*i.e.,* the six-stage Food Pyramid) and the actual food consumption in the population for the six stages of the Swiss Food Pyramid. *The illustration was established from my data analyses for mean daily consumption for 75 food groups.*

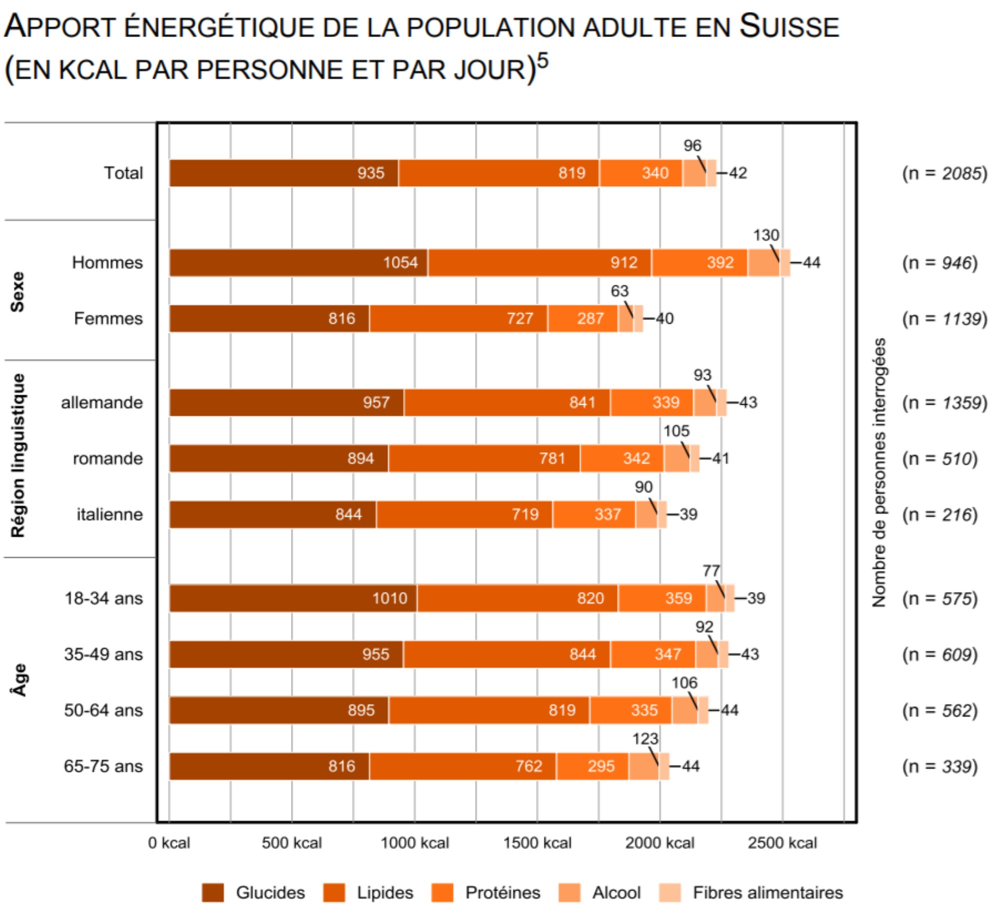


Figure 2. Illustration designed by the FSVO showing energy intake (in kcal), for the whole population, by sex, linguistic region and age group. *The illustration was established from my data analyses for mean daily macronutrient consumption.*

5. Diet across the linguistic regions

Title of the manuscript: Major Differences in Diet across Three Linguistic Regions of Switzerland: Results from the First National Nutrition Survey menuCH.

Authors: Angeline Chatelan[1], Sigrid Beer-Borst[2], Alex Randriamiharisoa[1], Jerome Pasquier[1], Juan Manual Blanco[1], Stefan Siegenthaler[3], Fred Paccaud[1], Nadia Slimani[4], Genevieve Nicolas[4], Esther Camenzind-Frey[5], Christine Anne Zuberbuehler[5], Murielle Bochud[1]

Affiliations: [1] Institute of Social and Preventive Medicine (IUMSP), Lausanne University Hospital (CHUV), Lausanne, Switzerland, [2] Institute of Social and Preventive Medicine (ISPM), University of Bern, Bern, Switzerland, [3] Health Division, Bern University of Applied Sciences, Bern, Switzerland, [4] International Agency for Research on Cancer (IARC), Lyon, France, [5] Risk Assessment Division, Scientific Evaluation Sector, Federal Food Safety and Veterinary Office (FSVO), Bern, Switzerland.

Author contributions: AC drafted the manuscript under the supervision of MB. SBB was responsible for preparation and implementation of the survey protocol and data collection. AC, StS and SBB. trained field dietitians, defined and conducted field quality controls. StS carried out GloboDiet® data cleaning. ECF and CAZ established the trilingual Swiss version of GloboDiet® and related picture book with GN and NS. ECF and CAZ linked food consumption data with the composition data, in collaboration with Premotec, GmbH. AC, SBB, and ECF defined the food groups. AC, AR, JMB and MB conducted data analyses. JP established survey weights and provided statistical advice. MB and FP were in charge of survey direction. All co-authors reviewed the manuscript, approved the final version, read and meet ICMJE criteria for authorship.

Publication status: Manuscript published in Nutrients.

Awarded by the Foundation for Social and Preventive Medicine - University of Lausanne in 2018 and as best abstracts of the SSPH+ PhD students at the Swiss Public Health Conference in 2017.

5.1. Abstract

Switzerland is a multilingual country located between Germany, France and Italy, which differ by dietary habits and related outcomes. We explored differences in food consumption as well as compliance to the Swiss food-based dietary guidelines (FBDG) across the German-, French-, and Italian-speaking regions. The 2014-2015 nationwide cross-sectional survey was conducted among a stratified random sample of 2 057 adults aged 18 to 75 years. Trained dietitians assessed food consumption via two non-consecutive 24-h dietary recalls using the international validated software GloboDiet®. Recorded foods and beverages were classified into six groups and 31 subgroups relevant for assessing compliance to the FBDG (Swiss Food Pyramid). Usual daily intake distributions were modelled and weighted for sampling design, non-response, weekdays and season. Participation rate was 38%. Significant differences across regions were observed in 18 of 31 food subgroups ($P \leq 0.01$). Weighted mean daily intakes in the German-, French- and Italian-speaking regions were, respectively, 245 g, 155 g, 140 g for soft drinks, 273 g, 214 g, 135 g for coffee, 127 g, 72 g, 109 g for milk, 32 g, 45 g, 43 g for red meat, 18 g, 29 g, 34 g for fish/seafood, 8.1 g, 6.4 g, 3.7 g for butter, and 206 g, 214 g, 168 g for vegetables. The seven FBDGs were followed by <1% of the population. Four in 10 participants met ≥3 FBDG. Eighteen percent of participants ate ≥5 portions of fruit and vegetables a day, without regional differences. Food consumption substantially differed across the three linguistic regions of Switzerland. Adherence to FBDG was uniformly low. This highlights the potential influence of culture on diet. Nutritional education along with public health interventions are needed and may be most efficient if regionally targeted.

5.2. Introduction

Switzerland is centrally located in Europe at the crossroads between Germany, France and Italy. Despite a small size, the country has three main linguistic regions: German (63%, in the north, east and centre), French (23%, in the west) and Italian (8%, in the south) [1]. In all three regions, the population has very high life expectancy [2,3], high income [2,4], universal health coverage and one of the lowest prevalence of obesity in western countries [3,5]. Chammartin [6] and Faeh [7] *et al*. observed, however, significant regional variations in mortality rates for chronic diseases known to be influenced by diet, such as coronary heart disease, stroke, type 2 diabetes, gastric and liver cancer.

Diet quality, independently of energy or macronutrient intake, is a major modifiable determinant of most chronic diseases (*e.g.*, cardio-metabolic diseases and cancers) [8,9,10]. Until 2015, Switzerland had no national survey to assess food consumption and diet quality, such as adherence to food-based dietary guidelines (FBDG). Until then, scientists and policy makers relied on national agricultural statistics [11,12], regional epidemiologic studies [13,14,15] and assessment of single nutrition-related items in the Swiss Health Survey [16,17]. These data have limitations such as high aggregation or do not allow comparison between the linguistic regions. The first national nutrition survey menuCH was conducted in 2014-2015 to fill this gap.

The European Prospective Investigation into Cancer and Nutrition (EPIC) study has shown large differences in diet between and within countries [18,19]. For example, diets in Northern European countries, including Germany, are richer in animal and processed foods compared to the ones in Italy and Greece [18]. In a multilingual country such as Belgium, the national nutrition survey also showed substantial differences in food consumption between people from the French- and the Dutch-speaking regions [20]. Due to Switzerland's multilingual situation and geographical location in-between three countries with differing dietary habits, we expected language-regional differences in food consumption. Using data from the first national nutrition survey menuCH, we investigated the differences in food consumption, as well as adherence to national FBDG, across the German-, French-, and Italian-speaking regions of Switzerland.

5.3. Methods

We followed the STROBE-nut recommendations for reporting [21].

Study Design and Sampling

The population-based cross-sectional survey was conducted in ten study centres among non-institutionalised residents of Switzerland aged 18 to 75 years from January 2014 to February

2015. The Federal Statistical Office drew a stratified random sample from the national sampling frame for person and household surveys [22]. The sample was intended to be representative for the following 35 strata (7 × 5): (1) the seven major areas of Switzerland (Lake Geneva, Midlands, Northwest, Zurich, East, Central, and South), covering the three main linguistic regions (German, French and Italian) and considering 12 cantons/states; and (2) five predefined age categories. Recruitment of participants followed a previously tested procedure [23]. In short, 13,606 individuals were invited to participate via a post-mailed letter with response card. People with known phone numbers were called by specifically trained recruiters (up to seven call attempts) to schedule an interview in a study centre. Recruiters collected information about the reasons of refusals.

Dietary Assessment

Fifteen field dietitians had six weeks of intensive training and regular retraining during data collection. They assessed food consumption through two non-consecutive 24 h dietary recalls (24HDR), as described elsewhere [23]. In brief, the first face-to-face and the second phone 24HDR (two to six weeks later) were distributed across all weekdays and seasons. The 24HDR were multiple-pass and automated using the software GloboDiet® (GD, formerly EPIC-Soft®, version CH-2016.4.10, International Agency for Research on Cancer (IARC), Lyon, France) [24,25], adapted to the Swiss food market (GD trilingual databases dated 12.12.2016, IARC, Lyon, France and Federal Food Safety and Veterinary Office, Bern, Switzerland). GD displayed food group specific descriptors allowing highly standardised description of foods and recipes, such as cooking and preservation methods, sugar and fat contents. To support survey participants in quantifying consumed amounts, a book with 119 series of six graduated portion-size pictures [26] and a set of about 60 actual household measures were used. A newly developed matching tool FoodCASE (Premotec GmbH, Winterthur, Switzerland) allowed linkage between foods, recipes and ingredients from GD with the most appropriate item from the Swiss Food Composition Database [27]. In this paper, energy and macronutrients were assessed mainly for the estimation and interpretation of misreporting.

Food Grouping and Comparisons to FBDG

The national FBDG, which is the 2011 six-stage Swiss Food Pyramid [28], was the reference for food grouping. Every stage represents a main food group with several subgroups: non-caloric beverages (three subgroups), fruit and vegetables (three subgroups), cereal products and potatoes (four subgroups), protein-based products (nine subgroups), added fats and nuts (four subgroups), sweets, salty snacks and alcohol (eight subgroups) (Table S1). Two registered dietitians independently classified recorded foods and beverages into these six main food groups and 31 subgroups according to their nutritional profile. This grouping allowed overall comparison between the guidelines for each stage of the Pyramid [28] and the actual food consumption at a population level. Finally, we selected seven FBDG with quantitative cut-offs for daily consumption to assess the proportions of people meeting these across the three linguistic regions. The selected FBDG were about the consumption of non-caloric beverages, fruit/vegetables, dairy products, meat, vegetable oil, nuts/seeds, and alcohol.

Anthropometry and Other Parameters

Body weight, height and waist circumferences were measured following international standard protocols [29] as described elsewhere [23,30]. Self-reported values were used for pregnant and lactating women or when measurements were impossible (N=34). Participants' education and physical activity level (PAL) were assessed by standardised questionnaire. The latter was assessed using the short-form International Physical Activity Questionnaire (IPAQ) [31,32] and categorised into three levels following IPAQ classifications: low, moderate and high [33].

Quality Controls

Three survey coordinators attended 88 (2%) interviews evenly distributed over the survey period, and assessed compliance to 49 survey specific standard operating procedures. Dietitians were all rated between 2.78 and 2.99 (1 = inadequate; 3 = good practice). A senior registered dietitian cleaned GD data according to the guidelines prescribed by IARC [34,35,36]. Data were also screened for inconsistencies (*e.g.*, extreme energy intakes) applying all IARC's recommended criteria [34]. Following European guidelines [37], the ratio of reported Energy Intake (mean of the two 24HDR) to Basal Metabolic Rate (EI:BMR) was calculated at a population level. To compute the percentage of misreporters, BMR per participant was estimated using Schofield equations [38]. We used weight, height, age and sex, and applied the age-specific expected PAL-values and Goldberg cut-offs [39,40]. When IPAQ data were incomplete (N=524), participants were considered as moderately active (PAL = 1.6). Under- and over-reporters were included in the analyses. More details about quality controls can be found in a separate paper [23].

Weighting

All survey results were weighted for age, sex, marital status, major area based on home address, nationality and household size to take account of the sampling design and non-response. The 2014 sampling frame was used as the reference population of the 12 selected cantons. We could not weight results for socio-economic status (*e.g.*, education) because we had no data available for non-participants. For analyses on food subgroup and macronutrient intakes, we also corrected for the uneven distribution of 24HDR over the year (Figure S1). Weighting variables included seasonality (four seasons, date between both 24HDR) and days of the week (two week days (Monday-Thursday), two weekend days (Friday-Sunday), or one week day and one weekend day). A detailed documentation about the weighting strategy is available in the open survey data repository.

Statistical Analysis

Mean daily food intakes by food subgroups and mean daily macronutrient intakes were computed out of the two 24HDR. Additionally, usual intake distributions adjusting for within individual day-to-day variation were modelled with the Statistical Program to Assess Dietary Exposure (SPADE, version 3_1, option backtrsn = 2) [41,42] implemented in R [43]. The modelling option for episodically consumed food subgroups (all subgroups, except water and vegetables) and macronutrients (only for alcohol) was applied when more than 4% of participants reported zero intakes on both recorded days. In the absence of food frequency data, usual intakes were modelled only from 24HDR. Standard errors of the means were derived from weighted bootstrap samples using age as covariate (four categories). Sensitivity analyses were performed applying a second model to derive usual intakes, *i.e.,* Multiple Source Method (MSM) [44]). We conducted survey-weighted logistic regressions to assess differences in adherence to FBDG across linguistic regions. Except for usual intake modelling, analyses were performed using STATA 14 (Stata Corporation, College Station, TX, USA). The statistical significance of differences across linguistic regions was assessed with a Wald test, applying correction for multiple testing ($P \leq 0.001$). We used ArcMap™ 10.4 (Esri, Redlands, CA, USA) to create maps describing consumption at a canton/state level and applied natural breaks (Jenks) for class definition.

Ethics

This survey was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures were approved by the corresponding regional ethics committees (lead committee in Lausanne, Protocol 26/13, approved on 12 February 2013). Written informed consent was obtained from all participants. The survey is registered (International Standard Randomised Controlled Trial Number (ISRCTN): ISRCTN16778734).

5.4. Results

Sample Characteristics

Net participation rate was 38.0% (Figure S2). Out of 3410 refusals, 1942 (57%) gave a reason for refusal. The main reasons were lack of time (56%), no interest (28%), and difficulty to reach the study centre (6%). Participants and non-participants had similar age and marital status, but participants were more frequently women and Swiss nationals (**Table 1**). Among the 2 086 survey participants, 2 057 (99%) had two complete 24HDR and were included in the analyses. The latter represent 4.6 million residents. **Table 2** shows their key characteristics. The prevalence of overweight and obesity was higher in men (41% and 13%, respectively) than in women (20% and 11%). One third of participants were at increased, or substantially increased risk, of metabolic complications, based on the waist circumference cut-off points from the World Health Organization [45]. The mean EI:BMR ratio (±SD) was 1.43 (±0.44) and similar in both sexes. We observed 17% of under-reporters overall, with a higher proportion in the Italian-speaking region.

Table 1. Characteristics of participants vs. non-participants, Swiss Nutrition Survey, 2014-2015.

Characteristics	**Non-participants**	**Participants**	**P-value**[1]
Total (*n,* %)	11 520 (84.7)	2 086 (15.3)	
Sex (*n,* %)			
Men	5 757 (50.0)	946 (45.3)	<0.001
Women	5 763 (50.0)	1 140 (54.7)	
Age (year, mean ± SD)	46.1 (±15.4)	46.8 (±15.8)	0.096
Marital status (*n,* %)			
Single	3 864 (33.5)	695 (33.3)	0.114
Married	6 118 (53.1)	1 147 (55.0)	
Widowed	332 (2.9)	43 (2.1)	
Divorced	1 177 (10.2)	194 (9.3)	
Others	29 (0.3)	7 (0.3)	
Number of household members (*n,* %)			
1 person	2 085 (18.1)	309 (14.8)	0.003
2 people	3 712 (32.2)	712 (34.1)	
3 people	2 154 (18.7)	381 (18.3)	
4 people	2 209 (19.2)	440 (21.1)	
5 or more	1 360 (11.8)	244 (11.7)	
Nationality (*n,* %)			
Swiss	8 251 (71.6)	1 801 (86.3)	<0.001
Non-Swiss	3 269 (28.4)	285 (13.7)	
Major areas (*n,* %)			
Lake Geneva (French)	2 387 (20.7)	405 (19.4)	0.029
Midlands (French & German)	2 060 (17.9)	387 (18.6)	
Northwest (German)	1 677 (14.6)	304 (14.6)	
Zurich (German)	1 497 (13.0)	304 (14.6)	
East (German)	1 333 (11.6)	251 (12.0)	
Centre (German)	1 114 (9.7)	219 (10.5)	
South (Italian)	1 452 (12.6)	216 (10.4)	

[1] *Differences between the two groups (participants vs. non-participants) were assessed using chi-square tests, respectively two-sample t test for age.*

Table 2. Description of participants, by sex and linguistic region, Swiss Nutrition Survey, 2014-2015.

Characteristics	All	Men	Women	German-speaking region[4]	French-speaking region[4]	Italian-speaking region[4]	P-value[5]
Participants with 2 complete 24HDR (n(%))	2 057 (100)	933 (45)	1 124 (55)	1 341 (65)	502 (24)	214 (10)	
People for weighted analyses (n(%))	4 627 878 (100)	2 305 141 (50)	2 322 737 (50)	3 203 780 (69)	1 167 173 (25)	256 925 (6)	
Age[1]							
(year, mean ± SD)	46.1±15.4	46.9±15.4	45.3±15.3	46.5±15.6	45.0±14.6	46.0±15.7	0.134
Age groups[1] (%)							
18-34 years old	28.5	27.4	29.6	27.5	30.7	30.2	0.007
35-49 years old	30.6	29.4	31.8	30.7	31.1	27.3	
50-64 years old	26.9	28.0	25.8	26.5	27.5	28.4	
65-75 years old	14.0	15.2	12.9	15.3	10.7	14.1	
Education: Highest degree[1] (%)							
Only primary school or no degree	4.7	4.8	4.6	3.6	6.4	10.3	<0.001
Secondary (*e.g.,* apprenticeship)	42.6	39.2	46.0	41.4	44.5	49.6	
Tertiary (*e.g.,* high technical school, university)	52.7	56.0	49.4	55.0	49.1	40.1	
Self-rep. physical activity[1] (%)							
Low	10.9	13.0	8.8	11.7	8.1	12.8	0.313
Moderate	24.9	23.2	26.7	24.8	25.0	25.8	
High	40.4	43.2	37.6	40.4	41.5	34.8	
Does not know	23.8	20.6	26.9	23.0	25.4	26.5	
Body Mass Index (BMI) [1]							
(kg/m2, mean ±SD)	25.0±4.4	25.9±3.9	24.0±4.7	25.0±4.4	24.8±4.3	25.5±4.9	0.325
BMI categories[1] (%)							
Underweight (BMI < 18.5 kg/m2)	2.4	0.9	3.8	2.5	2.1	2.1	0.948
Normal (18.5 ≤ BMI < 25 kg/m2)	54.2	43.3	65.0	53.8	55.7	52.7	
Overweight (25 ≤ BMI < 30 kg/m2)	30.5	41.2	19.8	30.8	29.9	29.9	
Obese (BMI ≥ 30 kg/m2)	12.9	14.5	11.3	12.9	12.4	15.4	
Risk of metab. complications[1] (%)							
Waist circumference: ≥94 cm (♂); ≥80 cm (♀)	33.1	35.1	31.2	34.4	28.7	37.4	0.028
Waist circumference: ≥102 cm (♂); ≥88 cm (♀)	16.5	16.7	16.3	17.2	14.2	18.8	0.208
Energy Intake : Basal Metabolic Rate[2]							
(mean ± SD)	1.43±0.44	1.44±0.47	1.42±0.41	1.46±0.44	1.39±0.43	1.33±0.50	<0.001
Energy misreporting[2,3] (%)							
Under-reporters	16.9	18.9	15.0	15.9	17.6	27.3	0.051
Plausible reporters	81.6	79.3	83.8	82.7	81.1	70.3	
Over-reporters	1.5	1.7	1.2	1.4	1.3	2.4	

[1] Means and proportions are weighted for sex, age, marital status, major area, household size, and nationality. [2] Energy intake is the mean of both 24HDR. BMR was estimated by Schofield equations. Means and proportions are weighted for sex, age, marital status, major area, household size, nationality, season and weekday of 24HDR. [3] In under-reporters 23% reported being dieting during one or both 24HDR, respectively 11% in plausible reporters, and 4% in over-reporters. [4] German-speaking region included the cantons of Aargau, Basel-Land, Basel-Stadt, Bern, Lucerne, St. Gallen, Zurich; French-speaking region: Geneva, Jura, Neuchatel, Vaud, and Italian-speaking region: Ticino. [5] Differences between the three linguistic regions were assessed using weighted chi-square tests, respectively ANOVA tests.

Food Group and Macronutrient Intakes

Large regional differences in food intake were observed in all six Food Pyramid stages, and in 18 out of 31 subgroups (**Table 3**, $P \leq 0.01$). Coffee consumption was higher in the German- than the French- and Italian-speaking regions *(P* < 0.001). Residents in the French-speaking region consumed on average 46 g more vegetables per day than in the Italian one *(P* < 0.001). Milk intake was the highest in the German-speaking (127 g/day) and the lowest in the French-speaking regions (72 g/day). Processed meat (42 g/day) was the most consumed food group among meat- and fish-based products (127 g/day) in the Swiss population. Consumption of fish, red meat and other unprocessed meat (*i.e.,* mainly poultry) was higher in both, the French- and Italian-speaking regions, than in the German one. Consumption of added fats substantially differed across linguistic regions. The largest quantities of butter and cream/fatty sauces were consumed in the German-speaking region (8.1 g/day and 36 g/day, respectively, $P < 0.001$), whereas vegetable oil was more abundant in the Italian-speaking region ($P = 0.01$). Soft drinks consumption (including fruit lemonades and sugar-free soft drinks) was much higher in the German- (245 g/day) than in the French- (155 g/day) or Italian-speaking regions (140 g/day, $P < 0.001$). **Figure 1** details the consumption at a cantonal/state level of added fats (stage 5 of the Pyramid) (a-c) and coffee, milk and soft drinks (d-f), three food subgroups with large regional differences. Sensitivity analyses found similar regional differences when usual intakes were modelled by MSM (*data not shown*).

Table 3. Food subgroup and macronutrient intake, total, and by linguistic region.

Swiss Food Pyramid stage		Daily food subgroup or nutrient intakes, *(g or kcal for energy)*	Total population 2 recalls Crude mean	Total population 2 recalls Weighted mean[1]	Total population Usual intakes[2] Weighted mean[1]	SEM[1]	Weighted P25[1]	Weighted P50[1]	Weighted P75[1]	German Usual intakes[2] Weighted mean[1]	French Usual intakes[2] Weighted mean[1]	Italian Usual intakes[2] Weighted mean[1]	Diff. (P-value)[3] Ger. vs. Fre.	Ger. vs. Ita.	Fre.vs. Ita.
1	Non-caloric beverages	Water	1199.9	1188.0	1190.6	16.6	715.2	1088.2	1612.1	1215.1	1075.3	1291.6	0.001*	0.250	0.002
		Tea	295.2	289.6	278.0	10.5	29.3	190.7	432.9	281.6	299.8	162.7	0.457	<0.001*	<0.001*
		Coffee	250.5	254.1	246.5	5.8	108.3	220.3	350.0	273.4	214.4	135.4	<0.001*	<0.001*	<0.001*
2	Fruit & vegetables	Vegetables	204.3	203.2	203.1	3.2	137.9	192.3	256.8	205.9	214.4	168.0	0.269	<0.001*	<0.001*
		Fruit	171.2	171.0	163.2	4.2	86.4	145.7	220.4	162.0	160.3	140.6	0.855	0.109	0.174
		100% juices	59.9	58.6	60.1	3.0	9.7	34.1	83.2	59.5	62.7	38.0	0.636	0.006	0.006
3	Cereal products & potatoes	Tuber products	49.6	50.7	44.8	1.8	33.8	43.4	61.6	50.9	46.9	49.7	0.470	0.863	0.721
		Bread products	113.7	114.7	111.5	2.4	72.9	102.4	140.0	118.0	101.9	95.6	0.002	0.008	0.477
		Pasta, rice	91.5	93.4	93.3	2.5	55.0	85.0	122.5	88.6	96.8	114.5	0.159	0.019	0.131
		Other cereal products	38.1	38.5	39.3	1.5	18.6	31.8	51.5	37.1	41.5	41.0	0.232	0.443	0.927
4	Protein-based products	Milk	114.1	113.4	110.6	3.9	29.1	73.5	149.9	126.6	71.5	108.9	<0.001*	0.124	0.001*
		Yogurt, fresh cheese	61.5	59.8	60.1	2.1	14.9	44.6	89.9	61.7	57.7	35.4	0.411	<0.001*	0.001*
		Soft cheese	16.5	16.2	16.1	0.7	7.4	13.4	21.9	15.7	15.2	24.7	0.740	0.002	0.002
		Hard cheese	25.7	27.0	25.6	1.1	12.1	20.8	33.6	26.8	22.8	20.2	0.101	0.029	0.445
		Red meat	36.5	37.2	36.1	1.4	20.4	32.7	46.7	31.7	44.5	42.7	<0.001*	0.085	0.787
		Other unprocessed meat	26.3	29.0	27.5	5.5	18.7	26.5	34.8	26.1	34.4	33.4	0.417	0.576	0.939
		Processed meat	42.0	42.7	42.3	1.4	20.4	36.1	54.6	43.4	36.7	43.0	0.030	0.938	0.206
		Fish, seafood	19.5	21.0	20.6	1.1	7.9	16.3	28.3	17.7	29.0	34.0	<0.001*	<0.001*	0.318
		Other protein-based products	23.6	23.9	22.3	1.2	7.9	15.3	28.5	23.7	20.7	17.5	0.293	0.126	0.453
5	Added fats & nuts	Vegetable oil	12.8	12.4	12.3	0.3	7.7	11.1	15.6	11.4	13.9	15.0	0.003	0.010	0.468
		Butter	8.1	7.9	7.6	0.3	2.7	5.8	10.5	8.1	6.4	3.7	0.004	<0.001*	<0.001*
		Cream, fatty sauces, oth. fats	30.9	31.0	30.7	1.07	18.1	27.2	39.4	35.5	22.2	16.7	<0.001*	<0.001*	0.045
		Nuts, seeds, olives	9.3	10.5	9.73	0.6	2.2	5.72	12.5	10.7	9.0	5.6	0.197	0.002	0.045
6	Sweets, salty snacks & alcohol	Added sweeteners	22.1	22.1	21.6	0.7	8.9	17.5	29.6	20.7	25.1	17.5	0.010	0.131	0.002
		Cakes, desserts, ice-cream	38.3	39.2	38.7	1.5	19.8	34.3	52.0	38.8	39.0	36.2	0.959	0.601	0.615
		Chocolate products	10.4	10.7	10.1	0.4	3.3	7.5	14.1	10.7	10.1	6.0	0.566	<0.001*	0.002
		Other sweet products	11.8	11.2	11.1	0.5	2.9	7.5	15.3	11.0	10.2	14.9	0.496	0.088	0.048
		Salty snacks	9.1	9.7	9.15	0.7	2.7	6.1	12.1	8.9	11.1	5.6	0.304	0.064	0.019
		Soft drinks	219.8	240.6	212.2	8.9	41.5	135.7	302.5	245.0	155.3	140.0	<0.001*	<0.001*	0.574
		Beer	96.7	107.3	101.5	6.8	7.1	42.5	136.7	109.5	82.2	100.3	0.072	0.651	0.415
		Wine, other alcohols	87.6	91.9	89.5	3.7	20.2	61.3	129.3	81.6	104.5	84.9	0.013	0.757	0.124
	Macronutrients	Total energy	2183.1	2225.7	2185.5	16.6	1781.8	2126.4	2526.4	2240.7	2114.3	2025.6	0.001*	<0.001*	0.155
		Total proteins	82.6	84.6	82.7	0.7	66.5	80.3	96.4	82.5	83.5	82.0	0.570	0.853	0.614
		Total carbohydrates	230.0	233.0	230.4	2.1	177.9	221.9	274.0	237.3	219.9	215.2	<0.001*	0.003	0.569
		Total fat	89.0	90.8	89.7	1.2	71.6	87.2	105.2	92.6	89.3	77.7	0.349	<0.001*	0.006
		Total alcohol	12.8	13.8	13.4	0.5	3.7	8.5	17.7	13.1	14.4	12.0	0.274	0.488	0.170

[1] Survey weights corrected for non-response based 6 socio-demographic parameters (i.e., age, sex, marital status, major area, nationality and household size) and uneven distribution of 24HDR over seasons and weekdays. [2] Usual intakes were modelled with SPADE using weighted bootstrap samples and age as covariate. [3] Differences between linguistic regions were assessed with Wald tests on the standard errors of the means from weighted bootstrap samples (P ≤ 0.001).*

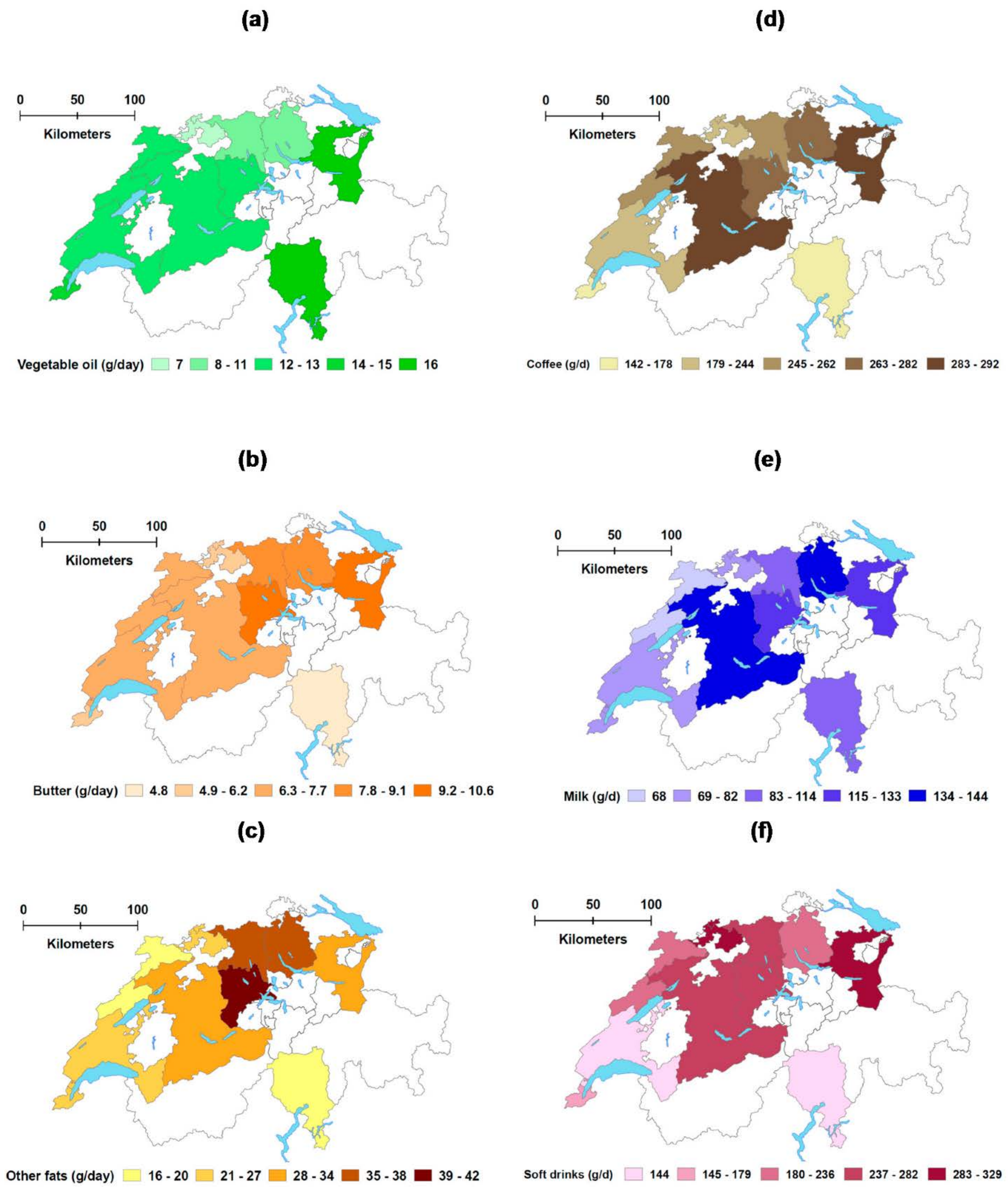


Figure 1. Daily consumption (weighted mean) of vegetable oil (**a**); butter (**b**); other fats (*i.e.,* cream, fatty sauces and other fats) (**c**); coffee (**d**); milk (**e**); and soft drinks (**f**) for 12 cantons/states.

Daily energy intake was 2 185 kcal, when both genders were considered together: *i.e.,* 2 538 and 1 899 kcal for men and women, respectively (Table S2). Proteins (83 g/day), carbohydrates (230 g/day), fat (90 g/day), and alcohol (13 g/day) contributed 15%, 42%, 37%, and 4% of total energy intake, respectively (remaining 2% for fibres). Although protein sources differed across regions (stage 4 of the Pyramid) at a food level, total protein intake was similar (82-83 g/day). Usual food and macronutrient intakes stratified by age groups are presented in Table S3.

Adherence to FBDG

Figure 2 provides an overview of the national FBDG (*i.e.,* Swiss Food Pyramid) (left) and the actual consumption for the six stages (right). At a population level, only the non-caloric beverages were consumed in accordance with the guideline. **Table 4** presents the proportion of participants who followed the FBDG. Less than 1% of the total population followed all seven selected FBDG and 41% at least three of them, without regional differences. More than three quarters of people fulfilled the guidelines to consume at least 1 L/day of non-caloric beverages. Only 18% consumed at least five portions of fruit and vegetables per day, without regional differences *(P* = 0.79 to 0.92). Nevertheless, in the German-speaking region, more residents (29%) followed the fruit specific guideline compared to the Italian-speaking region (20%, *P* = 0.013). One out of five Swiss residents reported eating daily three portions of dairy products and less than 35 g of cooked/prepared meat, which corresponds to 2-3 times a week a portion of 110 g of any type of raw meat. Population in the Italian-speaking region followed twice as much the guideline on vegetable oil than their German-speaking counterparts (*P* < 0.001). In the French-speaking region, the guideline for alcoholic beverages (72%) was less respected than in the German- (78%, *P* = 0.029) or Italian-speaking regions (79%, *P* = 0.094).

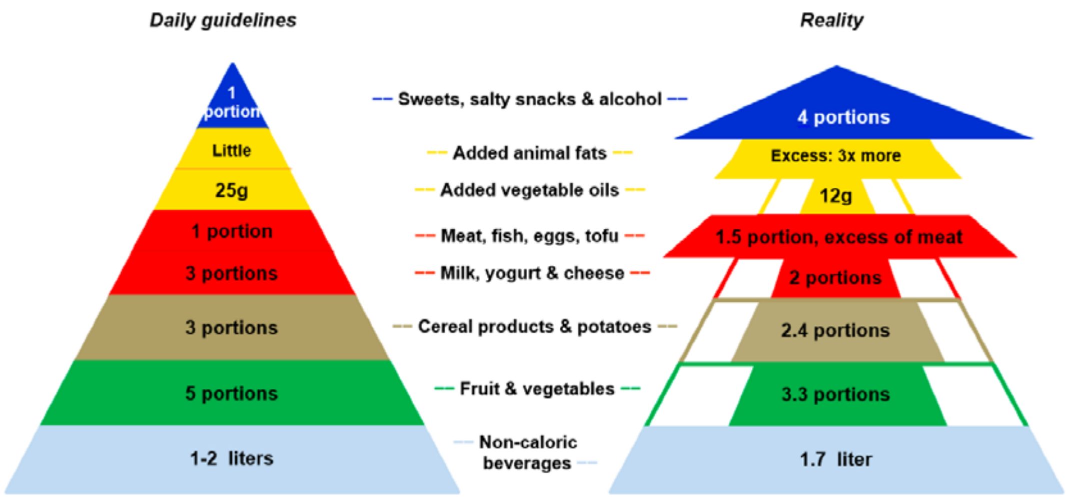


Figure 2. The daily national food-based dietary guidelines (*i.e.,* Swiss Food Pyramid) (left) compared to the actual food consumption for the six stages at a population level (right).

Table 4. Proportion of participants following the seven food-based dietary guidelines, total, by sex and linguistic region.

Food-based dietary guidelines (FBDG)[1]	Total population		Men	Women	German	French	Italian	Diff. (P-value)[4]		
	2 recalls		2 recalls		2 recalls					
	Crude %	Weighted %[3]	Weighted %[3]	Weighted %[3]	Weighted %[3]	Weighted %[3]	Weighted %[3]	Ger.vs. Fre.	Ger. vs. Ita.	Fre. vs. Ita.
Non-caloric beverages *≥ 1 L/d of water, tea and coffee*	82.8	81.9	77.6	86.2	82.6	80.4	79.8	0.359	0.340	0.864
Fruit and vegetables *≥ 5 portions/d: max. 1 portion can be provided by 2dl of 100% fruit or vegetable juices*	18.2	18.1	16.5	19.6	18.1	18.3	17.2	0.920	0.824	0.790
Vegetables *≥ 3 portions/d: 1 portion = 120g, 30g if dried, 2.5dl of soup, and 100g of sauce*	9.4	9.4	8.8	10.0	8.9	10.1	12.1	0.527	0.291	0.545
Fruit *≥ 2 portions/d: 1 portion = 120g, 30g if dried*	29.3	28.1	24.4	31.8	29.0	27.2	20.0	0.510	0.013	0.063
Dairy products *≥ 3 portions/d: 1 portion= 200ml of milk, 175g of yogurt or fresh cheese, 60g of soft cheese and 30g of hard cheese*	21.1	21.7	24.7	18.7	23.4	17.6	19.1	0.036	0.226	0.696
Total meat *≤ 35g/d of prepared meat[2]*	22.6	22.1	16.1	28.1	23.4	19.3	19.7	0.098	0.340	0.904
Red meat *≤ 35g/d of prepared meat*	62.6	62.9	56.0	69.8	64.8	57.7	63.3	0.021	0.703	0.238
Processed meat *≤ 15g/d*	43.0	41.7	31.8	51.6	40.0	46.0	43.1	0.054	0.477	0.542
Vegetable oil *≥ 25g/d*	13.8	13.5	15.2	11.7	11.8	15.4	24.5	0.077	<0.001*	0.020
Nuts, seeds, and olives *≥ 25g/d*	6.2	6.2	5.9	6.6	6.7	5.9	2.4	0.634	0.110	0.174
Alcohol *≤ 30g (♂) or ≤ 15g (♀)* of pure alcohol	77.9	76.7	75.7	77.7	78.2	72.2	79.0	0.029	0.814	0.094
All 7 FBDG above	0.1	0.1	0.0	0.2	0.1	0.0	0.0		*Not applicable*	
At least 3 FBDG	41.9	40.5	37.3	43.7	42.4	36.0	38.1	0.037	0.341	0.666

[1] Reference from the Swiss Food Pyramid. [2] 35 g of cooked/prepared meat per day corresponds to the guideline of 2-3 portions of 110g of any type of raw meat per week (max.1 portion of processed meat per week). [3] Survey weights corrected for non-response based 6 socio-demographic parameters (i.e., age, sex, marital status, major area, nationality and household size) and uneven distribution of 24HDR over seasons and weekdays. [4] Differences between linguistic regions were assessed using Wald tests on survey-weighted logistic regression coefficients (P ≤ 0.001).*

5.5. Discussion

The intake of 18 of 31 FBDG-related food subgroups significantly differed across the three main linguistic regions of Switzerland, suggesting regional specificities in the 'Swiss diet'. This is the first time such large differences could be observed in populations with similar ethnic (*i.e.,* mostly Caucasian), economic [4] and educational backgrounds living only 100-400 km apart. Regional differences in the amount of foods consumed were especially marked for coffee, vegetables, dairy products, red meat, fish/seafood, added fats, and soft drinks. This highlights the potential influence of cultural background on diet, although we cannot exclude socio-economic differences across linguistic regions may play a role. Despite large regional differences in food subgroup intake, we found no major regional differences in compliance to the national FBDG, which was uniformly low.

Regional Differences in Food Consumption

Differences in food consumption within a multilingual country were previously documented in Canada and Belgium, but to a lesser extent. The 2004 Canadian Community Health Survey did not find significant differences in food and nutrient intakes between English- and French-speaking regions [46], even though Quebecers ate less fruit and vegetables than the English-speakers [46,47]. In Belgium, noticeable differences in the French- and Dutch-speaking regions were seen for fruit (86 g vs. 121 g, respectively), fish/seafood (16 g vs. 24 g) and beer (53 g vs. 113 g) but not for water, vegetables, and soft drinks [20]. Similarly to our study, milk was also less consumed by the people living in the French-speaking region, closer to France, than those residing in the Dutch-speaking region (140 g vs. 171 g, respectively, milk and yogurt together) [20].

In spite of some food market globalisation, the Swiss residents may be influenced by dietary habits from the larger bordering countries—Germany, France and Italy. Linseisen *et al*. [48] reported similar findings for added fats in the 1995-1998 EPIC study. Using the same dietary assessment tool, they found that the Italians consumed about seven times as much vegetable oil as the Germans while as many times less butter [48]. Preferences for red meat in France and Italy, and for processed meat such as sausages in Germany, have also been observed in the EPIC study [49]. Milk consumption is another good example showing how the multilingual and cultural setting of Switzerland is in line with differences observed between bordering countries. National nutrition surveys have shown a daily milk intake among adults of 115 g in Germany [50], 75 g in France [51] and 103 g in Italy [52], while our survey showed respectively 127 g, 72 g, 109 g in the German-, French- and Italian-speaking regions. Being poorer in milk, and richer in vegetable oil, fish, and poultry, diets in the French and Italian-speaking regions have some closer characteristics to the Mediterranean diet. This may partly explain the lower cardiovascular mortality in these regions of Switzerland [6,53]. Higher alcohol consumption in the French-speaking region was previously documented by Faeh *et al*. [7], who also reported less circulatory mortality, but more alcohol consumption related deaths (*e.g.*, due to upper aerodigestive tract and liver cancers) in this region, compared to the German-speaking one.

Despite sizeable differences in food consumption, no major regional differences in BMI or waist circumference were observed. Indeed, these two indicators were relatively similar across the regions considering that the French-speaking population was slightly younger. This observation is in line with the 2012 Swiss Health Survey [3,17], where obesity prevalence across linguistic regions was shown to be similar (close to 11%).

Adherence to FBDG

FBDG deliver messages to the population about healthy eating, mainly in the context of primary prevention of diet-related chronic diseases. There is a wide consensus from observational and experimental studies that fruits, vegetables, nuts, vegetable oils, whole grains, and fish are protective against most cardio-metabolic diseases and cancers, whereas red and processed meats as well as foods rich in refined grains, added sugars, and salt should be limited [8,9,10,54]. Imamura *et al*. [55] reported overall low diet quality in adult populations from high-income countries using a systematic assessment across countries. Other studies in Western Europe [56,57], and in two Swiss French-speaking cities using a food frequency questionnaire [13,14], have found overall low compliance to the national FBDG. Therefore, low compliance to the Swiss FBDG was expected. Our survey showed that less than one out of five Swiss residents met the fruit and vegetable guidelines. Mean daily consumption of fruit and vegetables (excluding juices) was higher in Switzerland (203 and 163 g/day, respectively) than in France (144 and 131 g/day) [51]. It was however lower than in Germany (236 and 254 g/day) [50] and Italy (205 and 223 g/day) [52]. The tendency to consume more fruit in Germany compared to France and Italy was also found in our survey, which showed higher percentage of people meeting the guidelines of two portions a day in the German-speaking than in both Latin parts of Switzerland.

Comparison of compliance rate to FBDG may be difficult since each country has different food classification and cut-offs. For nutrients, such as energy, comparisons are simpler. In menuCH, mean daily energy intakes for men and women (*i.e.,* 2 538 and 1 899 kcal) were close to recommendations for moderately active adults [58]. These findings were also very similar to those found in the 2005-2007 German food consumption survey (2571 and 1915 kcal, respectively) [59] as well as the 2014-2015 French (2 462 and 1 788 kcal) [51] and the 2005-

2006 Italian surveys (2 390 and 1 939 kcal) [60]. This emphasises the value of the Swiss data and the relevance of between-country comparisons.

Strengths

The survey participants were recruited based on stratified random population-based sampling. Interviewers were extensively trained and retrained over the year of data collection to maximise standardisation and quality of 24HDR in all study centres. The use of the GloboDiet® software has eased data comparison between the three linguistic regions and other high-income countries since it is the reference tool in European food consumption surveys and it is very similar the Automated Multiple-Pass Method used in North-America. Dropouts for the second 24HDR were rare (1%). The implemented weighting strategy allowed, to some extent, the correction for non-response and uneven distribution of 24HDR over season and weekdays. Finally, differences in food consumption across the linguistic regions were assessed on usual intake distributions modelled by both SPADE and MSM (for sensitivity analyses). Both modelling methods provided similar findings, as previously tested by others [41,61].

Limitations

The survey included only the most populous cantons/states of Switzerland (Figure S3) in this first nationwide initiative for logistic and financial reasons. Participation rate was low but in the range of other food consumption surveys in Europe [50,52]. Twenty-nine percent of the sample could not be reached by recruiters due to lack of available phone numbers. Although survey participants resembled non-participants in terms of socio-demographic characteristics, we cannot exclude participation bias. Participants may have been more nutrition conscious than non-participants. Nevertheless, the prevalence of overweight (31%) and obesity (13%) in our participants was comparable to the one reported in the phone-administrated Swiss Health Survey, whose participation rate was higher [17]. Energy under-reporting was detected in 19% of men and 15% of women, which is lower or comparable with rates found in European studies applying similar calculations [50,62]. This may reflect true day-to-day variations. In menuCH, 25% of underreporting cases could be explained by the fact they were on a diet at the time of 24HDR. Social desirability and recall bias are other well-known sources of underreporting in 24HDR [63]. Lastly, we could not estimate the probability of consumption in the modelling of usual intakes because no appropriate national food frequency/propensity questionnaire was available and validated at time of the survey. For the same reason, we focused only on the amount of foods consumed per day and not the consumption frequency.

Conclusions

The first Swiss nutrition survey showed significant differences in food consumption across the three main linguistic regions, in particular for beverages (*i.e.,* non-caloric or soft drinks), protein-based products (*e.g.*, fresh dairy, red meat and fish) and added fats. This emphasises the potential influence of culture on diet in populations with similar ethnic and economic backgrounds in a high-income country, and may partly contribute to previously reported regional variations in causes of death in Switzerland [6,7]. Adherence to national FBDG was low in the population, and similar across the three regions. This may reflect lack of awareness or willingness to follow the dietary guidelines, limited practicability of current guidelines, and/or lack of access to healthy foods. Efforts should be increased to continuously raise awareness of the national FBDG and make healthier foods the easiest options in order to help the whole population adhere to the dietary recommendations. Findings from this survey will help the Swiss government elaborate targeted actions for implementation of the 2017-2024 Nutrition Strategy [64]. Finally, education messages along with public health interventions may be most efficient if regionally targeted.

5.6. References

1. Federal Statistical Office. Language – facts and figures. [cited 2017 Oct 6]; Available from: https://www.eda.admin.ch/aboutswitzerland/en/home/gesellschaft/sprachen/die-sprachen---fakten-und-zahlen.html.

2. Organisation for Economic Cooperation and Development (OECD). OECD better life index. [cited 2017 Jul 5]; Available from: http://www.oecdbetterlifeindex.org/countries/switzerland/.

3. Swiss Health Observatory. Indicators. [cited 2017 Apr 10]; Available from: http://www.obsan.admin.ch/en/indicators.

4. Federal Statistical Office. Revenus et dépenses des ménages selon la région linguistique (Household income and expenditure per linguistic region based on 2012-2014 Household Budget Survey). [cited Jun 7]; Available from: https://www.bfs.admin.ch/bfs/en/home/statistics/economic-social-situation-population/income-consumption-wealth/household-budget.assetdetail.1400471.html.

5. Organisation for Economic Cooperation and Development. Obesity and the economics of prevention: fit not fat. Key facts – Switzerland, update 2014. [cited 2017 Apr 5]; Available from: https://www.oecd.org/switzerland/Obesity-Update-2014-SWITZERLAND.pdf.

6. Chammartin, F., et al., Mortality atlas of the main causes of death in Switzerland, 2008-2012. Swiss Med Wkly, 2016. 146: p. w14280.

7. Faeh, D., et al., Culture, risk factors and mortality: can Switzerland add missing pieces to the European puzzle? J Epidemiol Community Health, 2009. 63(8): p. 639-45.

8. Mozaffarian, D., Dietary and Policy Priorities for Cardiovascular Disease, Diabetes, and Obesity: A Comprehensive Review. Circulation, 2016. 133(2): p. 187-225.

9. Kastorini, C.M., et al., The effect of Mediterranean diet on metabolic syndrome and its components: a meta-analysis of 50 studies and 534,906 individuals. J Am Coll Cardiol, 2011. 57(11): p. 1299-313.

10. World Cancer Research Fund Global Network (WCRF) / American Institute for Cancer Research (AICR), ed. Food, Nutrition, Physical activity and the Prevention of Cancer: a Global Perspective. 2007, AICR: Washington DC, United States of America.

11. Federal Office of Public Health (FOPH), ed. Swiss Nutrition Policy 2013-2016. Based on the main findings of he 6th Swiss Nutrition Report. 2012, FOPH: Bern, Switzerland.

12. Federal Office of Public Health (FOPH), ed. Sixième rapport sur la nutrition en Suisse (6th Swiss Nutrition Report). 2012, FOPH: Bern, Switzerland.

13. de Abreu, D., et al., Low compliance with dietary recommendations for food intake among adults. Clin Nutr, 2013. 32(5): p. 783-8.

14. de Abreu, D., et al., Compliance with the Swiss Society for Nutrition's dietary recommendations in the population of Geneva, Switzerland: a 10-year trend study (1999-2009). J Acad Nutr Diet, 2014. 114(5): p. 774-80.

15. Suggs, L.S., S. Della Bella, and P. Marques-Vidal, Low adherence of Swiss children to national dietary guidelines. Prev Med Rep, 2016. 3: p. 244-9.

16. de Mestral, C., et al., Fifteen-year trends in the prevalence of barriers to healthy eating in a high-income country. Am J Clin Nutr, 2017. 105(3): p. 660-668.

17. Federal Statistical Office (FSO), ed. Swiss Health Survey 2012. Overview. 2013, FSO: Neuchatel, Switzerland.

18. Slimani, N., et al., Diversity of dietary patterns observed in the European Prospective Investigation into Cancer and Nutrition (EPIC) project. Public Health Nutr, 2002. 5(6B): p. 1311-28.

19. Freisling, H., et al., Region-specific nutrient intake patterns exhibit a geographical gradient within and between European countries. J Nutr, 2010. 140(7): p. 1280-6.

20. De Ridder, K., et al., Enquête de consommation alimentaire 2014-2015 (Belgian Food Consumption Survey). 2016, Institut Scientifique de Santé Publique (WIV-ISP): Bruxelles, Belgique.

21. Lachat, C., et al., Strengthening the Reporting of Observational Studies in Epidemiology-Nutritional Epidemiology (STROBE-nut): An Extension of the STROBE Statement. PLoS Med, 2016. 13(6): p. e1002036.

22. Federal Statistical Office. Stichprobenrahmen für Personen- und Haushaltserhebungen (Swiss persons and households registry). [cited 2017 Apr 28]; Available from: https://www.bfs.admin.ch/bfs/de/home/grundlagen/volkszaehlung/volkszaehlung-teil-gesamtsystem/stichprobenrahmen.html.

23. Chatelan, A., et al., Lessons learnt about conducting a multilingual nutrition survey in Switzerland: results from menuCH pilot survey. Int J Vitam Nutr Res (in press).

24. Slimani, N., et al., The standardized computerized 24-h dietary recall method EPIC-Soft adapted for pan-European dietary monitoring. Eur J Clin Nutr, 2011. 65 Suppl 1: p. S5-15.

25. Crispim, S.P., et al., Two non-consecutive 24 h recalls using EPIC-Soft software are sufficiently valid for comparing protein and potassium intake between five European centres--results from the European Food Consumption Validation (EFCOVAL) study. Br J Nutr, 2011. 105(3): p. 447-58.

26. Camenzind-Frey, E. and C. Zuberbuehler, menuCH - Schweizerisches Fotobuch / Livre Photo Suisse / Manuale Fotografico Svizzero (Picture book for menuCH). 2014, Bern, Switzerland: Federal Office of Public Health / Federal Food Safety and Veterinary Office.

27. Federal Food Safety and Veterinary Office. Swiss Food Composition Database. [cited 2017 Jul 13]; Available from: http://naehrwertdaten.ch/request?xml=MessageData&xml=MetaData&xsl=Start&lan=en&pageKey=Start.

28. Swiss Society for Nutrition / Federal Food Safety and Veterinary Office. Pyramide alimentaire suisse 2011 (Swiss Food Pyramid 2011). [cited 2017 Jul 16]; Available from: http://www.sge-ssn.ch/fr/toi-et-moi/boire-et-manger/equilibre-alimentaire/pyramide-alimentaire-suisse/.

29. World Health Organization. MONICA Manual, Part III: Population Survey. Section 1: Population Survey Data Component. 4.6 Height, weight, waist and hip measurement. [cited 2017 Jul 1]; Available from: http://www.thl.fi/publications/monica/manual/part3/iii-1.htm#s4-6.

30. Bochud, M., et al., Anthropometric characteristics and indicators of eating and physical activity behaviors in the Swiss adult population. Results from menuCH 2014-2015. 2017, Institute of Social and Preventive Medicine (on behalf of Federal Office of Public Health and the Food Safety and Veterinary Office): Lausanne, Switzerland.

31. Hagstromer, M., P. Oja, and M. Sjostrom, The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. Public Health Nutr, 2006. 9(6): p. 755-62.

32. Craig, C.L., et al., International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc, 2003. 35(8): p. 1381-95.

33. International Physical Activity Questionnaire. Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire - Short and Long Forms. [cited 2017 Mar 17]; Available from: http://www.academia.edu/5346814/Guidelines_for_Data_Processing_and_Analysis_of_the_International_Physical_Activity_Questionnaire_IPAQ_Short_and_Long_Forms_Contents.

34. Crispim, S.P., et al., Quality assurance of the international computerised 24 h dietary recall method (EPIC-Soft). Br J Nutr, 2014. 111(3): p. 506-15.

35. International Agency for Research on Cancer (IARC), GloboDiet Data cleaning protocol: draft version. 2013, IARC: Lyon, France.

36. Crispim, S., Quality control and data handling of the Epic-Soft 24-HDR interviews. 2013, International Agency for Research on Cancer: Lyon, France.

37. European Food Safety Authority (EFSA), Guidance on the EU Menu methodology. Appendix 8.2.1. Example of a protocol for identification of misreporting (under- and overreporting of energy intake) based on the PILOT-PANEU project. EFSA Journal 2014. 12(12): p. 3944.

38. Schofield, W.N., Predicting basal metabolic rate, new standards and review of previous work. Hum Nutr Clin Nutr, 1985. 39: p. Suppl 1:5-41.

39. Goldberg, G.R., et al., Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. Eur J Clin Nutr, 1991. 45(12): p. 569-81.

40. Black, A.E., Critical evaluation of energy intake using the Goldberg cut-off for energy intake: basal metabolic rate. A practical guide to its calculation, use and limitations. Int J Obes Relat Metab Disord, 2000. 24(9): p. 1119-30.

41. Souverein, O.W., et al., Comparing four methods to estimate usual intake distributions. Eur J Clin Nutr, 2011. 65 Suppl 1: p. S92-101.

42. Dekkers, A.L., et al., SPADE, a new statistical program to estimate habitual dietary intake from multiple food sources and dietary supplements. J Nutr, 2014. 144(12): p. 2083-91.

43. R Core Team. R: A language and environment for statistical computing. [cited 2017 Jul 31]; Available from: http://www.R-project.org/.

44. Harttig, U., et al., The MSM program: web-based statistics package for estimating usual dietary intake using the Multiple Source Method. Eur J Clin Nutr, 2011. 65 Suppl 1: p. S87-91.

45. World Health Organization (WHO), Waist Circumference and Waist-Hip Ratio: Report of a WHO Expert Consultation. 2008, WHO: Geneva, Switzerland.

46. Batal, M., et al., Comparison of dietary intake between Francophones and Anglophones in Canada: data from CCHS 2.2. Can J Public Health, 2013. 104(6 Suppl 1): p. S31-8.

47. Garriguet, D., Overview of Canadians' Eating Habits. 2006, Statistics Canada: Health Statistics Division: Ottawa, Canada.

48. Linseisen, J., et al., Consumption of added fats and oils in the European Prospective Investigation into Cancer and Nutrition (EPIC) centres across 10 European countries as assessed by 24-hour dietary recalls. Public Health Nutr, 2002. 5(6B): p. 1227-42.

49. Linseisen, J., et al., Meat consumption in the European Prospective Investigation into Cancer and Nutrition (EPIC) cohorts: results from 24-hour dietary recalls. Public Health Nutr, 2002. 5(6B): p. 1243-58.

50. Heuer, T., et al., Food consumption of adults in Germany: results of the German National Nutrition Survey II based on diet history interviews. Br J Nutr, 2015. 113(10): p. 1603-14.

51. Agence nationale de sécurité sanitaire de l'alimentation de l'environnement et du travail (ANSES), Étude individuelle nationale des consommations alimentaires 3 (INCA 3) (3rd French Food Consumption Survey). 2017, ANSES: Maisons-Alfort, France.

52. Leclercq, C., et al., The Italian National Food Consumption Survey INRAN-SCAI 2005-06: main results in terms of food consumption. Public Health Nutr, 2009. 12(12): p. 2504-32.

53. Muller-Nordhorn, J., et al., An update on regional variation in cardiovascular mortality within Europe. Eur Heart J, 2008. 29(10): p. 1316-26.

54. World Cancer Research Fund International. Animal foods. Limit red meat and avoid processed meat. [cited 2017 Apr 16]; Available from: http://www.wcrf.org/int/research-we-fund/cancer-prevention-recommendations/animal-foods.

55. Imamura, F., et al., Dietary quality among men and women in 187 countries in 1990 and 2010: a systematic assessment. Lancet Glob Health, 2015. 3(3): p. e132-42.

56. Alkerwi, A., et al., Population compliance with national dietary recommendations and its determinants: findings from the ORISCAV-LUX study. Br J Nutr, 2012. 108(11): p. 2083-92.

57. Diethelm, K., et al., Food intake of European adolescents in the light of different food-based dietary guidelines: results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. Public Health Nutr, 2012. 15(3): p. 386-98.

58. Swiss Society for Nutrition (SGE), Austrian Society for Nutrition (OEGE), and German Society for Nutrition (DGE), D-A-CH Referenzwerte für die Nährstoffzufuhr (Reference Daily Intake for Germany, Austria and Switzerland). 2nd ed. 2015, Bonn, Germany: SGE, OEGE, DGE.

59. Max Rubner-Institut (MRI), Nationale Verzehrsstudie II - Ergebnisbericht Teil 2 (2nd German Food Consumption Survey, Part 2). 2008, MRI: Karlsruhe, Germany.

60. Sette, S., et al., The third Italian National Food Consumption Survey, INRAN-SCAI 2005-06--part 1: nutrient intakes in Italy. Nutr Metab Cardiovasc Dis, 2011. 21(12): p. 922-32.

61. Laureano, G.H., et al., Comparison of the ISU, NCI, MSM, and SPADE Methods for Estimating Usual Intake: A Simulation Study of Nutrients Consumed Daily. Nutrients, 2016. 8(3): p. 166.

62. Ferrari, P., et al., Evaluation of under- and overreporting of energy intake in the 24-hour diet recalls in the European Prospective Investigation into Cancer and Nutrition (EPIC). Public Health Nutr., 2002. 5(6b): p. 1329-1345.

63. Archer, E., G.A. Hand, and S.N. Blair, Validity of U.S. nutritional surveillance: National Health and Nutrition Examination Survey caloric energy intake data, 1971-2010. PLoS One, 2013. 8(10): p. e76632.

64. Federal Food Safety and Veterinary Office (FSVO), Swiss Nutrition Policy 2017–2024. 2017, FSVO: Bern, Switzerland.

5.7. Supplementary material

Table S1. Description of foods and beverages included in each food group by Swiss Food Pyramid stage.

Swiss Food Pyramid stage		Food subgroup name	Foods included in this group
Non-caloric beverages	1	Water	All types of water (*e.g.,* tap, mineral, still, carbonated), *consumed 99 of times without added sugars/artificial sweeteners.*
	2	Tea	Tea, herbal and fruit tea, *consumed 98 of times without added sugars/artificial sweeteners.*
	3	Coffee	Coffee (*e.g.,* instant, from capsules), and coffee with milk or cream (*e.g.,* cappuccino), coffee substitutes (*e.g.,* chicory), *consumed 98 of times without added sugars/artificial sweeteners.*
Fruit & vegetables	4	Vegetables	All types of vegetables, green leaves, sprouts, mushrooms, seaweeds, sweet corn, snow peas, fresh green beans, and onions: raw, cooked, dried, canned, in puree, pickled, in soups, in sauce (*e.g.,* tomato sauce), on pizza and quiches, and in sandwiches. Except: avocadoes, olives, herbs, vegetable juices, nor if contained in small amounts in salty snacks, bread, nor sauces.
	5	Fruit	All types of fruit: raw, cooked, dried, in puree/compote, and in pies made essentially with fruit (*e.g.,* apples in apple pies). Except: fruit juices, fruit jams, candied fruit, nor if contained in small amounts in yogurts, cakes, ice-cream nor other sweets.
	6	100% juices	100% fruit and vegetable juices, and smoothies, *without added sugars.*
Cereal products & potatoes	7	Tuber products	All types of unprocessed tubers (*e.g.,* potatoes, sweet potatoes) and potato products (*e.g.,* rösti, gnocchi, French fries, mashed potatoes).
	8	Bread products	All types of bread (*e.g.,* baguette, bread rolls, milk bread), flat bread, croissants, and crisp bread (*e.g.,* rice crackers, Swedish rolls). Except: stuffed croissants and sweet pastries (*e.g.,* chocolate croissants).
	9	Pasta and rice	Plain pasta (*e.g.,* penne, spaghetti), stuffed pasta (*e.g.,* ravioli, tortellini), schupfnudeln, spatzli, rice and rice noodles.
	10	Other cereal products	Natural cereal flakes and bran, oatmeal, natural birchermuesli mixes, dried wheat germs, *all without added sugars/artificial sweeteners and without major food processing*, legumes, wheat and other cereal grains (*e.g.,* barley, quinoa), cereal semolina, flours and starches, and all types of dough.
Protein-based products	11	Milk	Mammals' milk, branded fermented milk drinks, yogurt drink and buttermilk, *in liquid form, consumed 96 of times without added sugars/artificial sweeteners.*
	12	Yogurt and fresh cheese	Mammals' yogurt, branded fermented milk and kefir, fresh cheese (*e.g.,* quark, cottage cheese, ricotta), *in semi-solid form, consumed 53 of times with added sugars/artificial sweeteners.*
	13	Soft cheese	Mammals' spread cheese, processed/melted cheese, and soft cheese.
	14	Hard cheese	Mammals' hard cheese.
	15	Red meat	Fresh meat and offal from beef, veal, pork, lamb, mutton, horse, goat, rabbit, and wild red meat (*e.g.,* venison/deer).

	16	Other unprocessed meat	Fresh meat and offal from chicken, turkey, duck, goose, ostrich, frog, and unprocessed meat and offal from any unspecified animals.
	17	Processed meat	Sausages, cold cuts, smoked and cured meat (*e.g.,* ham, bacon, salami, corned beef, beef jerky), meat-based sauces (*e.g.,* Bolognese sauce), and meat-based spread (*e.g.,* liver spread).
	18	Fish and seafood	Fresh fish, seafood and snails, and processed fish and seafood products (*e.g.,* fish in crumb, surimi).
	19	Other protein-based products	Eggs, milk and yogurt substitutes (*e.g.,* soya milk), tofu, quorn, and other vegetarian products (*e.g.,* vegetarian sausages), dietetic products rich in proteins (*e.g.,* meal replacements, protein shakes). Except: eggs contained in small amounts in cakes nor salty snacks, nor sauces.
Added fats & nuts	20	Vegetable oil	Added vegetable oils (*e.g.,* rapeseed oil, olive oil, sunflower oil) or in dressing sauces (*e.g.,* French dressing, Italian dressing, estimated percentage of vegetable oils in dressings: 40).
	21	Butter	Added butter to cook and spread on bread.
	22	Cream, fatty sauces and other fats	Mammals' cream, margarine, coco fat, added animal fats (*e.g.,* pig fat), any unspecified added fats, mascarpone, sauces rich in oil or butter (*e.g.,* mayonnaise, pesto, sauce café de Paris), other sauces rich in cream or other fats (*e.g.,* carbonara, cocktail sauce, hummus, satay sauce), and coco milk.
	23	Nuts, seeds, and olives	Dried nuts and seeds (*e.g.,* almonds, coconut, pumpkin seeds), olives, avocadoes, guacamole, *all with or without salt.*
Sweets, salty snacks & alcohol	24	Added sweeteners	Beet and cane sugar, jams, jelly, honey, syrups, polyols, sweet sauces (*e.g.,* caramel and chocolate sauce, maple syrup), sweet spreads (*e.g.,* chocolate spread, peanut butter), sweet topping (*e.g.,* icing), and chocolate powder. Except: stevia and artificial sweeteners.
	25	Cakes, desserts, ice-cream	Ice-cream, sorbet, iced cakes, desserts made with dairy products (*e.g.,* pudding, chocolate mousse, tiramisu), sweet cakes, pies and tarts (*e.g.,* brownies, lemon cakes, muffins), and sweet pastries (*e.g.,* chocolate croissants, doughnuts, waffles).
	26	Chocolate products	Pure chocolate, chocolate products and confectionary made with chocolate (*e.g.,* filled chocolate, pralines, branded chocolate bars).
	27	Other sweet products	Sweet and dried biscuits (*e.g.,* shortbread, amaretto, chocolate chip cookies), branded breakfast cereals (*e.g.,* corn-flakes) and industrial birchermuesli mixes, *processed and with added sugars/artificial sweeteners,* sweets and confectionery (*e.g.,* marzipan, candied fruit, lollipop, marshmallows, nougat), sweet and sports cereal bars (*e.g.,* energy bars).
	28	Salty snacks	Crisps, salty popcorn, dried salty crackers (*e.g.,* golden fish biscuits, sticks, pretzels), cocktail canapés, crostini/bruschetta, spring rolls, ham croissants, and sausage rolls.
	29	Soft drinks	Sweetened and sugar-free soft drinks, sports and energy drinks, fizzy drinks, ice tea, diluted syrup, drinks made with fruit juices (*e.g.,* lemonades, nectars), and alcoholic drink substitutes (*e.g.,* alcohol-free beers), 'schorle' (*i.e.,* juices mixed with water), *consumed 18 of times with artificial sweeteners only.*
	30	Beer	Beers (with alcohol), ciders and shandy.
	31	Wine and other alcoholic beverages	White and red wine, champagne, wine products (*e.g.,* sangria, punch/bowle with alcohol), port, vermouths, liquors, spirits, cocktails and long drinks, 'alcopops', and any other alcoholic drinks (*e.g.,* coffee with spirit).

Table S2. Food subgroup and macronutrient intake, by sex.

Daily food subgroup or nutrient intakes, *(g or kcal for energy)*	Men				Women			
	Usual intakes[1]				Usual intakes[1]			
	Weighted mean	Weighted P25	Weighted P50	Weighted P75	Weighted mean	Weighted P25	Weighted P50	Weighted P75
Water	1218.2	672.9	1099.4	1632.6	1221.5	755.2	1136.4	1593.9
Tea	194.6	2.3	68.3	314.1	362.8	115.6	301.1	526.5
Coffee	267.0	128.8	237.6	369.3	228.1	90.3	203.9	330.3
Vegetables	197.2	133.2	184.6	247.8	209.5	141.4	196.5	263.9
Fruit	147.4	76.6	128.7	198.5	173.7	97.2	157.8	232.4
100% juices	59.7	12.3	37.0	82.3	57.2	7.9	32.4	81.5
Tuber products	54.8	33.7	51.8	72.8	44.8	35.3	43.4	52.8
Bread products	137.5	95.6	129.1	170.3	90.4	61.9	84.6	112.6
Pasta and rice	115.1	72.2	106.6	148.7	72.6	42.7	67.5	96.7
Other cereal products	39.5	18.4	31.7	51.9	37.5	18.3	30.7	49.0
Milk	120.1	27.4	74.1	161.0	105.7	33.9	78.0	146.3
Yogurt and fresh cheese	58.5	9.0	38.5	91.2	61.4	21.2	48.8	88.9
Soft cheese	19.3	7.6	15.7	27.1	13.8	7.4	11.9	18.1
Hard cheese	29.6	13.5	23.3	38.5	20.8	10.8	17.8	27.5
Red meat	47.6	28.1	42.5	61.4	25.9	15.3	23.2	33.5
Other unprocessed meat	33.8	17.0	29.0	45.5	26.0	22.9	25.7	28.9
Processed meat	55.5	30.4	48.5	73.1	29.6	14.4	24.5	39.2
Fish and seafood	21.7	6.5	15.8	30.9	19.6	9.3	16.1	26.1
Other protein-based products	23.4	8.5	16.1	29.7	22.1	7.5	14.9	28.2
Vegetable oil	12.6	7.0	10.8	16.1	12.1	8.5	11.4	14.9
Butter	8.5	2.9	6.7	12.1	6.6	2.6	5.1	9.0
Cream, fatty sauces and other fats	35.1	21.4	31.2	44.5	26.0	15.0	23.0	33.6
Nuts, seeds, olives	9.1	1.9	4.7	10.9	11.3	2.8	7.1	14.7
Added sweeteners	26.6	10.4	21.4	36.8	18.7	8.5	15.7	25.6
Cakes, desserts, ice-cream	43.2	20.4	38.3	60.5	34.5	19.5	30.5	45.0
Chocolate products	10.1	2.3	6.7	14.3	10.5	4.5	8.4	14.2
Other sweet products	12.2	2.0	7.1	17.1	11.0	3.8	8.0	14.8
Salty snacks	10.8	2.6	6.8	14.4	7.8	3.5	6.3	10.4
Soft drinks	290.3	60.7	206.5	430.3	154.9	33.0	94.4	212.8
Beer	185.8	31.4	109.2	259.4	31.8	3.4	15.3	42.9
Wine and other alcoholic beverages	106.1	24.2	73.7	154.2	71.5	17.4	49.7	103.5
Total energy	2537.8	2104.6	2487.9	2914.1	1899.2	1624.4	1871.7	2145.2
Total proteins	98.3	80.5	96.4	114.0	70.1	59.4	68.6	79.3
Total carbohydrates	264.8	206.8	256.5	313.6	202.2	162.9	197.5	236.3
Total fat	101.9	81.3	99.3	119.6	79.2	65.6	77.6	91.2
Total alcohol	18.4	6.9	13.7	24.8	8.7	2.0	5.0	11.1

[1] *Usual intakes were modelled with SPADE using age as covariate. Survey weights corrected for non-response based 6 socio-demographic parameters (i.e., age, sex, marital status, major area, nationality and household size) and uneven distribution of 24HDR over seasons and weekdays.*

Table S3. Food subgroup and macronutrient intake, by age.

Daily food subgroup or nutrient intakes, *(g or kcal for energy)*	18-34 years old		35-49 years old		50-64 years old		65-75 years old	
	Usual intakes[1]		Usual intakes[1]		Usual intakes[1]		Usual intakes[1]	
	Weighted mean	Weighted P50	Weighted mean	Weighted P50	Weighted mean	Weighted P50	Weighted mean	Weighted P50
Water	1471.4	1382.4	1267.5	1176.2	1083.7	990.8	923.1	832.5
Tea	223.2	120.6	264.6	174.4	298.3	219.8	361.7	301.4
Coffee	152.0	116.5	263.5	238.2	303.2	275.4	276.9	249.7
Vegetables	185.2	172.2	207.1	194.5	213.5	200.3	216.7	204.1
Fruit	127.3	110.4	151.7	135.4	181.3	164.8	214.9	199.2
100% juices	62.7	34.4	60.5	33.7	58.2	33.8	58.1	35.0
Tuber products	49.7	47.6	47.0	44.6	48.2	45.7	53.4	50.9
Bread products	115.2	105.7	112.9	104.0	109.2	100.4	106.6	98.0
Pasta and rice	111.3	103.4	99.6	92.0	81.2	73.5	71.8	64.6
Other cereal products	46.3	38.4	41.1	33.8	36.0	29.2	29.3	23.5
Milk	127.7	86.8	115.8	79.0	100.0	65.9	89.7	59.1
Yogurt and fresh cheese	52.1	35.7	54.4	38.2	66.2	52.0	73.7	60.9
Soft cheese	15.6	12.9	17.0	14.2	16.0	13.2	15.6	13.1
Hard cheese	20.5	16.4	25.8	21.2	27.2	22.3	31.3	26.1
Red meat	33.3	29.1	38.2	33.8	36.1	31.9	35.9	31.6
Other unprocessed meat	37.0	35.2	29.4	28.0	23.3	22.0	17.0	15.9
Processed meat	46.2	39.2	41.4	35.0	38.2	32.1	36.8	30.8
Fish and seafood	18.0	13.5	22.8	18.1	22.7	17.9	17.7	13.0
Other protein-based products	25.3	17.6	22.8	15.8	20.8	14.3	18.8	12.7
Vegetable oil	11.5	10.3	12.6	11.4	12.7	11.4	12.4	11.1
Butter	5.4	3.8	6.9	5.4	8.2	6.6	11.4	9.7
Cream, fatty sauces and other fats	31.7	28.0	31.8	28.1	30.5	27.0	29.5	26.1
Nuts, seeds, olives	10.0	5.8	10.1	5.9	9.6	5.7	8.9	5.2
Added sweeteners	18.0	14.1	21.4	17.4	22.2	18.2	26.8	22.7
Cakes, desserts, ice-cream	36.6	31.4	41.4	36.6	38.0	33.3	37.1	32.8
Chocolate products	12.3	9.5	11.3	8.7	8.4	6.2	7.0	4.9
Other sweet products	11.0	7.2	11.2	7.5	10.8	7.3	11.4	8.1
Salty snacks	12.9	9.5	10.1	7.2	6.0	3.7	6.4	4.3
Soft drinks	317.4	244.0	219.7	149.9	161.7	100.1	106.0	51.3
Beer	137.2	68.6	118.0	59.8	80.5	33.3	45.7	10.5
Wine and other alcoholic beverages	55.9	27.8	81.2	54.0	107.0	81.1	132.5	107.6
Total energy	2254.6	2195.9	2222.4	2164.4	2153.7	2096.1	2052.8	1999.3
Total proteins	85.2	82.7	85.0	82.5	81.6	79.2	76.2	74.0
Total carbohydrates	251.5	243.3	234.9	226.8	219.4	211.5	205.3	198.0
Total fat	90.8	88.3	91.2	88.7	88.7	86.2	86.7	84.4
Total alcohol	9.4	5.7	12.5	8.2	15.3	10.3	18.7	12.9

[1]Usual intakes were modelled with SPADE. Survey weights corrected for non-response based 6 socio-demographic parameters (i.e., age, sex, marital status, major area, nationality and household size) and uneven distribution of 24HDR over seasons and weekdays.

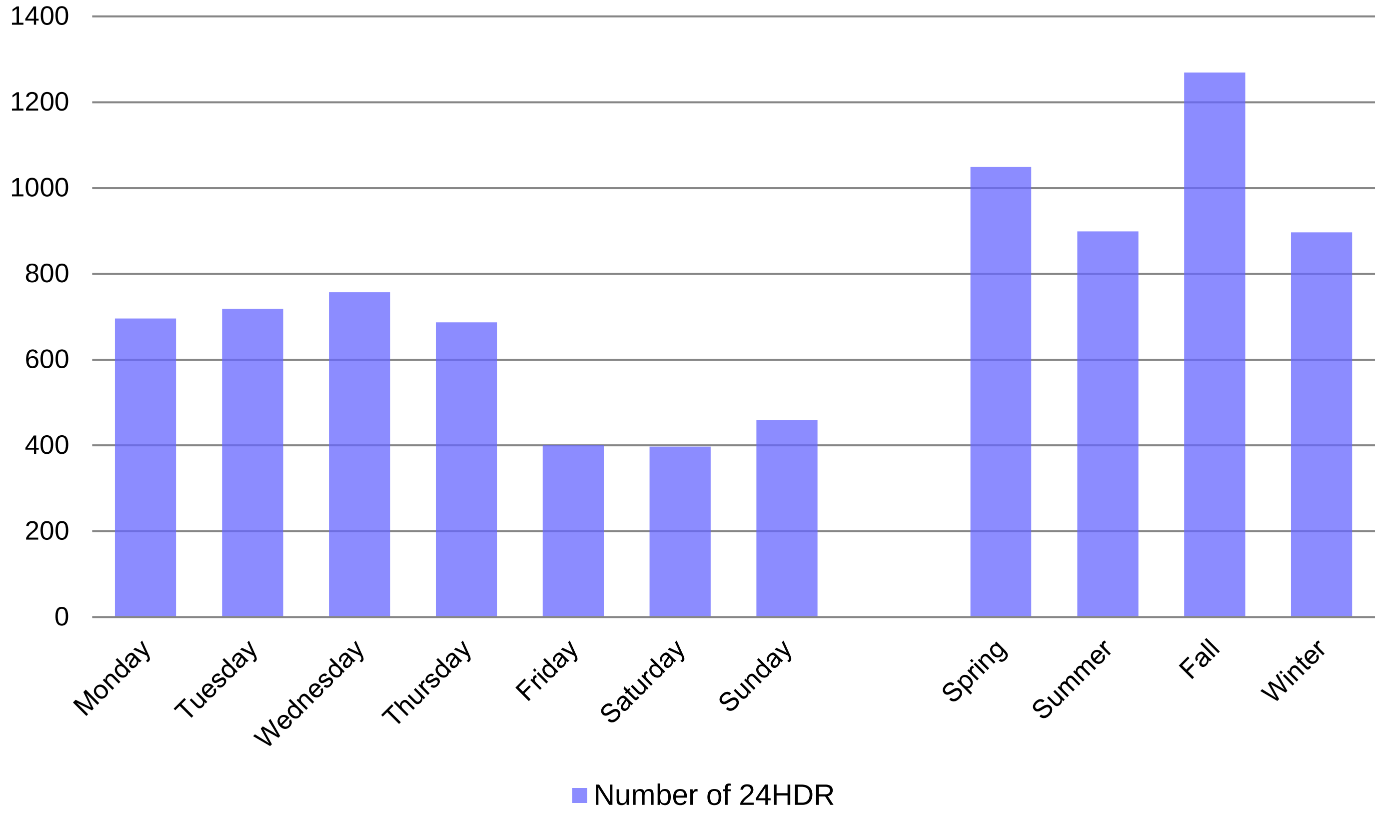


Figure S1. Distribution of 24 HDR days (N=4 114) over weekdays and seasons.

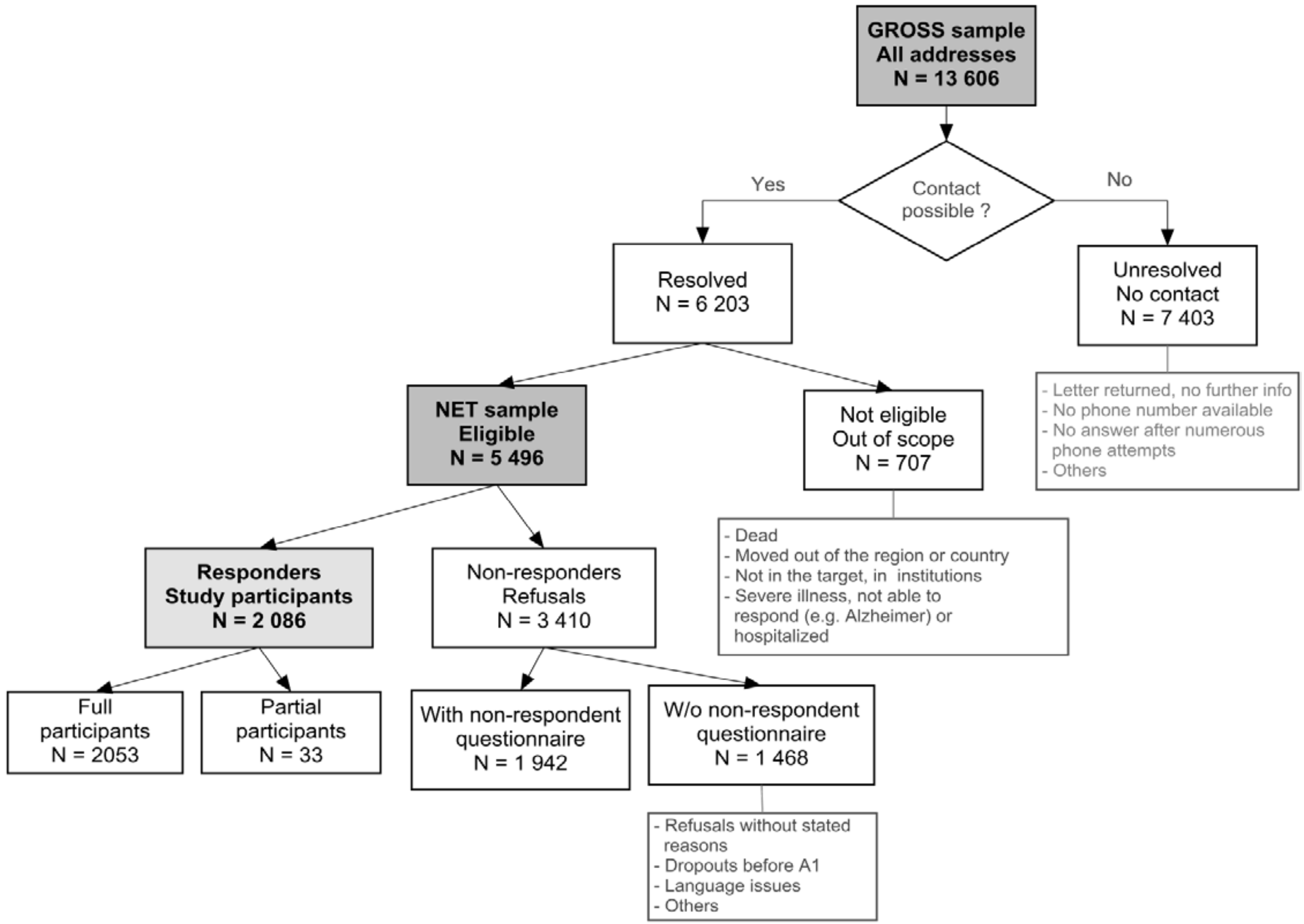


Figure S2. Participation classification, following 2014 European Food Safety Authority's classification recommendations for food consumption surveys. *Full participation implies the entire dataset was available: two 24HDR, a complete questionnaire, measured (or self-reported when impossible) weight and height.*

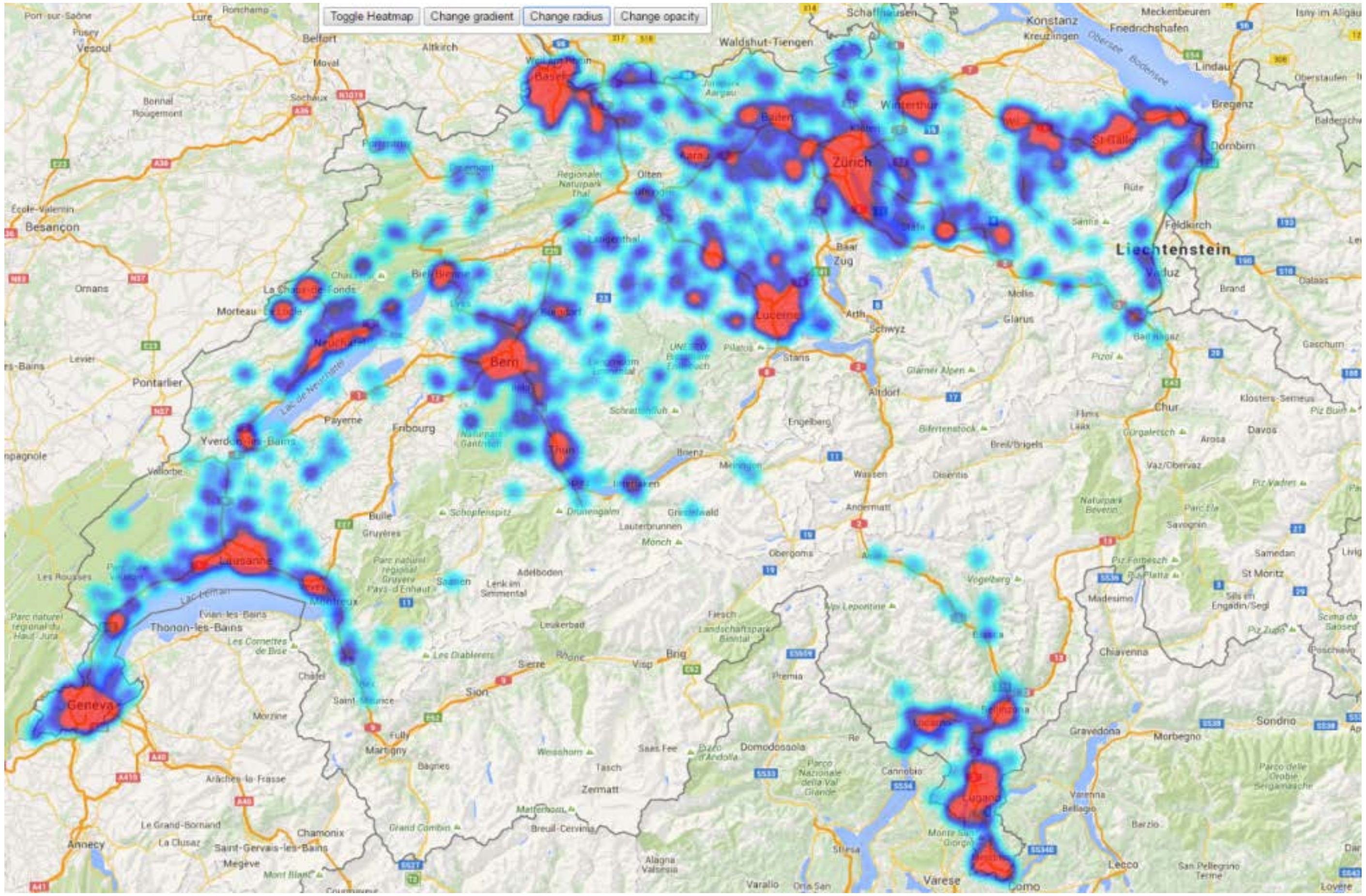


Figure S3. Heatmap from Switzerland presenting the survey participants' geographical provenance based on the addresses provided by the Federal Statistical Office. *Geolocalization through Google Maps.*

6. Breakfast and abdominal obesity

Title of the manuscript: Association between breakfast composition and abdominal obesity in the Swiss adult population eating breakfast regularly.

Authors: Angeline Chatelan[1], Katia Castetbon[2], Jerome Pasquier[1], Chloe Allemann[1], Alexandre Zuber[1], Esther Camenzind-Frey[3], Christine Anne Zuberbuehler[3], Murielle Bochud[1].

Affiliations: [1] Institute of Social and Preventive Medicine (IUMSP), Lausanne University Hospital (CHUV), Lausanne, Switzerland, [2] Université libre de Bruxelles, Ecole de Santé Publique, Centre de Recherche en Epidémiologie, Bruxelles, Belgium, [3] Risk Assessment Division, Scientific Evaluation Sector, Federal Food Safety and Veterinary Office (FSVO), Bern, Switzerland.

Author contributions: AC, KC and MB conceived the manuscript. AC defined the methodology, analysed the data and drafted the manuscript. JP advised for the data analyses. CA and AZ were involved in literature review and primary data analyses. ECF and CAZ reviewed and complemented the parts of the manuscript about the Swiss version of GloboDiet® and linkage of the food consumption data with the Swiss Food Composition Database. All co-authors reviewed the manuscript and provided critical recommendations, and approved the final manuscript.

Publication status: Manuscript published in International Journal of Behavioral Nutrition and Physical Activity.

6.1. Abstract

Evidence from experimental and observational studies is limited regarding the most favourable breakfast composition to prevent abdominal fat accumulation. We explored the association between breakfast composition (*a posteriori* derived dietary patterns) and abdominal obesity among regular breakfast eaters from a Swiss population-based sample. The cross-sectional survey assessed diet using two 24-hour dietary recalls in a nationally representative sample of adults aged 18 to 75 years. We derived dietary patterns using principal component analysis based on the intake of 22 breakfast-specific food groups. All regular breakfast eaters were predicted an individual score for each identified pattern, and then classified into tertiles (T1, T2, T3). We defined abdominal obesity as waist-to-hip ratio (WHR) ≥0.9 in men and ≥0.85 in women. Logistic models were adjusted for socio-demographic characteristics, relevant nutrition- and health-related behaviours, and diet quality during the rest of the day. Of the 2019 included survey participants, 1 351 (67%) were regular breakfast eaters. Among them, we identified three breakfast types: 1) 'traditional' - white bread, butter, sweet spread, 2) 'prudent' - fruit, unprocessed and unsweetened cereal flakes, nuts/seeds, yogurt, and 3) 'western' - processed breakfast cereals, and milk. The 'prudent' breakfast was negatively associated with abdominal obesity. After full adjustment, including diet quality during the rest of the day, the association was weaker (T3 vs. T1: OR 0.72, 95%CI: 0.47 to 1.08). People taking a 'prudent' breakfast (in T3) had 1.2% lower WHR compared to people taking a breakfast distant from 'prudent' (in T1) (*P* = 0.02, fully adjusted model with continuous log-WHR). We found no association between 'traditional' or 'western' breakfasts and WHR (OR 1.00, 95%CI: 0.67 to 1.50 and OR 1.16, 95%CI: 0.79 to 1.71, respectively). Findings were in the same directions for the three breakfast types when defining obesity with waist circumference, waist-to-height ratio, or body mass index (≥ 30 kg/m2, for 'prudent' breakfast: OR 0.51, 95%CI: 0.31 to 0.85). Regular breakfast consumers had less abdominal obesity if their breakfast was composed of fruit, natural cereal flakes, nuts/seeds and yogurt. This association was partly explained by their healthier diet during the rest of the day.

6.2. Introduction

The impact of breakfast on obesity and cardio-metabolic health is disputed [1-5]. Two distinct aspects need to be considered: 1) breakfast skipping, and 2) type of breakfast in terms of food and nutrient composition. Breakfast also needs to be examined in the context of eating patterns throughout the entire day [6] because its consumption and composition may be related to meals and snacks consumed at other times of the day [7]. Cross-sectional and cohort studies have consistently reported skipping breakfast to be associated with an increased body weight [8-10]. However, experimental evidence is lacking to substantiate these observations [1, 2, 11, 12]. Fewer studies have investigated the impact of breakfast composition on cardio-metabolic risk factors [13]. There is growing experimental evidence suggesting that consuming a breakfast rich in protein and fibre is associated with benefits in terms of weight management [2] and cardio-metabolic health [3].

While intervention-based research is instrumental in deciphering causality, most clinical trials are of restricted duration (max. a few months) [2, 3], and hence do not assess the long-term impact of selected dietary behaviours on health. In addition, experimental studies often have limited external validity; indeed, their conclusions may not be generalized to the general population. Clearly, further research on whether and how breakfast may influence metabolic health is needed [2-5]. In this context, population-based observational studies provide important complementary evidence because they assess breakfast consumption in real-life settings, in more diverse populations, larger sample sizes, and over longer duration in case of longitudinal design. A few cross-sectional studies investigated the association of breakfast composition with body composition especially abdominal obesity in adult populations [13-17]. Studies in Canada [16] and the United States (U.S.) [14, 15, 17] using nationally representative food consumption data showed that adults taking breakfast made of pre- or un-sweetened ready-to-eat cereals or cooked cereals had lower waist circumference (WC) [14, 15] and/or body mass index (BMI) [14-17]. Iqbal *et al*. [13] showed in both male and female German middle-aged adults that eating salty protein-based breakfast was associated with increased BMI and WC. None of these studies accounted for diet quality during the rest of the day, and most used breakfast skippers as the comparison group. Such comparison is, however, less relevant when investigating the optimal breakfast composition because, as stated previously, most observational studies found that breakfast skippers had increased body weight [7-10].

Switzerland is located in the centre of Europe and surrounded by three countries with very different dietary habits: France, Germany and Italy [18-20]. This unique multicultural setting revealed major differences in the consumption of food groups across the three main linguistic regions of the country [21]. In that sense, Switzerland represents an interesting setting to study how various dietary patterns may associate with abdominal obesity. In this study, we explored whether breakfast composition (*a posteriori* derived dietary patterns) were associated with abdominal obesity in Swiss regular breakfast eaters, using cross-sectional data from the first national nutrition survey, menuCH.

6.3. Methods

We followed the STROBE-nut recommendations for reporting (Additional file 1) [22].

Design and study population

We analysed data from the Swiss Nutrition Survey menuCH collected between January 2014 and February 2015 [21]. menuCH is a cross-sectional, nationwide, population-based survey among adults aged 18 to 75 years living in Switzerland [21]. Selection of participants was based on a stratified random sample of the national sampling frame for surveys [23]. Response rate was 38%: of the 5496 eligible people reachable by phone, 2 086 participated in the survey [21]. Participants and non-participants had similar age and marital status, but participants were more frequently women and Swiss nationals [21]. menuCH details are available at: https://menuch.iumsp.ch.

Dietary assessment

Food consumption assessment was based on multiple-pass 24-hour dietary recalls (24HDR), using the validated software GloboDiet®, previously known as EPIC-Soft [24, 25]. Dietitians conducted two non-consecutive 24HDR per participant. The first 24HDR was face-to-face and the second by phone, two to six weeks later. Food intake could have been recorded on any day of the week. When possible, dietitians planned interviews with participants on two different weekdays (*e.g.,* not both on Mondays). Special days (*e.g.,* party, holiday, or traveling days) were not excluded from analyses because of high frequency (*i.e.,* about a third of 24HDR). Each food item was then linked with the most appropriate item from an extended research version of the Swiss Food Composition Database [26] (data available for energy, macronutrients, and sodium). For more details on dietary assessment and estimation of misreporting, read [21].

Breakfast definition

We considered as breakfast all foods and beverages (including water) consumed in the food consumption occasions labelled by participants as ‘pre-breakfast (wake-up time)’ and ‘breakfast’. Breakfast was defined as skipped if less than 100 kcal were consumed. This cut-off choice was mainly data driven as shown in Additional file 2, but also based on literature [6].

Survey participants also reported in a questionnaire which day they usually skipped breakfast in a standard week (Monday to Sunday). For further analyses, we took only regular breakfast eaters into consideration, *i.e.,* those breakfasting in both 24HDR and reporting eating breakfast at least 5 days in a standard week. Agreement between 24HDR and questionnaire was good: 93% of participants who consumed a breakfast in both 24HDR also reported taking a breakfast regularly in the questionnaire.

Food group intake

Two registered dietitians independently classified foods and beverages into 36 groups of interest according to their nutritional value per typical portion size and their classification in the national food-based dietary guidelines [27] (Additional file 3). We then selected only the 22 food groups whose mean breakfast intake (in g) was at least 5% of the total daily intake. For example, vegetables were excluded because the mean breakfast intake represented 1% of the daily intake. We modelled the usual breakfast intake for the selected food groups using Multiple Source Method (MSM, https://nugo.dife.de/msm) [28-30].

Definition of breakfast composition

We derived dietary patterns using principal component analysis (PCA, more specifically factor analysis) based on the standardized usual intake for the 22 food groups. In accordance with the scree plot (Additional file 4), we kept three factors. We applied varimax rotation to ease the interpretation. The food groups with a factor loading higher than an absolute value of 0.2 were considered as significant contributors to the pattern. We labelled the dietary patterns based on the food groups positively and negatively correlated to the identified patterns. Each regular breakfast eater was predicted a factor score for each pattern and was then categorized into a tertile (T1, T2, T3). The participants in the third tertile (T3) ate breakfast whose content was the closest to the pattern. The applicability of the data to factor analysis was considered as acceptable based on Kayser-Meyer-Olkin and the Bartlett's sphericity tests (respectively, 0.59 and < 0.001) [31, 32].

Outcome assessment

We assessed abdominal obesity based on waist-to-hip ratio (WHR, ≥ 0.9 for men, 0.85 for women) [33]. To compare with literature and test whether our findings were dependent on the choice of the anthropometric parameters, we also used WC (*i.e.,* obesity if WC > 90 cm for men, 84 cm for women) [33], waist-to-height ratio (WHtR, ≥ 0.5) [34-36], and BMI (≥ 30 kg/m2) [33]. Dietitians were extensively trained to measure body weight, height, waist and hip circumferences following an international protocol [37]. For waist and hip circumferences, we calculated the mean of the three consecutive measurements taken to the nearest 0.1 cm using a Gulick I unstretchable tape, equipped with a dynamometer (North Coast Medical, CA, USA).

Covariates

We calculated total energy and nutrient intake (including alcohol) per recall day, but also at breakfast and during the rest of the day. We computed the mean nutrient intake out of the two days. The intakes of fibre, saturated fat, and sodium during the rest of the day were chosen as proxies for diet quality outside breakfast. We also estimated diet quality outside breakfast creating a nutritional score with six food components, selected from the 2010 Alternate Healthy Heating Index [38]: vegetables, fruit, whole grain, sugar sweetened drinks and fruit juice, nuts and legumes, and red and processed meat. More details about the scoring method and cut-offs are available in the Additional file 5.

Physical activity was assessed with the short-form International Physical Activity Questionnaire (IPAQ, six questions) [39, 40]. Data were converted into Metabolic Equivalent of Task (MET) minutes per week [41]. Information about education (university degree: yes / no), food literacy (knowing the existence of the Swiss Food Pyramid: yes / no), smoking (never / past / current), nationality (Swiss / non-Swiss), household status (alone / couple with children / couple without children) were assessed by questionnaire. The season was defined according to the date of the first 24HDR when anthropometric measurements were taken (April 15th to October 14th: warm / October 15th to April 14th: cold). Finally, we considered linguistic regions based on survey participants' home address (German / French / Italian-speaking regions).

Statistical analyses

We imputed missing data from the six IPAQ questions (between 1% and 16% of missing value for a single question) to passively calculate MET-min per week using multiple imputations by predictive mean matching through a Markov chain Monte Carlo method. We used multiple regressions accounting for sex, age, physical activity, and height to test the differences between T1 and T3 in food and nutrient intakes at breakfast and during the rest of the day. To assess the association between breakfast composition and abdominal obesity, we computed multiple logistic regressions using abdominal obesity assessed with WHR (WC, WHtR or BMI, respectively) as the binary outcome variable and the tertiles of breakfast type as exposure variables. For sensitivity analyses, we stratified by sex. We also applied multiple linear regression models using log-WHR as the outcome variable. The statistical significance of the differences in odds ratios between the three tertiles of each breakfast type was assessed using a Wald test. In addition, we estimated a P-value for trend based on a model considering the tertiles as a continuous exposure variable. We carried out all statistical analyses using STATA version 14 (Stata Corp., College Station, TX, USA).

6.4. Results

Of the 2 086 original survey participants [21], we excluded 67 of them (3%): 34 for missing waist and hip circumference measurements (*i.e.,* 27 for pregnancy or lactation, 6 for handicap and 1 for refusal), 29 for missing second 24HDR, 4 for incomplete questionnaire on socio-demographic data and usual breakfast skipping days. **Table 1** summarizes the characteristics of the included 2019 survey participants (46% of men). About one quarter of the survey sample presented a WHR above current recommendations and 13% were obese according to BMI measurement.

Sixty-seven per cent of survey participants (N=1 351) were regular breakfast eaters. Their mean daily energy intake, estimated out of two 24HDR, was 2 217 kcal, respectively 2 574 kcal for men and 1 953 for women (Table 1). Mean (±SD) breakfast energy intake was 479 kcal (± 232), *i.e.,* 554 and 424 kcal for men and women, respectively. The proportions of regular breakfast eaters with a WHR above the recommended cut-off were 26%; 45% and 12% in men and women, respectively.

From PCA, three main dietary patterns emerged among the 1 351 regular breakfast eaters (**Figure 1**): 1) 'traditional' breakfast, rich in refined bread and bread products, butter and sweet spread (*e.g.,* jam, honey), 2) 'prudent' breakfast, made of fruit, unprocessed and unsweetened cereal flakes, nuts/seeds and yogurt, which are typical ingredients of the Swiss recipe of 'Birchermuesli', and 3) 'western' breakfast, rich in processed and pre-sweetened breakfast cereals, milk, sugar confectionary and sugary soft drinks, including fruit nectars made of fruit juice, sugar and water. The cumulative percentage of explained variance was 26% (Additional file 4).

Table 1. Description of survey participants, by breakfasting regularity, and by breakfast type (by tertile in regular breakfast eaters).

Characteristics	**All survey participants**		**Occasional breakfast eaters**		**Regular breakfast eaters**[5]		**'Traditional' - Pattern 1**			**'Prudent' - Pattern 2**			**'Western' - Pattern 3**		
							T1[6]	**T2**	**T3**	**T1**	**T2**	**T3**	**T1**	**T2**	**T3**
N of participants	2 019 (*100%*)		668 (33%)		1 351 (67%)		451	450	450	451	450	450	451	450	450
Sex, *n (%)*															
Male	926	46	353	53	573	42	37	38	53	43	44	40	37	43	47
Female	1093	54	315	47	778	58	63	62	47	57	56	60	63	57	53
Age*, n (%)*															
18-34 years old	541	27	238	36	303	22	28	23	17	32	18	18	20	17	30
35-49 years old	588	29	205	31	383	28	30	29	26	31	27	27	26	29	29
50-64 years old	554	27	167	25	387	29	29	28	29	23	32	31	31	30	25
65-75 years old	336	17	58	9	278	21	13	20	29	14	24	24	22	23	16
Education: Highest degree, *n (%)*															
Secondary (*e.g.,* apprenticeship and below)	1 042	52	363	54	679	50	48	49	54	52	53	45	49	54	48
Tertiary (*e.g.,* high technical school, university)	977	48	305	46	672	50	52	51	46	48	47	55	51	46	52
Total energy intake, *mean (±SD)*[1]															
Mean of two 24-hour dietary recalls (*in kcal*)	2 175	710	2 092	740	2 217	690	2 110	2 074	2 467	2 182	2 243	2 225	2 106	2 171	2 373
Breakfast energy intake, *mean (±SD)*															
Mean of two 24-hour dietary recalls (*in kcal*)	381	261	181	192	479	232	386	412	639	420	499	519	451	440	546
Self-reported physical activity, *mean (±SD)*															
MET-min per week (from IPAQ)	3 761	3 287	3 816	3 404	3 730	3 220	3 580	3 547	3 974	3 473	3 960	3 665	3 751	3 680	3 654
Abdominal obesity assessment, *n (%)*															
Waist-to-hip ratio: ≥ 0.9 (♂); ≥ 0.85 (♀)[2,3]	546	27	191	29	355	26	21	27	31	24	32	24	25	29	25
Waist circumference: > 90 cm (♂); > 84 cm (♀)[2]	701	35	237	35	464	34	30	35	38	30	42	31	36	37	30
Waist-to-height ratio: ≥ 0.5 (♂, ♀)[4]	799	40	285	43	514	38	32	39	43	35	46	34	38	42	34
Body mass index: ≥ 30 kg/m^2 (♂, ♀)[2]	255	13	114	17	141	10	9	11	11	12	12	7	10	10	11

[1] Mean daily energy intake was 2 511 and 1 891 kcal among all male and female survey participants, and 2 574 and 1 953 kcal among male and female regular breakfast eaters, respectively. [2] Cut-offs from the World Health Organization [33]. [3] The proportions of men and women above the cut-off for waist-to-hip ratio was 44% and 13% among all survey participants, and 45% and 12% among regular breakfast eaters, respectively. [4] Cut-off suggested by Schneider [34], Browning [35] and Ashwell [36] et al. [5] Regular breakfast eaters were defined as survey participants who took a breakfast of at least 100 kcal in both of their 24-hour dietary recalls and reported eating breakfast at least 5 days in a usual week. Breakfast energy intake was 554 and 424 kcal among male and female regular breakfast eaters, respectively. [6] In this second part of the table, only proportions, respectively, means for continuous variables, are presented in the 1 351 regular breakfast eaters. After adjustment for sex, age, physical activity, total energy intake, education, food literacy, smoking, nationality, household status, season, and linguistic region, the odds of having an increased WHR were 1.6 times larger for occasional than for regular breakfast eaters (OR 1.59, 95% CI: 1.21 to 2.08, Additional file 6).

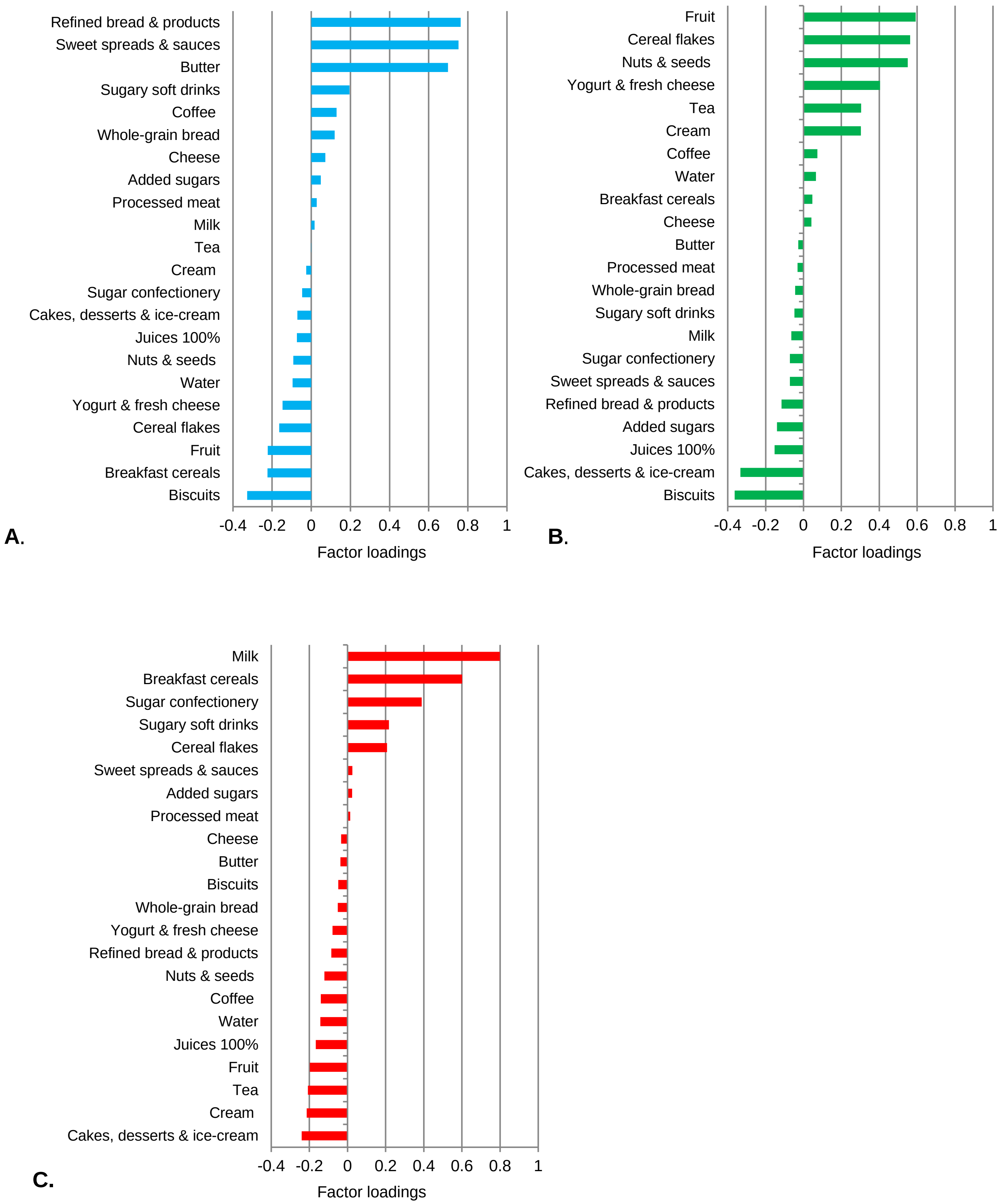


Figure 1. Breakfast dietary patterns. Factor loadings for the three breakfast dietary patterns derived from for 22 food groups (y-axis). Pattern 1 (**A**) was called ‘Traditional’ (refined bread, butter, and sweet spread), Pattern 2 (**B**) ‘Prudent’ (‘Birchermuesli’), and Pattern 3 (**C**) ‘Western’ (processed breakfast cereals and milk).

Table 1 shows that people adhering the most to the 'traditional' breakfast were rather older men with increased abdominal fat. Older and more educated people preferred the 'prudent' breakfast while younger men favoured the 'western' breakfast. More details about participants' characteristics by breakfast type can be found in Additional file 7.

Additional file 8 describes the nutrient intakes at breakfast by breakfast type. Succinctly, the 'traditional' breakfast was the richest in saturated fat and sodium. The 'prudent' breakfast had the highest fibre content. The median fibre intake among participants in T3 was more than doubled compared to those in T1 (6.7g vs 2.8g; +3.9g). After adjustment for sex, age, physical activity, and measured height, this difference was reduced to +0.2g (Additional file 8) but remains significant ($P < 0.001$). Additional files 9 and 10 show the differences in nutrient and food intakes between T1 and T3 for the rest of the day. In brief, for the 'prudent' breakfast, people classified in T3 scored significantly higher in the six-food-component nutritional score (+3%) compared to people in T1. For the 'western' breakfast, sugars intake were higher in people classified in T3 than those in T1. The former (T3) scored 4% below the latter (T1) in the six-food-component nutritional score.

After full adjustment for potential confounding factors, including diet quality for the rest of the day, the 'traditional' and 'western' breakfasts were not associated with elevated WHR (OR 1.00 for T3 vs. T1, 95% CI: 0.67 to 1.50, and OR 1.16, 95% CI: 0.79 to 1.71, respectively, **Table 2**). The 'prudent' breakfast was negatively associated with abdominal obesity. Participants with highest factor score (T3) for the 'prudent' pattern were less likely to have abdominal obesity than those with lowest factor score (T1). After adjustment for diet quality during the rest of the day (Model 4), the association became weaker and non-significant (T3 vs. T1: OR 0.72, 95%CI: 0.47 to 1.08, P for trend = 0.10). When WHR was analysed continuously, a shift from T1 to T3 was associated with a significant difference of -0.012 in log-WHR (Additional file 11). This corresponds to 1.2% lower WHR (95% CI: -0.2% to -2.2%). In sensitivity analyses, stratification by sex did not influence the results: odds ratios remained similar in both sexes for all three patterns (*data not shown*).

Table 2. Association between breakfast type and abdominal obesity (WHR ≥ 0.9 (♂); ≥ 0.85 (♀), N=1 351).

	Breakfast composition							
	T1	**T2**			**T3**			
	OR	**OR**	**95% CI**		**OR**	**95% CI**		**P-value for trend** [2]
	'Traditional' - Refined bread, butter and sweet spread							
Crude	1 (ref)	1.40	1.03	1.90	1.72	1.27	2.32	<0.001**
Model 1 *(sex + age)*	1 (ref)	1.25	0.87	1.80	0.89	0.61	1.28	0.45
Model 2 *(age + sex + physical activity + total energy intake)*[1]	1 (ref)	1.31	0.91	1.90	0.93	0.64	1.36	0.67
Model 3 *(11 covariates)*[1]	1 (ref)	1.39	0.95	2.03	1.00	0.68	1.48	0.95
Model 4 *(16 covariates, including diet quality during the rest of the day - nutrient + food-based approach)*[2]	1 (ref)	1.32	0.90	1.93	1.00	0.67	1.50	0.99
	'Prudent' - Fruit, unprocessed and unsweetened cereal flakes, nuts/seeds and yogurt							
Crude	1 (ref)	1.48	1.10	1.99	0.99	0.73	1.35	0.96
Model 1 *(sex + age)*	1 (ref)	0.98	0.68	1.40	0.60	0.41	0.87	0.006*
Model 2 *(age + sex + physical activity + total energy intake)*[1]	1 (ref)	1.00	0.70	1.44	0.59	0.40	0.86	0.005*
Model 3 *(11 covariates)*[1]	1 (ref)	1.01	0.70	1.47	0.60	0.41	0.90	0.011*
Model 4 *(16 covariates, including diet quality during the rest of the day - nutrient + food-based approach)*[2]	1 (ref)	1.09	0.74	1.59	0.72	0.47	1.08	0.10
	'Western' - Processed breakfast cereals and milk							
Crude	1 (ref)	1.24	0.93	1.67	1.00	0.74	1.36	0.98
Model 1 *(sex + age)*	1 (ref)	1.12	0.79	1.58	1.07	0.74	1.53	0.71
Model 2 *(age + sex + physical activity + total energy intake)*[1]	1 (ref)	1.14	0.80	1.62	1.09	0.75	1.57	0.63
Model 3 *(11 covariates)*[1]	1 (ref)	1.18	0.83	1.70	1.21	0.83	1.77	0.32
Model 4 *(16 covariates, including diet quality during the rest of the day - nutrient + food-based approach)*[2]	1 (ref)	1.10	0.76	1.58	1.16	0.79	1.71	0.45

[1] Sex, age (continuous), physical activity (MET-min per week, continuous, imputed), total energy intake (mean out of two 24-hour dietary recalls), alcohol intake (mean intake out of two 24-hour dietary recalls), education (university degree: yes / no), food literacy (knowing about the Swiss Food Pyramid: yes / no), smoking (never / past / current), nationality (Swiss / non-Swiss), household status (alone / couple with children / couple without children), season of the first 24-hour dietary recall (cold / warm), linguistic region (German / French / Italian). [2] Idem plus diet quality during the rest of the day (outside breakfast) considering dietary fibre, saturated fat, sodium, and the six-food-component nutritional score (mean intake out of two 24-hour dietary recalls).[3]Differences were assessed using multiple logistic regressions (P ≤ 0.05, ** P ≤ 0.001).*

Figure 2 compares the odds ratios between the 'prudent' breakfast and abdominal obesity assessed with the three other parameters (*i.e.,* WC, WHtR or BMI) using the fully adjusted models (see Additional file 12 for the 'traditional' and 'western' patterns). We observed a significant negative association between the 'prudent' breakfast and BMI (OR 0.51, 95%CI: 0.31 to 0.85). When considering elevated WC and WHtR as outcomes, the associations were in the same direction although the CIs contained the null value.

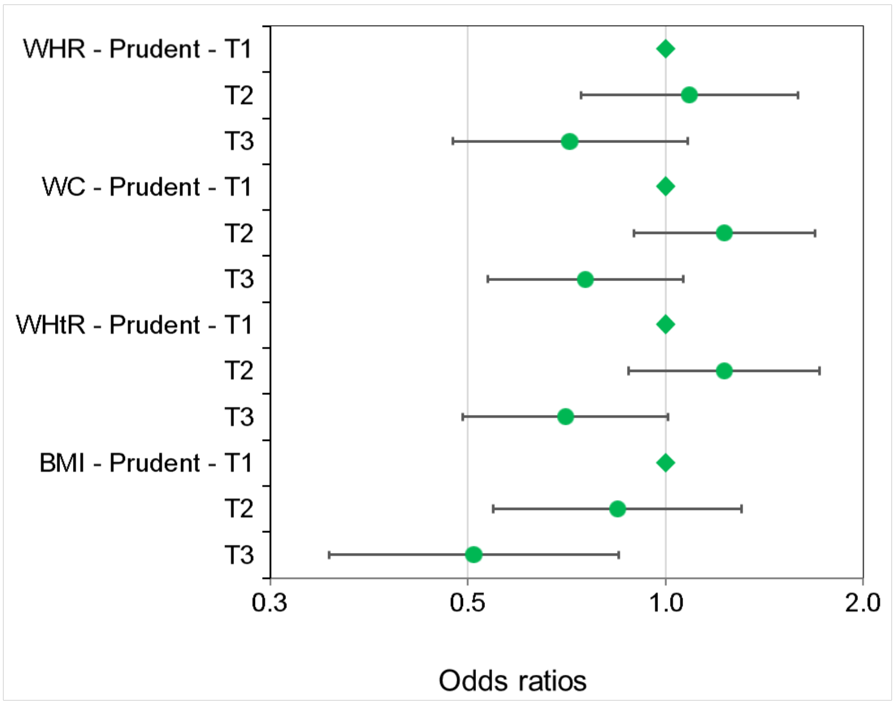


Figure 2. Association between the 'prudent' breakfast and four obesity anthropometric parameters. *Odds ratios between the 'prudent' breakfast (tertiles 1 to 3: T3 being closely associated with the pattern) and abdominal obesity (waist-to-hip ratio (WHR): ≥ 0.9 (♂); ≥ 0.85 (♀); waist circumference (WC): > 90 cm (♂); > 84 cm (♀), waist-to-height ratio (WHtR): ≥ 0.5 (♂, ♀), body mass index (BMI): ≥ 30 kg/m2 (♂, ♀), N=1 351). The logistic models were adjusted for sex, age, physical activity, total energy intake, alcohol intake, education, food literacy, smoking, nationality, household status, season of the first 24-hour dietary recall, linguistic region, diet quality during the rest of the day (outside breakfast).*

6.5. Discussion

We found out that consuming a 'prudent' breakfast composed of fruit, unprocessed and unsweetened cereal flakes, nuts/seeds and yogurt (typical Swiss recipe of 'Birchermuesli') was associated with less abdominal obesity in Swiss regular breakfast eaters. The association was partly due to higher overall diet quality in these people. Our finding is in line with results from a recent meta-analysis of 13 observational studies regarding overall dietary patterns also derived by PCA [42]. The highest category of 'healthy/prudent' pattern (with high-factor loadings in fruits, vegetables, and whole grain) was associated with reduced risk of central obesity compared with the lowest category (pooled OR 0.81, 95% CI: 0.66 to 0.96, I2= 69.8) [42].

High-fibre breakfast

In our research, all three breakfast types derived by PCA were rich in carbohydrates. Only the 'prudent' pattern 'Birchermuesli' had the particularity to be also rich in fibre coming from whole grain cereals, fruit and nuts/seeds, even though the higher fibre intake in T3 was partly confounded by differences in sex, age, physical activity, and height of the people in T3 compared to people in T1 (Additional file 8). The few randomized controlled trials that tested the effect of breakfast composition on cardio-metabolic health have also suggested that eating a high fibre breakfast might be the most protective strategy [2, 3]. Among those trials, one is particularly interesting for its relative long-term intervention. Adamsson *et al*. [43] demonstrated in 79 regular breakfast eaters that a normocaloric whole grain cereal-based breakfast, which was very similar to our 'prudent' pattern, could reduce the sagittal abdominal diameter by 0.6 cm (P = 0.034). The authors also showed a reduction in circulating plasma inflammation markers within the three-month intervention. In our findings, Swiss regulars breakfast eaters taking a 'prudent' breakfast (in T3) had 1.2% lower WHR compared to those taking a breakfast distant from this pattern (in T1) (Additional file 11). Given the mean WHR at 0.829 in our sample and supposing the mean hip circumference staying constant at 100.1 cm, this would correspond to a mean difference of -1 cm in WC.

The biological mechanisms behind the potential protective effect of consuming a breakfast rich in viscous and cereal fibres could be multiple. On the one hand, low-glycaemic index carbohydrates, such as those in whole grain cereals, could lessen postprandial glucose response, limiting thus insulin production [3, 44-46]. On the other hand, dietary fibre may lower the release of free fatty acids from adipose tissues that cause insulin resistance. In turn, the diminution of insulin resistance reduces the production of pro-inflammatory mediators, and in fine, abdominal fat [3, 44, 47, 48]. Mediation mechanisms through the microbiota are likely to exist, stressing again the importance of dietary fibre for cardio-metabolic health [48].

Breakfast composition in other population-based studies

Contrary to previous publications in North America, we did not detect an association between eating breakfast cereals (*i.e.,* 'western' pattern) and abdominal obesity. In the U.S. National Health and Nutrition Examination Survey (NHANES) 1988-1994, eating ready-to-eat or cooked cereals, or quick breads was associated with significantly lower BMI compared to skipping breakfast or eating meats and/or eggs for breakfast [17]. Similarly, in young adults aged 20-39 years from the NHANES 1999-2006, breakfast including ready-to-eat cereals was associated with an improved cardio-metabolic risk profile [14]. O'Neil *et al*. also found in older adults that breakfasts composed of grains, pre- or un-sweetened ready-to-eat or cooked cereals, low-fat milk, and fruit were associated with lower BMI and WC than breakfast skipping [15]. The 2004 Canadian Community Health Survey also showed that mean BMI was significantly lower among consumers of ready-to-eat cereals at breakfast [16]. The fact that their comparison groups were breakfast skippers [15, 16], heterogeneous groups of 'other breakfast' consumers [14, 16], and/or groups with dietary patterns providing variable energy and nutrient intakes [15, 17] may explain the apparent inconsistency between North American and Swiss findings.

The other European study (in Germany) using PCA to derive breakfast composition from three 24HDR [13] found that the breakfast made of milk and breakfast cereals (undefined in terms of nutrient content) was not associated with increased or decreased WC, nor BMI. This 'dairy & breakfast cereal pattern' was, however, associated with a better multi-biomarker cardio-metabolic profile in men. The same article highlighted that the 'processed food pattern', composed of processed meat, cheese, vegetables, margarine, eggs, and bread, was positively associated with WC and BMI in both sexes. In Switzerland, a comparison between a high-fibre carbohydrate-based breakfast such as 'Birchermuesli' and a protein-based breakfast would have been interesting, since some evidence suggests that eating a protein-based breakfast may have beneficial effects too [2, 3]. Nevertheless, no protein-based breakfast emerged from the PCA as a main pattern, probably because this type of breakfast is less common than in Germany. Of note, the North American and German studies did not adjust for diet quality during the rest of the day.

While types of foods and beverages usually consumed at breakfast vary across countries, variations also exist in the contribution of breakfast to the daily energy intake. In our survey, breakfast brought 22% of total energy intake among regular breakfast eaters, and 18% among all survey participants, including occasional breakfast eaters. This proportion is slightly higher than in other western high-income countries: *e.g.,* 14% in the Netherlands [49], 15% in Britain [50], 15% in the U.S. [15], 17% in France [51], or 16% in Spain [52]. This may represent different eating habits in the distribution of daily food consumption occasions, the proportion of breakfast skippers, and/or the definition of breakfast. Although breakfast accounts only for less than one fifth of the total energy intake across countries, understanding the impact of breakfast composition on health could complement the overall diet approach. This can also help define meal-based recommendations to assist populations in achieving the recommended daily intake [6, 53].

Strengths and limitations

The present study has several strengths. First, we used data from a large, relatively representative sample of the Swiss population. Second, we focused on regular breakfast eaters to avoid comparison with breakfast skippers, who are known to have higher obesity prevalence in observational studies [1, 8-10] (Additional file 6). Third, specifically trained dietitians conducted the 24HDR using the internationally validated software GloboDiet®. In addition, we assessed the quality of 24HDR via several quality control procedures and underreporting was limited [21, 54]. Fourth, the same dieticians were also intensely trained to measure waist and hip circumferences. We tested inter-dietitian reproducibility during training sessions and organized two retraining sessions during the year of data collection. Intra-dietitian reproducibility was very high (Pearson's correlation coefficients: $r \geq 0.99$, *data not shown*). Fifth, we derived breakfast composition pattern based on the usual food intake modelled by MSM instead of using only the mean of two days. Sixth, we adjusted for most known confounders, including diet quality during the rest of the day. Seventh, our conclusions were independent of the choice of the anthropometric parameters we used as proxies of abdominal obesity.

The main limitation is the cross-sectional design. Thus, it is difficult to ascertain the temporal order of exposure and disease, essential for causal inference. Namely, people may have changed their diet for weight management. In addition, residual confounding may have biased the associations found between breakfast composition and abdominal obesity. Our results, however, open new hypotheses regarding the best choice for breakfast and complement the limited evidence from randomized controlled trials. An additional limitation is related to the method of PCA, which makes the comparison between groups/tertiles unintuitive. Indeed, breakfast eaters were not classified based on fixed food intake cut-offs, but their closeness or distance to a pattern. In other words, it is hard to picture the breakfast of people in the reference group (T1). Additionally, the three main identified dietary patterns explained only 26% of total variance. This indicates that breakfast patterns were complex and multiple in Switzerland. Thus, focusing only on three patterns explaining most variance reduces complexity but is imperfect. In our study, 27% of regular breakfast consumers were classified into none of the three T3 (Additional file 13), and 24% into more than one T3. These people respectively took other types of breakfast or foods overlapping several of the three selected patterns. We may also assume that some participants took one type of breakfast on the first recall day and another type on the second day. Currently, we know little about within-person variability in breakfast choice. In the U.S., Kant and Graubard showed that 17% of adults in NHANES 2005-2010 reported taking a breakfast in only one of the two 24HDR [55], and Sieger *et al*. [56] reported higher energy intake variability for snack and breakfast than for lunch and dinner.

However, these references inform only about the variability in energy intake and not in food choices, which may be more limited at breakfast than for other meals, especially among regular breakfast eaters. Novel data mining techniques (*e.g.,* maching learning algorithms) may help in defining more precisely the usual type of consumed meals [57, 58]. Furthermore, the inconsistent definitions of breakfast and breakfast skipping across studies and countries [6, 59] renders comparisons difficult. Finally, the method of 24HDR is sensitive to social desirability and recall bias, which may be important sources of under- or over-reporting in terms of food intake [60].

Conclusions

Our study shows that a ‘prudent’ breakfast, based on fruit, unprocessed and unsweetened cereal flakes, nuts/seeds and yogurt, was associated with reduced abdominal obesity. This association was partly explained by a healthier diet during the rest of the day. Our findings need confirmation in other settings, such as in longitudinal studies, and, preferably, in long-term randomized controlled trials in free-living subjects.

6.6. References

1. Brown, A.W., M.M. Bohan Brown, and D.B. Allison, Belief beyond the evidence: using the proposed effect of breakfast on obesity to show 2 practices that distort scientific evidence. Am J Clin Nutr, 2013. 98(5): p. 1298-308.
2. Leidy, H.J., et al., Evaluating the Intervention-Based Evidence Surrounding the Causal Role of Breakfast on Markers of Weight Management, with Specific Focus on Breakfast Composition and Size. Adv Nutr, 2016. 7(3): p. 563S-75S.
3. Maki, K.C., A.K. Phillips-Eakley, and K.N. Smith, The Effects of Breakfast Consumption and Composition on Metabolic Wellness with a Focus on Carbohydrate Metabolism. Adv Nutr, 2016. 7(3): p. 613S-21S.
4. Rosato, V., et al., Energy Contribution and Nutrient Composition of Breakfast and Their Relations to Overweight in Free-living Individuals: A Systematic Review. Adv Nutr, 2016. 7(3): p. 455-65.
5. Quatela, A., et al., The Energy Content and Composition of Meals Consumed after an Overnight Fast and Their Effects on Diet Induced Thermogenesis: A Systematic Review, Meta-Analyses and Meta-Regressions. Nutrients, 2016. 8(11).
6. Leech, R.M., et al., Understanding meal patterns: definitions, methodology and impact on nutrient intake and diet quality. Nutr Res Rev, 2015. 28(1): p. 1-21.
7. St-Onge, M.P., et al., Meal Timing and Frequency: Implications for Cardiovascular Disease Prevention: A Scientific Statement From the American Heart Association. Circulation, 2017. 135(9): p. e96-e121.
8. Mesas, A.E., et al., Selected eating behaviours and excess body weight: a systematic review. Obes Rev, 2012. 13(2): p. 106-35.
9. Horikawa, C., et al., Skipping breakfast and prevalence of overweight and obesity in Asian and Pacific regions: a meta-analysis. Prev Med, 2011. 53(4-5): p. 260-7.
10. Szajewska, H. and M. Ruszczynski, Systematic review demonstrating that breakfast consumption influences body weight outcomes in children and adolescents in Europe. Crit Rev Food Sci Nutr, 2010. 50(2): p. 113-9.
11. Chowdhury, E.A., et al., The causal role of breakfast in energy balance and health: a randomized controlled trial in obese adults. Am J Clin Nutr, 2016. 103(3): p. 747-56.
12. Geliebter, A., et al., Skipping breakfast leads to weight loss but also elevated cholesterol compared with consuming daily breakfasts of oat porridge or frosted cornflakes in overweight individuals: a randomised controlled trial. J Nutr Sci, 2014. 3: p. e56.
13. Iqbal, K., et al., Breakfast quality and cardiometabolic risk profiles in an upper middle-aged German population. Eur J Clin Nutr, 2017.

14. Deshmukh-Taskar, P., et al., The relationship of breakfast skipping and type of breakfast consumed with overweight/obesity, abdominal obesity, other cardiometabolic risk factors and the metabolic syndrome in young adults. The National Health and Nutrition Examination Survey (NHANES): 1999-2006. Public Health Nutr, 2013. 16(11): p. 2073-82.

15. O'Neil, C.E., T.A. Nicklas, and V.L. Fulgoni. Nutrient intake, diet quality, and weight/adiposity parameters in breakfast patterns compared with no breakfast in adults: National Health and Nutrition Examination Survey 2001-2008. J Acad Nutr Diet, 2014. 114(12 Suppl): p. S27-43.

16. Barr, S.I., L. DiFrancesco, and V.L. Fulgoni. Association of breakfast consumption with body mass index and prevalence of overweight/obesity in a nationally-representative survey of Canadian adults. Nutr J, 2016. 15: p. 33.

17. Cho, S., et al., The effect of breakfast type on total daily energy intake and body mass index: results from the Third National Health and Nutrition Examination Survey (NHANES III). J Am Coll Nutr, 2003. 22(4): p. 296-302.

18. Slimani, N., et al., Diversity of dietary patterns observed in the European Prospective Investigation into Cancer and Nutrition (EPIC) project. Public Health Nutr, 2002. 5(6B): p. 1311-28.

19. Freisling, H., et al., Region-specific nutrient intake patterns exhibit a geographical gradient within and between European countries. J Nutr, 2010. 140(7): p. 1280-6.

20. Huseinovic, E., et al., Meal patterns across ten European countries - results from the European Prospective Investigation into Cancer and Nutrition (EPIC) calibration study. Public Health Nutr, 2016. 19(15): p. 2769-80.

21. Chatelan, A., et al., Major Differences in Diet across Three Linguistic Regions of Switzerland: Results from the First National Nutrition Survey menuCH. Nutrients, 2017. 9(11).

22. Lachat, C., et al., Strengthening the Reporting of Observational Studies in Epidemiology-Nutritional Epidemiology (STROBE-nut): An Extension of the STROBE Statement. PLoS Med, 2016. 13(6): p. e1002036.

23. Federal Statistical Office. Stichprobenrahmen für Personen- und Haushaltserhebungen (Swiss persons and households registry). [cited 2017 Apr 28]; Available from: https://www.bfs.admin.ch/bfs/de/home/grundlagen/volkszaehlung/volkszaehlung-teil-gesamtsystem/stichprobenrahmen.html.

24. Slimani, N., et al., The standardized computerized 24-h dietary recall method EPIC-Soft adapted for pan-European dietary monitoring. Eur J Clin Nutr, 2011. 65 Suppl 1: p. S5-15.

25. Crispim, S.P., et al., Two non-consecutive 24 h recalls using EPIC-Soft software are sufficiently valid for comparing protein and potassium intake between five European centres--results from the European Food Consumption Validation (EFCOVAL) study. Br J Nutr, 2011. 105(3): p. 447-58.

26. Federal Food Safety and Veterinary Office. Swiss Food Composition Database. [cited 2017 Jul 13]; Available from: http://naehrwertdaten.ch/request?xml=MessageData&xml=MetaData&xsl=Start&lan=en&pageKey=Start.

27. Swiss Society for Nutrition / Federal Food Safety and Veterinary Office. Pyramide alimentaire suisse 2011 (Swiss Food Pyramid 2011). [cited 2017 Jul 16]; Available from: http://www.sge-ssn.ch/fr/toi-et-moi/boire-et-manger/equilibre-alimentaire/pyramide-alimentaire-suisse/.

28. Souverein, O.W., et al., Comparing four methods to estimate usual intake distributions. Eur J Clin Nutr, 2011. 65 Suppl 1: p. S92-101.

29. Laureano, G.H., et al., Comparison of the ISU, NCI, MSM, and SPADE Methods for Estimating Usual Intake: A Simulation Study of Nutrients Consumed Daily. Nutrients, 2016. 8(3): p. 166.

30. Harttig, U., et al., The MSM program: web-based statistics package for estimating usual dietary intake using the Multiple Source Method. Eur J Clin Nutr, 2011. 65 Suppl 1: p. S87-91.

31. Kaiser, H.F., An index of factorial simplicity. Psychometrika, 1974. 39(1): p. 31-36.

32. Cureton, E.E. and R.B. D'Agostino, Factor analysis: An applied approach. 1983, Hillsdale, United States of America: L. Erlbaum Associates.

33. World Health Organization (WHO), Waist Circumference and Waist-Hip Ratio: Report of a WHO Expert Consultation. 2008, WHO: Geneva, Switzerland.

34. Schneider, H.J., et al., The predictive value of different measures of obesity for incident cardiovascular events and mortality. J Clin Endocrinol Metab, 2010. 95(4): p. 1777-85.

35. Browning, L.M., S.D. Hsieh, and M. Ashwell, A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. Nutr Res Rev, 2010. 23(2): p. 247-69.

36. Ashwell, M., P. Gunn, and S. Gibson, Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. Obes Rev, 2012. 13(3): p. 275-86.

37. World Health Organization. MONICA Manual, Part III: Population Survey. Section 1: Population Survey Data Component. 4.6 Height, weight, waist and hip measurement. [cited 2017 Jul 1]; Available from: http://www.thl.fi/publications/monica/manual/part3/iii-1.htm#s4-6.

38. Chiuve, S.E., et al., Alternative Dietary Indices Both Strongly Predict Risk of Chronic Disease. The Journal of Nutrition, 2012. 142(6): p. 1009-1018.

39. Hagstromer, M., P. Oja, and M. Sjostrom, The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. Public Health Nutr, 2006. 9(6): p. 755-62.

40. Craig, C.L., et al., International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc, 2003. 35(8): p. 1381-95.

41. International Physical Activity Questionnaire. Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire - Short and Long Forms. [cited 2017 Mar 17]; Available from: http://www.academia.edu/5346814/Guidelines_for_Data_Processing_and_Analysis_of_the_International_Physical_Activity_Questionnaire_IPAQ_Short_and_Long_Forms_Contents.

42. Rezagholizadeh, F., et al., A posteriori healthy dietary patterns may decrease the risk of central obesity: findings from a systematic review and meta-analysis. Nutr Res, 2017. 41: p. 1-13.

43. Adamsson, V., et al., Role of a prudent breakfast in improving cardiometabolic risk factors in subjects with hypercholesterolemia: a randomized controlled trial. Clin Nutr, 2015. 34(1): p. 20-6.

44. Tsihlias, E.B., et al., Comparison of high- and low-glycemic-index breakfast cereals with monounsaturated fat in the long-term dietary management of type 2 diabetes. Am J Clin Nutr, 2000. 72(2): p. 439-49.

45. Nilsson, A.C., et al., Effect of cereal test breakfasts differing in glycemic index and content of indigestible carbohydrates on daylong glucose tolerance in healthy subjects. Am J Clin Nutr, 2008. 87(3): p. 645-54.

46. Jenkins, D.J., et al., Viscous and nonviscous fibres, nonabsorbable and low glycaemic index carbohydrates, blood lipids and coronary heart disease. Curr Opin Lipidol, 2000. 11(1): p. 49-56.

47. Boden, G., Obesity and free fatty acids. Endocrinol Metab Clin North Am, 2008. 37(3): p. 635-46, viii-ix.

48. Rodriguez-Carrio, J., et al., Free Fatty Acids Profiles Are Related to Gut Microbiota Signatures and Short-Chain Fatty Acids. Front Immunol, 2017. 8: p. 823.

49. van Rossum, C., et al., ed. Dutch National Food Consumption Survey 2007-2010. Diet of children and adults aged 7 to 69 years. 2011, National Institute for Public Health and the Environment (RIVM): Bilthoven, The Netherlands.

50. Almoosawi, S., et al., Daily profiles of energy and nutrient intakes: are eating profiles changing over time? Eur J Clin Nutr, 2012. 66(6): p. 678-86.

51. Agence nationale de sécurité sanitaire de l'alimentation de l'environnement et du travail (ANSES), Étude individuelle nationale des consommations alimentaires 3 (INCA 3) (3rd French Food Consumption Survey). 2017, ANSES: Maisons-Alfort, France.

52. Aparicio, A., et al., Differences in meal patterns and timing with regard to central obesity in the ANIBES ('Anthropometric data, macronutrients and micronutrients intake, practice of physical activity, socioeconomic data and lifestyles in Spain') Study. Public Health Nutr, 2017. 20(13): p. 2364-2373.

53. de Oliveira Santos, R., et al., Dietary patterns for meals of Brazilian adults. Br J Nutr, 2015. 114(5): p. 822-8.

54. Chatelan, A., et al., Lessons Learnt About Conducting a Multilingual Nutrition Survey in Switzerland: Results from menuCH Pilot Survey. Int J Vitam Nutr Res, 2018: p. 1-12.

55. Kant, A.K. and B.I. Graubard, Within-person comparison of eating behaviors, time of eating, and dietary intake on days with and without breakfast: NHANES 2005-2010. Am J Clin Nutr, 2015. 102(3): p. 661-70.

56. Sieber, J.L., et al., Can variability in energy intake be attributed to one meal versus another? (Abstract). FASEB J, 2008.

57. Guan, V.X., et al., Identifying usual food choices at meals in overweight and obese study volunteers: implications for dietary advice. Br J Nutr, 2018. 120(4): p. 472-480.

58. DeGregory, K.W., et al., A review of machine learning in obesity. Obes Rev, 2018. 19(5): p. 668-685.

59. Zhang, L., et al., The Association between Breakfast Skipping and Body Weight, Nutrient Intake, and Metabolic Measures among Participants with Metabolic Syndrome. Nutrients, 2017. 9(4).

60. Naska, A., A. Lagiou, and P. Lagiou, Dietary assessment methods in epidemiological research: current state of the art and future prospects. F1000Res, 2017. 6: p. 926.

6.7. Supplementary material

Additional file 1. Completed STROBE-nut checklist.

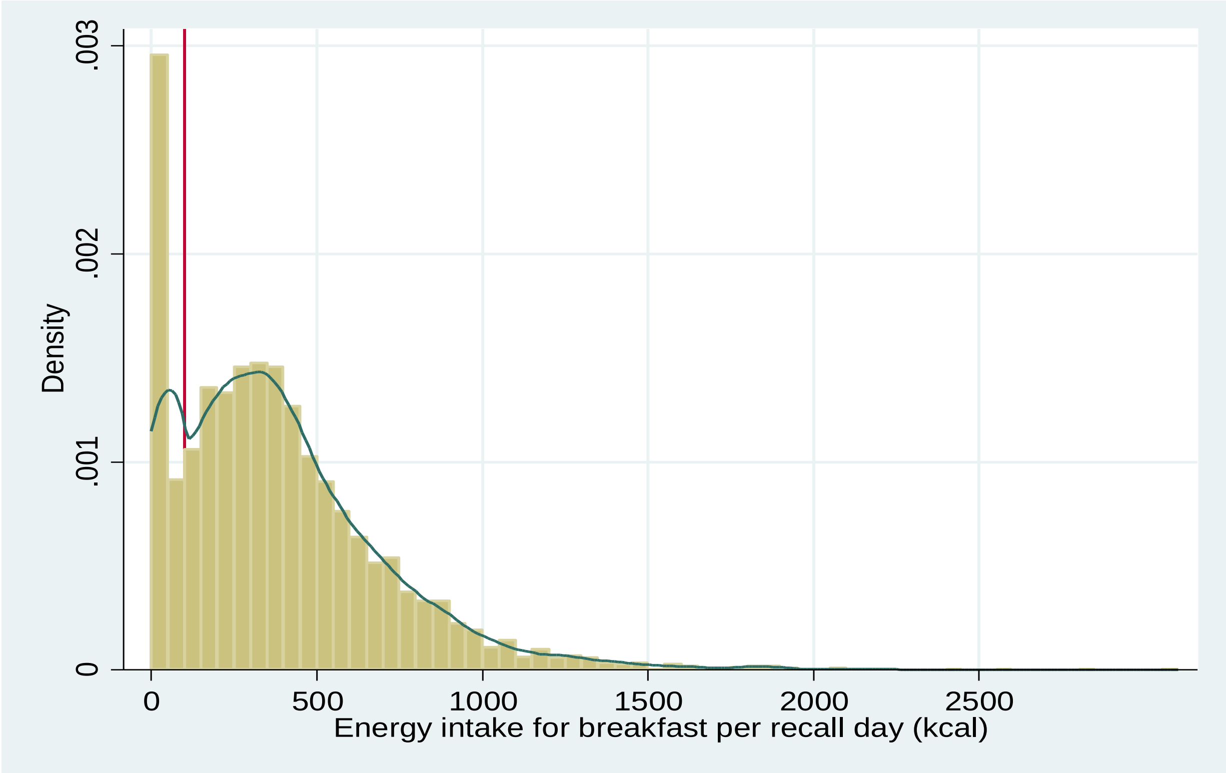
Item	No	Recommendation	Chapter
Title and abstract	nut-1	State the dietary/nutritional assessment method(s) used in the title, abstract, or keywords	Abstract
Introduction Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Background
Objectives	3	State specific objectives, including any pre-specified hypotheses	Background (end)
Methods Study design	4	Present key elements of study design early in the paper	Design and study population
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Design and study population, Ref [21]
	nut-5	Describe any characteristics of study settings that might affect the dietary intake or nutritional status of the participants, if applicable	Design and study population, Ref [21]
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	NA NA Design and study population, Ref [21]
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	NA NA
	nut-6	Report particular dietary, physiological, or nutritional characteristics that were considered when selecting the participants	NA
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Methods
	nut-7.1	Clearly define foods, food groups, nutrients, or other food components	Dietary assessment Food group intake, Add. file 3
	nut-7.2	When using dietary patterns or indices, describe the methods to obtain them and their nutritional properties	Definition of breakfast composition, Figure 1, Add. file 7

Data sources/measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Methods, Ref [21] NA
	nut-8.1	Describe the dietary assessment method(s), *e.g.,* portion size estimation, number of days and items recorded, how it was developed and administered, and how quality was assured. Report if and how supplement intake was assessed	Dietary assessment, Ref [21, 54] NA
	nut-8.2	Describe and justify food composition data used. Explain the procedure to match food composition with consumption data. Describe the use of conversion factors, if applicable	Dietary assessment Ref [21] Dietary assessment, Ref [24-25]
	nut-8.3	Describe the nutrient requirements, recommendations, or dietary guidelines and the evaluation approach used to compare intake with the dietary reference values, if applicable	NA
	nut-8.4	When using nutritional biomarkers, additionally use the STROBE extension for molecular epidemiology (STROBE-me). Report the type of biomarkers used and usefulness as dietary exposure markers	NA NA
	nut-8.5	Describe the assessment of non-dietary data (*e.g.,* nutritional status and influencing factors) and timing of the assessment of these variables in relation to dietary assessment	Covariates
	nut-8.6	Report on the validity of the dietary or nutritional assessment methods and any internal or external validation used in the study, if applicable	Dietary assessment, Strengths and limitations, Ref [24-25]
Bias	9	Describe any efforts to address potential sources of bias	Covariates, Strengths and limitations
	nut-9	Report how bias in dietary or nutritional assessment, *e.g.,* misreporting, changes in habits as a result of being measured, and data imputation from other sources, was addressed	Covariates, Strengths and limitations, Ref [21]
Study size	10	Explain how the study size was arrived at	Ref [21]
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Covariates, Statistical analyses
	nut-11	Explain the categorization of dietary/nutritional data (*e.g.,* use of n-tiles and handling of non-consumers) and the choice of reference category, if applicable	Definition of breakfast composition
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Statistical analyses
		(*b*) Describe any methods used to examine subgroups and interactions	Covariates, Statistical analyses, Add. file 5
		(*c*) Explain how missing data were addressed	Statistical analyses
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	NA NA NA

		(*e*) Describe any sensitivity analyses	Statistical analyses
	nut-12.1	Describe any statistical method used to combine dietary or nutritional data, if applicable	Covariates, Add. file 5, 8 & 9
	nut-12.2	Describe and justify the method for energy adjustments, intake modeling and use of weighting factors, if applicable	NA
	nut-12.3	Report any adjustments for measurement error, *i.e.,* from a validity or calibration study	NA
Results Participants	13	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed	Results, Table 1, Ref [21]
		(b) Give reasons for non-participation at each stage	Design and study population, Results, Ref [21]
		(c) Consider use of a flow diagram	Ref [21]
	nut-13	Report the number of individuals excluded based on missing, incomplete, or implausible dietary/nutritional data	Results, Ref [21]
Descriptive data	14	(a) Give characteristics of study participants (*e.g.,* demographic, clinical, social) and information on exposures and potential confounders	Results, Table1
		(b) Indicate number of participants with missing data for each variable of interest	Results
		(c) *Cohort study*—Summarize follow-up time (*e.g.,* average and total amount)	NA
	nut-14	Give the distribution of participant characteristics across the exposure variables if applicable. Specify if food consumption of total population or consumers only were used to obtain results	Results, Table 1, Add. files 7, 8 & 9
Outcome data	15	*Cohort study*—Report numbers of outcome events or summary measures over time	NA
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	NA
		Cross-sectional study—Report numbers of outcome events or summary measures	Results, Table1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Results, Table 2
		(*b*) Report category boundaries when continuous variables were categorized	Outcome assessment, Figure 2
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	Results
	nut-16	Specify if nutrient intakes are reported with or without inclusion of dietary supplement intake, if applicable	NA

Other analyses	17	Report other analyses done - eg analyses of subgroups and interactions, and sensitivity analyses	Results, Figure 2, Add. file 6
	nut-17	Report any sensitivity analysis (*e.g.,* exclusion of misreporters or outliers) and data imputation, if applicable	NA
Discussion Key results	18	Summarize key results with reference to study objectives	Discussion
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Strengths and limitations
	nut-19	Describe the main limitations of the data sources and assessment methods used and implications for the interpretation of the findings	Strengths and limitations
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Conclusion
	nut-20	Report the nutritional relevance of the findings, given the complexity of diet or nutrition as an exposure	Discussion
Generalisability	21	Discuss the generalisability (external validity) of the study results	Background, Strengths and limitations
Other information Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Funding, Ref [21]
	nut-22.1	Describe the procedure for consent and study approval from ethics committee(s)	Ethics approval and consent to participate
	nut 22.2	Provide data collection tools and data as online material or explain how they can be accessed	Availability of data and material

Additional file 2. Histogram of the variable energy intake consumed at breakfast per recall day using defined intervals of 50 kcal (N=2 019).



Additional file 3. Description of foods and beverages included in the food groups used to derive dietary patterns for 2,702 24-hour dietary recalls (N=1 351).

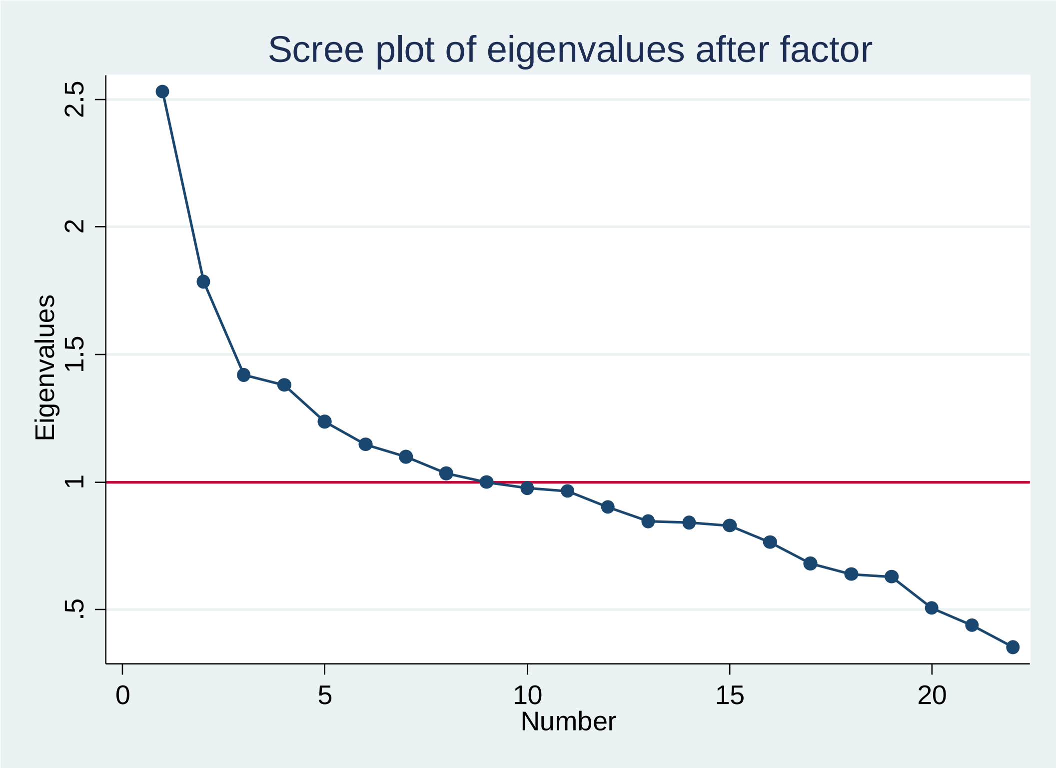
Swiss Food Pyramid stage	Food groups	Foods classified in the group	Mean quantity brought by breakfast *(in g and % of daily intake)*	
Non-caloric beverages	**Water**	All types of water (*e.g.,* tap, mineral, still, carbonated), *essentially (99%) consumed without added sugars/artificial sweeteners.*	149.8	**13%***
	Coffee	All types of coffee (*e.g.,* instant, from capsules), and coffee with milk or cream (*e.g.,* cappuccino), *essentially (98%) consumed without added sugars/artificial sweeteners.*	107.8	**44%***
	Tea	All types of tea, herbal and fruit tea, *essentially (98%) consumed without added sugars/artificial sweeteners.*	96.8	**28%***
Fruit & vegetables	Vegetables	All types of vegetables, green leaves, sprouts, mushrooms, seaweeds, sweet corn, snow peas, fresh green beans, and onions: *raw, cooked, dried, canned, in puree, pickled, in soups, in sauce (e.g., tomato sauce), on pizza and quiches, and in sandwiches.* Except: avocadoes, olives, herbs, vegetable juices, nor if contained in small amounts in salty snacks, bread, or sauces.	1.9	1%
	Fruit	All types of fruit: *raw, cooked, dried, in puree/compote, and in pies made essentially with fruit (e.g., apples in apple pies).* Except: fruit juices, fruit jams, candied fruit, nor if contained in small amounts in yogurts, cakes, ice-cream or other sweets.	44.3	**23%***
Cereal products & potatoes	Tubers	Unprocessed tubers (*e.g.,* potatoes, sweet potatoes).	0.2	1%
	Tuber products	Potato products (*e.g.,* French fries, rösti, mashed potatoes).	0.2	2%
	Whole-grain bread	All types of bread with more than 4.5g of dietary fibres per 100g (*e.g.,* whole-wheat bread or bread rolls, rye bread)	14.1	**47%***
	Refined bread & bread products	All types of white or semi-white bread with less than 4.5g of dietary fibres per 100g (*e.g.,* baguette, milk bread rolls, white toast, refined flat bread), croissants, and crisp bread (*e.g.,* rice crackers, Swedish rolls). Except: stuffed croissants and sweet pastries (*e.g.,* chocolate croissants).	36.1	**41%***
	Pasta	Plain pasta (*e.g.,* penne, spaghetti), schupfnudeln, spatzli, rice noodles, and stuffed pasta (*e.g.,* ravioli, tortellini).	0.1	0%
	Rice	All types of rice.	0.3	1%
	Cereal flakes	Natural cereal flakes, oatmeal, flakes from birchermuesli and porridge, dried wheat germs, and natural cereal bran, *with or without dried fruit and/or nuts, without added sugars/artificial sweeteners nor major food processing.*	5.3	**84%***
	Breakfast cereals	Ready-to-eat and processed breakfast cereals (*e.g.,* corn-flakes), and birchermuesli mixes, *highly processed and/or with added sugars/artificial sweeteners.*	5.4	**82%***

Protein-based products	**Milk**	Mammals' milk, branded fermented milk drinks (*e.g.,* bifidus), yogurt drink and buttermilk, *in liquid form, essentially (96%) without added sugars/artificial sweeteners.*	77.8	**62%***
	Yogurt & fresh cheese	Mammals' yogurt, branded fermented milk and kefir, fresh cheese (*e.g.,* petit suisse, quark, cottage cheese, ricotta), *in semi-solid form, mostly (67%) with added sugars/artificial sweeteners.*	32.3	**47%***
	Cheese	Mammals' soft and hard cheese, spread cheese, processed/melted cheese.	5.4	**13%***
	Red meat	Fresh meat and offal from beef, veal, pork, lamb, mutton, horse, goat, rabbit, and wild red meat (*e.g.,* venison/deer)	0.2	1%
	Poultry	Fresh meat and offal from chicken, turkey, duck, goose, and ostrich.	0.2	1%
	Processed meat	Sausages, cold cuts, smoked or cured meat (*e.g.,* ham, bacon, salami, corned beef, beef jerky, meat terrine), meat-based sauces (*e.g.,* Bolognese sauce), meat-based spread (*e.g.,* liver spread), and minced meat for burgers.	1.6	**5%***
	Fish & seafood	All types of fresh fish, seafood and snails, and processed fish and seafood products (*e.g.,* fish in crumb, surimi).	0.3	2%
Added fats & oils	Vegetable oils	Added vegetable oils (*e.g.,* rapeseed oil, olive oil, sunflower oil). Except: coco fat used to cook.	0.2	3%
	Butter	Added butter to cook and spread on bread.	5.6	**58%***
	Cream	All types of mammals' added creams.	1.4	**11%***
	Sauces rich in fats	Sauces rich in oil or in butter (*e.g.,* mayonnaise, pesto, sauce café de Paris), other sauces rich in cream or other fats (*e.g.,* carbonara, cocktail sauce, hummus, satay sauce), and coco milk.	0.1	1%
	Dressing sauces	All types of dressing sauces.	0.0	0%
	Nuts & seeds	Dried nuts and seeds (*e.g.,* almonds, hazelnuts, coconut), olives, and avocadoes, *with or without salt/sugars.*	1.6	**16%***
Sweets, salty snacks & alcohol	**Added sugars**	All types of beet or cane sugars, polyols. Except: stevia and artificial sweeteners.	1.3	**33%***
	Sweet spreads & sauces	Jams, jelly, honey, syrups, sweet sauces (*e.g.,* caramel or chocolate sauce, maple syrup), chocolate spread, peanut butter, and sweet topping (*e.g.,* icing).	17.5	**78%***
	Cakes, desserts & ice-cream	All types of sweet cakes, pies and tarts (*e.g.,* brownies, lemon cakes, muffins), sweet pastries (*e.g.,* waffles, chocolate croissants, doughnuts), desserts made with dairy products (*e.g.,* pudding, chocolate mousse, tiramisu), ice-cream, sorbet, iced cakes.	2.3	**6%***
	Biscuits	All types of sweet and dried biscuits (*e.g.,* shortbread, amaretto, Christmas biscuits, chocolate chip cookies, leckerli, meringue).	1.0	**12%***

Sweets, salty snacks & alcohol	**Sugar confectionery**	All types of sweets and candies (*e.g.,* marzipan, candied fruit, lollipop, marshmallows), pure chocolate, chocolate products and confections (*e.g.,* filled chocolate, pralines, branded chocolate bars), sports cereal bars (*e.g.,* energy bars), and sweet pop corn.	0.8	**6%***
	Salty snacks	Crisps, flips, salty popcorn, dried salty crackers (*e.g.,* golden fish biscuits, sticks, pretzels), cocktail canapés, crostini/bruschetta, spring rolls, ham croissants, samosa, and sausage rolls.	0.3	4%
	Juices 100%	100% fruit and vegetable juices (fresh or from concentrate), smoothie, fruit-schorle (*i.e.,* fruit juices, often apple juice, mixed with water), *all without added sugars/artificial sweeteners.*	31.4	**39%***
	Sugary soft drinks	Sweetened soft drinks, sports drinks, energy drinks, fizzy drinks, ice tea, diluted syrup, drinks made with fruit juice and water (*e.g.,* fruit nectars, lemonades), alcohol-free beers, *with added sugars.*	13.9	**11%***
	Beer	All types of alcoholic beers, apple or pear ciders, and shandy (*e.g.,* beer with lemonade).	0.0	0%
	Wine	White and red wine, champagne, wine products (*e.g.,* sangria, punch/bowle with alcohol), port, sherry, and vermouths.	0.0	0%

** Relevant for derivation of breakfast dietary patterns because ≤ 5% of the intake (in g) is brought by breakfast.*

Additional file 4. Scree plot of eigenvalues (y-axis) and number of factors (x-axis). *Three factors should be kept: factor one explains 11.5% of variance, factor two 8.1% and factor three 6.5% (cumulative percentage: 26.1%).*



Additional file 5. Components and scoring method of the nutritional score used to assess food-based diet quality for the rest of the day (*i.e.,* without breakfast) based on the 2010 Alternate Healthy Eating Index[1,2]

Components	**Criteria for minimum score (0)**	**Criteria for maximum score (10)**
Vegetables, excluding potatoes (servings/day)[3]	0	≥ 5
Fruit, excluding juice (servings/day)[4]	0	≥ 4
Whole grains (g/day)[5]		
Women	0	≥ 75
Men	0	≥ 90
Sugar-sweetened beverage and fruit juice (servings/day)[6]	≥ 1	0
Nuts, seeds, legumes, and tofu (servings/day)[7]	0	≥ 1
Red and processed meat (servings/day)[8]	≥ 1.5	0

[1] Adapted from Chiuve et al. 2012. [2] Intermediate food intake was scored proportionately between the minimum score 0 and the maximum score 10. [3] One serving was equal to 118.3g of raw or cooked vegetables, 30g of dried vegetables or 250g of homemade vegetable soup. [4] One serving was equal to 118.3g of raw or cooked fruit or 30g of dried fruit. [5] Any grain food (e.g., rice, pasta, bread, breakfast cereals, etc.) with a carbohydrate-to-fibre ratio smaller than 10:1 was considered as whole grain. [6] One serving was equal to 226.8g. [7] One serving was equal to 28.4g. [8] One serving was equal to 113.4g of red meat or 42.5g of processed meat.

Additional file 6. Association between breakfast skipping and abdominal obesity (WHR ≥ 0.9 (♂); ≥ 0.85 (♀), N=2 019).

	Regular eaters (N=1 531)	Occasional eaters (N=668)			
	OR	**OR**	**95% CI**		**P-value**
Crude	1 (ref)	1.12	0.91	1.38	0.27
Model 1 (sex + age)	1 (ref)	1.67	1.29	2.16	<0.001**
Model 2 *(11 covariates)* [1]	1 (ref)	1.59	1.21	2.08	<0.001**

*[1] Sex, age (continuous), physical activity (MET-min per week, continuous, imputed), total energy intake (mean out of two 24-hour dietary recalls), education (university degree: yes / no), food literacy (knowing about the Swiss Food Pyramid: yes / no), smoking (never / past / current), nationality (Swiss / non-Swiss), household status (alone / couple with children / couple without children), season of the first 24-hour dietary recall (cold / warm), linguistic region (German / French / Italian).[2] Differences were assessed using multiple logistic regressions (** P ≤ 0.001).*

Additional file 7. Associations between all the covariates and breakfast composition patterns (N=1 351).

Covariates	Association with the 'traditional' breakfast [1]		Association with the 'prudent' breakfast [1]		Association with the 'western' breakfast [1]	
	OR	P-value	OR	P-value	OR	P-value
Sex						
Male	1 (ref.)		1 (ref.)		1 (ref.)	
Female	0.597	<0.001**	1.097	0.361	0.728	0.002*
Age, *y*	1.020	<0.001**	1.021	<0.001**	0.986	<0.001**
Physical activity, *MET-min per week*	1.00009	<0.001**	1.000003	0.877	1.00001	0.593
Total energy intake, *kcal*	1.0006	<0.001**	1.0001	0.349	1.0004	<0.001**
Education						
Secondary (*e.g.,* apprenticeship and below)	1 (ref.)		1 (ref.)		1 (ref.)	
Tertiary (*e.g.,* high technical school, university)	0.816	0.042 *	1.242	0.030*	1.051	0.618
Food literacy						
No	1 (ref.)		1 (ref.)		1 (ref.)	
Yes	0.797	0.081	1.054	0.681	0.912	0.479
Linguistic region						
German	1 (ref.)		1 (ref.)		1 (ref.)	
French	1.064	0.595	0.486	<0.001**	0.708	0.003*
Italian	0.557	0.001*	0.191	<0.001**	0.764	0.102
Smoking						
Never	1 (ref.)		1 (ref.)		1 (ref.)	
Past	1.002	0.988	1.097	0.435	0.794	0.052
Current	0.892	0.406	0.675	0.005*	1.046	0.742
Season of the first 24-hour dietary recall						
Cold	1 (ref.)		1 (ref.)		1 (ref.)	
Warm	0.997	0.976	0.884	0.217	0.783	0.015*
Nationality						
Non-Swiss	1 (ref.)		1 (ref.)		1 (ref.)	
Swiss	1.995	<0.001**	1.363	0.030*	1.313	0.047*
Household status						
Alone	1 (ref.)		1 (ref.)		1 (ref.)	
Couple with children	1.016	0.882	0.589	<0.001**	1.037	0.735
Couple without children	0.877	0.435	0.574	0.001*	1.667	0.003*
Alcohol, *g*	1.004	0.229	0.998	0.407	0.993	0.016*
Fibre intake during the rest of the day, *g*	0.993	0.347	1.042	<0.001**	1.001	0.870
Saturated fat intake during the rest of the day, *g*	1.014	<0.001**	1.004	0.345	1.013	<0.001**
Sodium intake during the rest of the day, *g*	1.076	0.092	0.901	0.015*	1.124	0.006*
6-food-component score during the rest of the day, *0-60*	0.978	<0.001**	1.048	<0.001**	0.976	<0.001**

[1] *Assessed with univariate ordered logistic regression (T1, T2, T3, * P ≤ 0.05, ** P ≤ 0.001).*

Additional file 8. Differences in nutrient intakes at breakfast (unadjusted plus adjusted medians of the mean intake out of two 24-hour dietary recalls) by breakfast type (Tertiles, T1 vs. T3, N=1 351).

Unadjusted medians:

	'Traditional' - Pattern 1					'Prudent' - Pattern 2					'Western' - Pattern 3				
	T1	**T2**	**T3**	**T3 / T1 (%)**	**P-value [1]**	**T1**	**T2**	**T3**	**T3 / T1 (%)**	**P-value [1]**	**T1**	**T2**	**T3**	**T3 / T1 (%)**	**P-value [1]**
Energy (kcal)	350.4	387.3	595.8	170%	<0.001**	381.6	446.6	482.4	126%	<0.001**	396.4	407.1	493.8	125%	<0.001**
Protein (g)	11.1	10.8	14.7	133%	<0.001**	10.5	12.1	14.2	135%	<0.001**	10.2	10.3	15.8	155%	<0.001**
Total carbohydrate (g)	47.3	50.3	79.9	169%	<0.001**	52.1	57.9	63.6	122%	<0.001**	56.3	53.7	64.8	115%	<0.001**
Sugars (g)	27.7	24.5	38.7	140%	<0.001**	25.7	28.3	36.0	140%	<0.001**	30.4	25.7	34.4	113%	0.010*
Fibre (g)	4.2	3.6	5.1	120%	0.002*	2.8	4.0	6.7	235%	<0.001**	4.4	3.8	4.8	109%	0.09
Total Fat (g)	11.0	13.1	22.0	200%	<0.001**	13.8	16.1	15.2	111%	0.08	13.7	14.2	16.5	121%	0.001**
Saturated fat (g)	4.6	6.4	11.0	238%	<0.001**	6.6	7.8	6.1	93%	0.28	6.2	6.6	7.7	123%	0.001**
Sodium / Na (mg)	172.6	354.9	594.5	344%	<0.001**	356.8	446.4	258.1	72%	<0.001**	333.2	376.2	359.5	108%	0.30

[1] *Differences between T1 and T3 were assessed using Wald tests on quantile regression coefficients (no adjustment, * P ≤ 0.05, ** P ≤ 0.001).*

Adjusted[1] medians:

	'Traditional' - Pattern 1					'Prudent' - Pattern 2					'Western' - Pattern 3				
	T1	**T2**	**T3**	**T3 / T1 (%)**	**P-value [2]**	**T1**	**T2**	**T3**	**T3 / T1 (%)**	**P-value [2]**	**T1**	**T2**	**T3**	**T3 / T1 (%)**	**P-value [2]**
Energy (kcal)	433.0	434.4	457.1	106%	<0.001**	438.5	443.3	440.9	101%	<0.001**	433.1	442.6	447.0	103%	<0.001**
Protein (g)	12.1	12.0	12.5	104%	<0.001**	12.3	12.2	12.1	99%	<0.001**	11.9	12.2	12.5	104%	<0.001**
Total carbohydrate (g)	58.1	58.1	60.8	105%	<0.001**	59.1	59.2	58.8	99.6%	<0.001**	57.9	59.1	60.1	104%	0.012*
Sugars (g)	30.1	30.2	31.7	105%	<0.001**	30.7	30.8	30.6	99.7%	<0.001**	30.0	30.7	31.2	104%	0.16
Fibre (g)	4.3	4.3	4.5	105%	0.024*	4.2	4.4	4.4	104%	<0.001**	4.3	4.4	4.4	101%	0.14
Total Fat (g)	14.6	14.7	15.6	107%	<0.001**	14.7	15.1	15.1	102%	0.06	14.7	15.1	15.1	102%	0.006*
Saturated fat (g)	6.7	6.8	7.3	109%	<0.001**	6.8	7.1	7.0	103%	0.12	6.8	7.1	7.0	102%	<0.001**
Sodium / Na (mg)	351.0	356.4	377.1	107%	<0.001**	355.5	366.6	363.2	102%	<0.001**	356.5	365.9	363.9	102%	0.046*

[1] *Adjusted for sex, age (continuous), physical activity (MET-min per week, continuous, imputed), measured height.* [2] *Differences between T1 and T3 were assessed using Wald tests on multiple quantile regression coefficients (adjustment for sex, age, physical activity and height, * P ≤ 0.05, ** P ≤ 0.001).*

Additional file 9. Differences in nutrient intakes for the rest of the day (excluding breakfast intakes, unadjusted plus adjusted medians of the mean intake out of two 24-hour dietary recalls) by breakfast type (Tertiles, T3 vs. T1, N=1 351).

Unadjusted medians:

	'Traditional' - Pattern 1					'Prudent' - Pattern 2					'Western' - Pattern 3				
	T1	**T2**	**T3**	**T3 / T1 (%)**	**P-value [1]**	**T1**	**T2**	**T3**	**T3 / T1 (%)**	**P-value [1]**	**T1**	**T2**	**T3**	**T3 / T1 (%)**	**P-value [1]**
Energy (kcal)	1625.1	1583.8	1731.7	107%	0.018*	1660.5	1647.1	1625.3	98%	0.44	1581.0	1634.6	1718.6	109%	0.004*
Protein (g)	64.4	61.6	62.6	97%	0.34	64.4	63.6	61.6	96%	0.18	61.4	62.5	64.6	105%	0.10
Total carbohydrate (g)	154.2	153.7	172.9	112%	<0.001**	163.8	161.2	154.0	94%	0.06	148.0	156.1	173.6	117%	<0.001**
Sugars (g)	64.5	65.3	72.4	112%	0.005*	66.8	69.5	68.1	102%	0.66	61.3	67.8	73.8	120%	<0.001**
Fibre (g)	15.7	14.9	15.6	99%	0.92	14.4	15.5	16.7	115%	<0.001**	15.6	15.2	15.5	99%	0.88
Total Fat (g)	67.2	66.6	69.9	104%	0.28	68.0	67.6	67.9	100%	0.99	66.1	67.5	71.4	108%	0.019*
Saturated fat (g)	23.0	23.0	25.7	112%	0.002*	23.7	24.8	24.0	101%	0.73	23.3	23.9	25.1	108%	0.046*
Alcohol (g)	2.7	4.7	7.5	280%	<0.001**	2.5	5.4	5.3	214%	0.06	6.1	5.1	4.0	67%	0.22
Sodium / Na (mg)	2242.5	2209.2	2512.7	112%	0.001**	2349.9	2331.8	2204.2	94%	0.09	2220.5	2264.3	2420.1	109%	0.027*

[1] *Differences between T1 and T3 were assessed using Wald tests on quantile regression coefficients (no adjustment, * P ≤ 0.05, ** P ≤ 0.001).*

Adjusted[1] medians:

	'Traditional' - Pattern 1					'Prudent' - Pattern 2					'Western' - Pattern 3				
	T1	**T2**	**T3**	**T3 / T1 (%)**	**P-value [2]**	**T1**	**T2**	**T3**	**T3 / T1 (%)**	**P-value [2]**	**T1**	**T2**	**T3**	**T3 / T1 (%)**	**P-value [2]**
Energy (kcal)	1658.0	1637.2	1694.5	102%	0.22	1686.0	1654.7	1647.9	98%	0.73	1625.6	1655.1	1709.5	105%	0.08
Protein (g)	64.3	63.7	66.7	104%	0.74	65.7	64.7	64.2	98%	0.020*	63.2	64.7	66.7	106%	0.53
Total carbohydrate (g)	163.3	159.9	164.2	101%	0.012*	166.7	160.6	159.9	96%	0.86	157.9	161.0	169.0	107%	0.010*
Sugars (g)	68.0	67.5	68.9	101%	0.024*	68.9	67.8	67.4	98%	0.49	66.6	67.9	69.8	105%	<0.001**
Fibre (g)	15.3	15.2	15.5	101%	0.45	15.4	15.3	15.3	99.7%	<0.001**	15.2	15.3	15.5	102%	0.35
Total Fat (g)	68.9	68.2	70.1	102%	0.31	69.5	68.7	68.7	99%	0.19	67.7	68.7	70.5	104%	0.21
Saturated fat (g)	24.5	24.4	25.3	103%	0.07	24.7	24.7	24.7	100.1%	0.67	24.3	24.7	25.1	103%	0.13
Alcohol (g)	5.3	5.7	7.2	136%	0.69	5.6	6.4	6.2	110%	0.90	5.8	6.4	6.1	104%	0.44
Sodium / Na (mg)	2341.8	2304.1	2377.6	102%	0.22	2398.2	2318.8	2298.6	96%	0.50	2281.0	2320.6	2415.7	106%	0.17

[1] *Adjusted for sex, age (continuous), physical activity (MET-min per week, continuous, imputed), measured height.* [2] *Differences between T1 and T3 were assessed using Wald tests on multiple quantile regression coefficients (adjustment for sex, age, physical activity and height, * P ≤ 0.05, ** P ≤ 0.001).*

Additional file 10. Differences in food group intakes for the rest of the day (excluding breakfast intakes, mean score from 0 to 10 per component, derived from the mean intake out of two 24-hour dietary recalls) by breakfast type (Tertiles, T3 vs. T1, N=1 351).

See Additional file 5 for the calculation of the nutritional score

Unadjusted means:

	'Traditional' - Pattern 1					'Prudent' - Pattern 2					'Western' - Pattern 3				
	T1	**T2**	**T3**	**T3 / T1 (%)**	**P-value[1]**	**T1**	**T2**	**T3**	**T3 / T1 (%)**	**P-value[1]**	**T1**	**T2**	**T3**	**T3 / T1 (%)**	**P-value [1]**
Vegetables	3.4	3.4	3.2	93%	0.08	3.1	3.2	3.7	121%	<0.001**	3.6	3.3	3.1	85%	<0.001**
Fruit	3.2	3.2	3.1	97%	0.59	2.7	3.3	3.5	129%	<0.001**	3.2	3.2	3.1	96%	0.53
Whole grain	2.6	2.2	2.0	76%	0.003*	2.0	2.1	2.8	145%	<0.001**	2.5	2.1	2.3	92%	0.38
Sugary drinks	6.5	6.2	5.7	88%	0.008*	5.7	6.0	6.8	119%	<0.001**	6.6	6.1	5.7	87%	0.003*
Nuts and legumes	2.2	1.9	1.7	77%	0.030*	1.6	1.7	2.5	157%	<0.001**	2.3	1.9	1.6	71%	0.003*
Meat	4.9	4.3	4.2	85%	0.004*	3.7	4.3	5.4	147%	<0.001**	4.9	4.3	4.1	83%	<0.001**
Total score	22.9	21.3	19.9	87%	<0.001**	18.8	20.5	24.8	132%	<0.001**	23.1	21.1	19.8	86%	<0.001**

*[1] Differences between T1 and T3 were assessed using Wald tests on simple linear regression coefficients (no adjustment, * P ≤ 0.05, ** P ≤ 0.001).*

Adjusted[1] means:

	'Traditional' - Pattern 1					'Prudent' - Pattern 2					'Western' - Pattern 3				
	T1	**T2**	**T3**	**T3 / T1 (%)**	**P-value [2]**	**T1**	**T2**	**T3**	**T3 / T1 (%)**	**P-value [2]**	**T1**	**T2**	**T3**	**T3 / T1 (%)**	**P-value [2]**
Vegetables	3.3	3.3	3.4	101%	0.033*	3.3	3.4	3.4	103%	<0.001**	3.4	3.4	3.3	98%	<0.001**
Fruit	3.1	3.2	3.2	104%	0.22	3.1	3.2	3.2	105%	<0.001**	3.2	3.2	3.1	96%	0.97
Whole grain	2.3	2.3	2.3	97%	0.006*	2.3	2.3	2.3	99%	<0.001**	2.3	2.3	2.3	102%	0.23
Sugary drinks	6.1	6.2	6.1	101%	0.002*	5.9	6.2	6.3	106%	0.008*	6.3	6.2	5.9	93%	0.12
Nuts and legumes	2.0	2.0	1.9	93%	0.12	2.0	1.9	1.9	99%	<0.001**	2.0	1.9	1.9	100%	0.003*
Meat	4.6	4.6	4.3	94%	0.06	4.4	4.5	4.5	102%	<0.001**	4.6	4.5	4.3	95%	0.014*
Total score	21.4	21.5	21.1	99%	<0.001**	20.9	21.4	21.6	103%	<0.001**	21.7	21.4	20.9	96%	<0.001**

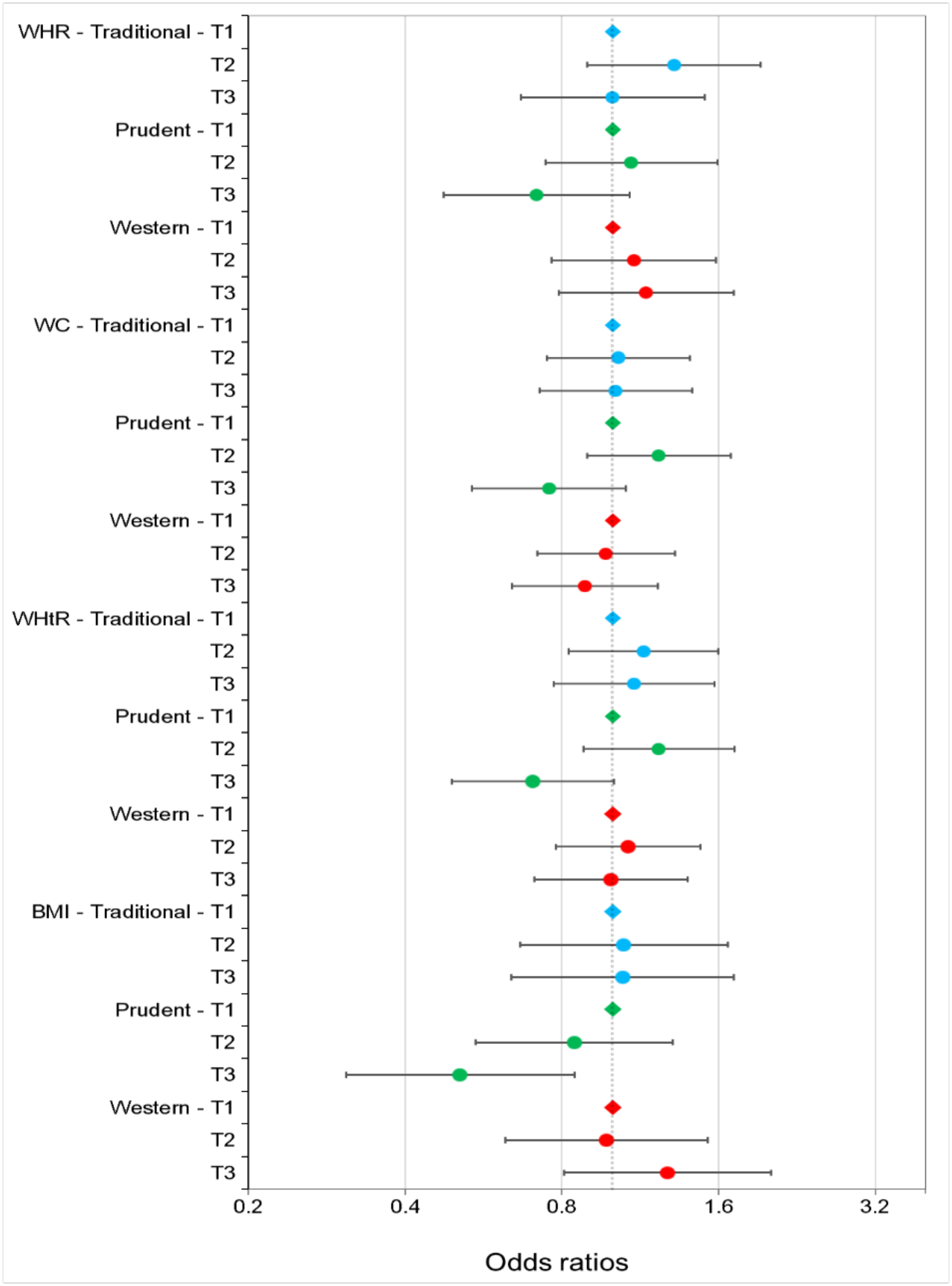
*[1] Adjusted for sex, age (continuous), physical activity (MET-min per week, continuous, imputed), measured height. [2] Differences between T1 and T3 were assessed using Wald tests on multiple linear regression coefficients (adjustment for sex, age, physical activity and height, * P ≤ 0.05, ** P ≤ 0.001).*

Additional file 11. Association between 'prudent' breakfast and abdominal obesity (based on log WHR, continuous, N=1 351).

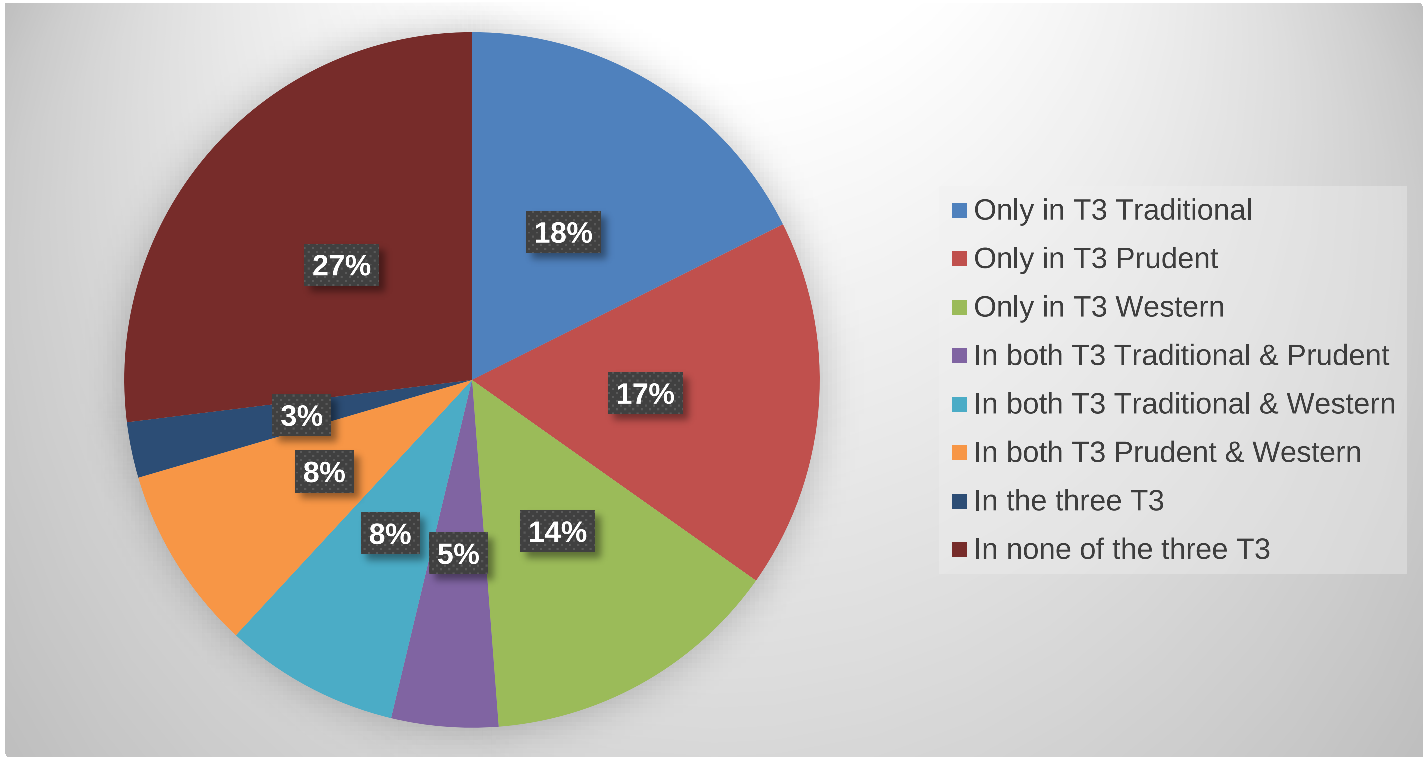
	'Prudent' - Fruit, unprocessed and unsweetened cereal flakes, nuts/seeds and yogurt							
	T1	**T2**			**T3**			
	β	**β**	**95% CI**		**β**	**95% CI**		**P-value for trend[3]**
Crude	0 (ref)	0.0211	0.0064	0.0359	0.0000	-0.0147	0.0147	0.99
Model 1 *(sex + age)*	0 (ref)	0.0004	-0.0092	0.0100	-0.0154	-0.0250	-0.0058	0.002*
Model 2 *(age + sex + physical activity + total energy intake)[1]*	0 (ref)	0.0012	-0.0084	0.0109	-0.0153	-0.0249	-0.0056	0.002*
Model 3 *(11 covariates)[1]*	0 (ref)	0.0007	-0.0097	0.0098	-0.0155	-0.0255	-0.0054	0.002*
Model 4 *(16 covariates, including diet quality during the rest of the day - nutrient + food-based approach)[2]*	0 (ref)	0.0015	-0.0083	0.0113	-0.0120	-0.0222	-0.0018	0.020*

[1] Sex, age (continuous), physical activity (MET-min per week, continuous, imputed), total energy intake (mean out of two 24-hour dietary recalls), alcohol intake (mean intake out of two 24-hour dietary recalls), education (university degree: yes / no), food literacy (knowing about the Swiss Food Pyramid: yes / no), smoking (never / past / current), nationality (Swiss / non-Swiss), household status (alone / couple with children / couple without children), season of the first 24-hour dietary recall (cold / warm), linguistic region (German / French / Italian). [2] Idem plus diet quality during the rest of the day (outside breakfast) considering dietary fibre, saturated fat, sodium, and the six-food-component nutritional score (mean intake out of two 24-hour dietary recalls).[3] Differences were assessed using multiple logistic regressions (P ≤ 0.05).*

Additional file 12. Association between the three breakfast types and four obesity anthropometric parameters. *Odds ratios between the three breakfast types (Tertiles 1 to 3: T3 being closely associated with the pattern) and abdominal obesity (waist-to-hip ratio (WHR): ≥ 0.9 (♂); ≥ 0.85 (♀); waist circumference (WC): > 90 cm (♂); > 84 cm (♀), waist-to-height ratio (WHtR): ≥ 0.5 (♂, ♀), body mass index (BMI): ≥ 30 kg/m2 (♂, ♀), N=1 351). The logistic models were adjusted for sex, age, physical activity, total energy intake, alcohol intake, education, food literacy, smoking, nationality, household status, season of the first 24-hour dietary recall, linguistic region, and diet quality during the rest of the day (outside breakfast).*



Additional file 13. Distribution of regular breakfast eaters (N= 1 351) in the three breakfast types (Tertile 3, T3, is the one closely associated with the pattern).



7. Nutrition survey in children

Title of the internal report for the Federal Food Safety and Veterinary Office (FSVO): Lessons learnt about a feasibility study among children and adolescents aged 3 to 17 years to prepare the next national nutrition survey

Authors: Angeline Chatelan[1], Murielle Bochud[1]

Affiliations: [1] Institute of Social and Preventive Medicine (IUMSP), Lausanne University Hospital (CHUV), Lausanne, Switzerland

Author contributions: AC, trained as a registered dietitian, designed the study and wrote the protocol. AC recruited participants. AC collected data in collaboration with a study nurse and another registered dietitian, trained by AC. AC organized biobanking procedures and laboratory analyses. AC performed the statistical analyses and wrote the report. MB, trained a medical doctor, was the study principal investigator. MB determined whether participants needed further medical investigation after the study. MB reviewed and approved the final report and the summary presented in this thesis.

Publication status: The detailed report (80 pages) is under revisions after review by FSVO.

In this thesis, only a summary of the full report is presented.

7.1. Abstract

Little is known about the diet and nutritional status of Swiss children and adolescents. In 2014-2015 the first national nutrition survey, menuCH, has been only performed in adults. Before setting up a national nutrition survey among children and adolescents, age-specific methodologies and acceptability for bio-sample collection needed to be tested in a feasibility study. The aim of this report is to describe this cross-sectional and single-centre small-scale nutrition survey and provide recommendations for the next national nutrition survey. We recruited healthy children aged 3 to 10 years and adolescents aged 11 to 17 years, who were randomly selected from the population registry. We completed this sample with a convenience sample (recruitment by flyers). We assessed dietary intake with two non-consecutive computerized 24-hour dietary recalls (24HDR, assisted by 24-hour food diaries in children under 11 years) and an on-line food propensity questionnaire. We scanned participants' palm skin for its carotenoid concentration using Raman spectroscopy. Bio-sample collection included spot urine, toenails, and capillary and venous blood. Participants' caregiver(s) and paediatricians were informed when results indicated potential nutritional or health problems based on laboratory analyses. Fifty-three children living in and near Lausanne took part in the feasibility study. Participation rate was low in the population registry sample (16%), but acceptation rate was high for bio-sample collection: spot urine (100%), toenail (96% in children), capillary blood (79% in children and 100% in adolescents), and venous blood (83% in adolescents). Tested dietary assessment tools were well accepted by children and adolescents. They would need only minor modifications before the main survey. The score established by the palm skin scanner was fairly correlated to the plasma carotenoid concentration (Pearson's r = 0.69). Personal feedback given to participants' caregiver(s) was appreciated but time-consuming for the study team since four in five adolescents who accepted venous blood collection had at least one marker indicating potential nutritional or health problems. Main recommendations for a national nutritional survey among children and adolescents are 1) to assess diet using two non-consecutive 24HDR (assisted by 24-hour food diary) and a FPQ, 2) to improve the recruitment procedures to increase participation rate, 3) to collect bio-samples and use biomarkers to assess nutritional status more precisely and to establish population references/norms, and 4) to re-think personal feedback to participants and their caregiver(s).

7.2. Introduction

Diet is a major determinant of health in all age groups and studying diet and nutritional status of children and adolescents is important for several reasons. First, deficiency in macro- and micronutrients are especially harmful during early life [1-3]. Second, health-related habits and eating behaviours are partly shaped during childhood and adolescence [4-6]. Third, multiple studies have shown a strong association between paediatric and adult obesity: about half of obese school-age children stay obese during adulthood [7]. This percentage may raise up to 90% in obese adolescents [8], depending on the age at baseline and criteria used in the definitions of obesity. Obese children are also at increased risk of suffering from obesity-related health consequences later in life [9]. Currently, little is known in Switzerland about the dietary intake and nutritional status of children and adolescents. The European Food Safety Authority (EFSA) warned about the risk of inadequate intakes in long-chain polyunsaturated fatty acids, iron, and vitamin D in different European countries [10]. In Switzerland, there have been historical concerns for low iodine status [10-12]. We also know that between 15% and 20% of Swiss children and adolescents are overweight or obese [13-15]. However, we lack detailed information about their dietary intake. Only one study in 2010, the FAN study in the Italian-speaking part of Switzerland, showed that the 568 included children aged 6 to 12 poorly followed the national dietary guidelines [16].

EFSA recommends including children and adolescents in national nutrition surveys [17, 18]. Since 2005, almost all countries in Western Europe have included children and adolescents in their national nutrition surveys [17] (Chapter 1.4.2). In Switzerland, they were excluded from the first national nutrition survey, menuCH, conducted in 2014-2015, but should be included in the second national nutrition survey. EFSA highly recommends using a 24-hour food diary in children below 10 years to guide the 24-hour dietary recalls (24HDR) [17]. So far this methodology has never been used at the national level. Within menuCH, dietary intake was only assessed with 24HDRs. Hence, a 24-hour food diary needs to be developed and tested in children before the next national survey. Additionally, no bio-samples were collected in menuCH, and thus experience is lacking regarding collection, storage and analyses of bio-samples. The degree of acceptability to various bio-sample collections among healthy Swiss children and adolescents is also unclear. A feasibility study in a population-based sample of children and adolescents to test 1) age-specific dietary assessment methods, 2) the acceptability of various bio-sample collections, and 3) bio-sample management and analyses, was therefore needed to help plan and budget the next national nutrition survey.

The main aims of this report summary are 1) to describe the planning and conduction of the feasibility study, and 2) to provide recommendations for the next national survey. Of note, this summary does not aim at describing food consumption or nutritional status of the interviewed children and adolescents since the sample size was small. Nevertheless, we present a few results considered as relevant for discussion.

7.3. Methods

The performed feasibility study was a cross-sectional, single-centre, small-scale nutrition survey.

Sampling and recruitment

The target population consisted of a representative sample of children and adolescents from the general population residing in, or near, Lausanne. All *a priori* healthy and free-living individuals aged between 3 and 17 years were eligible. The exclusion criteria were having a severe chronic disease, being hospitalized, pregnant, or having an insufficient knowledge of French to understand the study. The intended sample size was 50-70 participants (*i.e.,* about 3-4 individuals per age year).

We recruited participants through two methods: population registry and flyers. First, the cantonal authorities refused access to the cantonal population registry for research purposes. Thus, we bought names and addresses for commercial mailing from the foundation BVA (www.bva.ch) for one CHF per name/address. The resulting names and addresses came from the same cantonal population registry. We asked the foundation for a stratified random sample of child-caregiver pairs living in Lausanne and two suburbs of Lausanne (*i.e.,* Prilly and Renens). Invitation letters were sent by waves every month. Each letter included a pre-stamped response card on which the participant and/or his/her caregiver(s) could indicate their contact details (*i.e.,* email address and/or phone) and availabilities for a phone call with the PhD student to explain the study. Second, we completed the population registry sample with a convenient sample in order to compare these two recruitment methods. Participants were recruited by flyers, displayed in several buildings of ‘Centre Hospitalier Universitaire Vaudois’ (CHUV) in Lausanne.

Overall procedures

Face-to-face interviews with participants and caregiver(s) took place at the Clinical Trial Unit (CTU) in CHUV **(Figure 1**). The PhD student was a registered dietitian with expertise in research and methodologies previously used in menuCH.

1 **Phone call or preparatory interview with the PhD student (dietitian):** If participant interested in taking part to the study, duration: 10-20 min

- Information to participant and/or his/her caregiver(s) about the study
- Inclusion and exclusion criteria
- Schedule of the face-to-face interview
- Instructions for food diary completion for children aged 3 to 10 years
- Sending by mail post or giving the consent form + material for bio-sample collection and dietary assessment
- Emailing the web links for the on-line questionnaire(s)

2 **Face-to-face interview in CHUV with the PhD student (dietitian) and the study nurse :** 1-4 weeks later, duration: 45min-1h30, early morning while fasting, if possible

- Signature of informed consent
- Control of the completeness of web-based questionnaire(s)
- Spot urine (collected at home, first morning specimen)
- Palm skin spectroscopy
- Collection of toenails by the nurse or caregiver (only for children aged 3 to 10 years, optional)
- Collection of venous blood by the nurse (only for adolescents aged 11 to 17 years, optional)
- Collection of capillary blood by the nurse (optional)
- Weight and height measurements
- Breakfast
- First 24-hour dietary recall (24HDR), based on the food diary for children aged 3 to 10 years
- Instructions for the second 24HDR + giving material for dietary assessment
- Schedule of the phone interview

3 **Phone call from the study medical doctor:** 1-2 weeks later, duration: 5-10 min

- Only, if results indicated potential health or nutritional conditions or if the participant or caregiver(s) wanted to discuss or be referred to a medical doctor

4 **Phone call with the study dietitian:** 2-6 weeks later, duration: 45 min

- Second 24HDR
- Questions on the hypothetical acceptance to take picture of consumed foods and collect other types of bio-samples
- Information about compensation and results

5 **Post mailing:** max. 2 months after the phone call

- Compensation for participation
- Individual written results sent to participant and caregiver(s)

Figure 1. Procedures used in the feasibility study for children and adolescents aged 3 to 17 years old.

Dietary assessment and anthropometry

Food consumption information was collected through two non-consecutive 24HDR led by two registered dietitians, trained with the GloboDiet® software [19-21]. The first 24HDR was face-to-face and the second by phone. For children aged 3 to 10 years, the PhD student developed and pretested a detailed 24-hour food diary following EFSA recommendations [17, 22]. The picture book used in menuCH to support study participants in quantifying amounts of consumed foods [23] was complemented with pictures of household measures for toddlers (*e.g.,* small plates, plastic glasses) and baby bottles. The PhD student also established a food propensity questionnaire (FPQ), which was included in the on-line questionnaires (below). Body weight with light clothing (not underwear) was measured to the nearest 0.1 kg, respectively cm, following World Health Organization guidelines [24] and using a Seca 701 scale (Seca GmbH, Hamburg, Germany). Height was measured with a Seca 213 gauge.

Online questionnaires

The PhD student developed three web-based questionnaires in the LimeSurvey platform (LimeSurvey Project, Hamburg, Germany), a free open source survey tool. The first questionnaire was intended for caregiver(s) of children aged 3 to 10 years, the second one for adolescents aged 11 to 17 years, and the third one for adolescents' caregiver(s). Questionnaires assessed eating and drinking behaviours, perceived lack of access to food (financial, geographical and social barriers to healthy eating), food habits and avoidance, meal context, detailed uptake of supplements in vitamins, minerals and other substances, consumption of organic foods, nutrition literacy, weight management and satisfaction, general health, health behaviours of participants and caregiver(s), household eating habits, caregiver(s)' socio-economic status (SES). We used questions similar to those used in menuCH questionnaire, but added questions related for example to perceived lack of access to food from the 2015 Canadian Community Health Survey - Nutrition (https://www.canada.ca/en/health-canada.html), or household's barriers to healthy eating from the 2014 Belgian Food Consumption Survey (https://fcs.wiv-isp.be).

Bio-samples and biomarkers

The first morning void of urine (*i.e.,* overnight urine specimen) was collected at home and brought to the CTU. At the CTU, the PhD student measured palm skin carotenoid concentration on both hands (*e.g.,* lutein, zeaxanthin, α-carotene, β-carotene, and lycopene) using the validated Biozoom® scanner [25-27]. The nurse collected venous (15 ml) and capillary (4 to 10 drops) blood, if accepted by participant and caregiver(s). Two Elma® patches containing local anaesthetics (lidocaine and prilocaine) and relevant instructions on how, where and when to apply them were given to participants in advance so that they could place the patches at least 1h before on their finger or arm prick. Finally, the nurse collected a piece of each big toenail with a stainless steel clipper or scissors. If participants could attend the face-to-face interview in the morning, the PhD student asked them to be fasting. Those who were fasting were offered a breakfast after bio-sample collection.

Table 1 describes the list of biomarkers analysed per bio-sample, and which laboratory performed the analyses. Fresh venous blood and urine were directly analysed by the central laboratory in CHUV by routine clinical chemistry analyses. The rest of anonymized tubes were stored at -80°C in the IUMSP biobank for further analysis at the end of the study. If accepted by caregiver(s) in the consent forms, we kept reserve aliquots of urine and blood samples for potential further research in relation to nutrition or toxicology. Of note, toenail samples were not analysed for financial reasons, even though they could have been useful for trace elements measurements, such as selenium, copper, zinc, cadmium, *etc*. [38-41].

Other data

During the phone interview, participants and/or their caregiver(s) were asked whether they would accept or refuse collecting other bio-samples (*i.e.,* saliva, 24-hour urine, and faeces) and take pictures of what they or their children ate. These questions were naturally hypothetical since no follow-up study was planned.

Table 1. List of biomarkers according to the three collected bio-samples.

Biomarkers	Venous blood *Up to 15 ml*	Capillary blood *4 drops*	Spot urine *Up to 70 ml*	Clinical and epidemiological interpretation
Creatinine	x (plasma)[1]		x[1]	Kidney function and muscle mass
Albumin	x (plasma)[1]	x[4]		Nutritional status and protein intake
Glucose	x (plasma)[1]	x[4]		Glucose homeostasis
Triglycerides (TG)	x (plasma)[1]	x[4]		Lipid metabolism
Total cholesterol	x (plasma)[1]	x[4]		
HDL-cholesterol	x (plasma)[1]	x[4]		
LDL-cholesterol	x (calculation)[1]	x (calculation)[4]		
Bicarbonate (HCO3)	x (plasma)[1]			Acid-base homeostasis
Total proteins	x (plasma)[1]	x[4]		Nutritional status and protein intake
Urea	x (plasma)[1]		x[1]	Protein intake. Main end-product of the catabolism of amino acids
Urate	x (plasma)[1]		x[1]	Production of uric acid - diet rich in proteins
C-Reactive Protein (CRP)	x (plasma)[1]	x[4]		Inflammation
Hs-CRP	x (plasma)[1]			Low grade inflammation
Sodium (Na)	x (plasma)[1]		x[1]	Sodium intake Na/Cr ratio
Potassium (K)	x (plasma)[1]		x[1]	Potassium intake, fruit and vegetables
Total calcium (Ca)	x (plasma)[1]	x[4]	x[1]	Net absorption of calcium; calcium homeostasis
Corrected calcium (Ca)	x (calculation)[1]			
Magnesium (Mg)	x (plasma)[1]		x[1]	Magnesium intake and homeostasis
Phosphate (PO4)	x (plasma)[1]	x[4]	x[1]	Phosphate intake (dairy products, meat, whole grain, nuts, eggs, additives in processed food)
Transferrin	x (plasma)[1]	x[4]		Iron status
Ferritin	x (plasma)[1]	x[4]		
Iron (Fe)	x (plasma)[1]	x[4]		
Lead (Pb)	x (whole blood)[2]		x[2]	Lead intoxication
Chromium (Cr)	x (whole blood)[2]		x[2]	Chromium intake and intoxication
Nickel (Ni)	x (whole blood)[2]		x[2]	Nickel intake and intoxication
Selenium (Se)	x (whole blood and plasma)[2]		x[2]	Selenium intake and status
Iodine (I)			x[2]	Iodine intake
Retinol / Vitamin A	x (plasma)[3]			Vitamin A intake and status
Carontenoids (*e.g.,* α-/ β-carotene, α- / β-cryptoxanthin)	x (plasma)[3]			Carotenoid intake and status
Thiamine / Vitamin B1	x (plasma)[3]			Vitamin B1 intake and status
Folic acid / Vitamin B9	x (plasma)[3]			Vitamin B9 intake and status
Vitamin B12	x (plasma)[3]			Vitamin B12 intake and status
Vitamin C	x (plasma)[3]			Vitamin C intake and status
25-hydroxyvitamin D	x (plasma)[3]			Vitamin D intake and status
α-tocopherol / Vitamin E	x (plasma)[3]			Vitamin E intake and status
Phylloquinone / Vitamin K1	x (plasma)[3]			Vitamin K intake and status

[1] Analyses performed by Lausanne University Hospital. [2] Analyses performed in Federal Food Safety and Veterinary Office, Bern. [3] Analyses performed in Swiss Vitamin Institute, Lausanne. [4] Analyses performed in 'Centre Universitaire Romand de Médecine Légale, Lausanne - Genève', university centre of forensics medicine for French-speaking Switzerland, Lausanne by the start-up DBS System (DBS System / HemaXis, Gland, Switzerland).

Feedback to participants and compensation for participation

Once CHUV laboratory results on fresh urine and blood were available, they were shown to a medical doctor each time biomarker values were outside reference limits. At the end of the study, once all frozen blood and urine tubes had been analysed in the various external laboratories, extreme results were again discussed with the medical doctor. If results indicated potential nutritional or health problems, participant's caregiver(s) were informed, except when they specifically refused receiving any results in the consent form. Test results were then sent to the participant's paediatrician for possible further investigation and/or caregiver(s).

Participants and caregiver(s) received by registered post a compensation for participation (150 CHF in Reka checks plus three cinema vouchers). For ethical reasons, the collection of bio-samples did not lead to any financial benefit. In the same mailing, caregiver(s) received the skin scanner score of their offspring as well as general information about healthy eating according to the Swiss food-based dietary guidelines, *i.e.,* the Food Disk [28] for children, or the Food Pyramid [29] for adolescents. In the same mailing, caregiver(s) who had not been called after the face-to-face interview by the medical doctor were informed that all measured parameters were within reference limits.

Ethical consideration and funding

The research project was submitted via the national web portal of Swissethics, called BASEC (https://submissions.swissethics.ch/en). The 'Commission cantonale d'éthique de la recherche sur l'être humain du canton de Vaud' (CER-VD) approved the study protocol on February 8th 2017: *i.e.,* 1.5 month after its online submission (Project ID: Nutrition Survey 2016-02170). The end of the study was announced to the CER-VD in September 2018. Each recruited child and adolescent was assigned a unique random number. It was used for all collected data (*e.g.,* on blood tubes).

Participant information and informed consents, as required, were different according to participants' age. For participants aged 3 to 10 years, a verbal consent was obtained after a verbal briefing using pictograms. A simplified written information form (2 pages) was given to participants aged 11 and 13 years. As for participants above 14 years, they received the same information form as their caregiver(s) and also signed the consent form. For all participants, at least one legal representative of the participant (very often a parent) signed the written consent.

This feasibility study was fully funded by the Federal Food Safety and Veterinary Office (FSVO). The start-up DBS System (DBS System / HemaXis, Gland, Switzerland) conducted the laboratory analyses on capillary blood for free in exchange of the possibility to compare their results to those given by CHUV laboratory on fresh venous plasma (reference method).

7.4. Results and discussion

Sample and participation rate

Out of 194 contacted child-caregiver pairs with valid addresses, 31 (16%) accepted participation. Participation rate was lower among children aged 3 to 12 years (14%) than adolescents aged 13 to 17 years old (22%). Two selected households wanted that two children take part in the study. Our sample from the population registry was probably not representative of the general population due to the low participation rate. However, we have no data regarding non-participants, except age group and home address (not even sex), to compare with our study participants. As a reference, participation rate in menuCH, *i.e.,* among adults selected from the national registry and without collection of bio-samples, was 15% [30]. Participation rate in the feasibility study is only informative for three reasons. First, sample size was small and precision limited. Second, we suppose that selected people who were not eligible (*e.g.,* having no more children aged 3 to 17 years) did not always inform the PhD student about their ineligibility. Third, in the selected zones of residence, immigrations was high (*i.e.,* 41% of foreigners in Prilly to 51% in Renens [31]), which may have limited the number of people with good command of French. In total, 33 participants (31 + 2 siblings) were recruited based on the population registry and 20 by flyers (convenience sample). Since we used two methods to recruit participants, we compared participants' characteristics by recruitment methods (**Table 2**). Participants recruited by flyers seemed to have an overall higher SES and healthier diet.

Table 2. Characteristics of feasibility study participants, stratified by recruitment methods.

	All participants	Recruited via registry	Recruited via flyers
Total number of participants recruited (N)	53	33	20
Sex (male, %)	56	63	45
Age (in years, mean ± SD)	11.2 ± 4.3	11.0 ± 4.3	11.5 ± 4.4
Mother with university/high school degree (%)	55	45	75
Self-reported very good and good health (%)	91	91	90
Limited access to food due to lack of money (occurred sometimes in the last 12 months, %) [1]	8	14	0
Consumption of organic fruit and vegetables (%)	83	79	90
Vegetable intake (portion/day, mean ± SD) [2]	1.3 ± 0.8	1.1 ± 0.8	1.7 ± 0.7
Fruit intake (portion/day, mean ± SD) [3]	1.3 ± 1.0	1.2 ± 1.0	1.5 ± 0.9
Sugary soft drinks intake (g/day, mean ± SD)	203.4 ± 282.8	244.2 ± 313.0	136.2 ± 215.2
Sodium intake (g/day, mean ± SD) [4]	2.3 ± 0.7	2.3 ± 0.7	2.2 ± 0.7
Score from skin carotenoid scanner (from 0 to 10, mean ± SD)	5.8 ± 1.4	5.5 ± 1.2	6.3 ± 1.5
Lead/creatinine ratio in urine (ug/mmol, median [P25-P75]) [5]	0.12 [0.07-0.15]	0.12 [0.08-0.15]	0.11 [0.05-0.22]
Selenium/creatinine ratio in urine (ug/mmol, median [P25-P75])	3.6 [2.8-4.6]	3.8 [2.6-4.7]	3.5 [3.0-4.4]
Iodine/creatinine ratio in urine (ug/mmol, median [P25-P75])	13.7 [10.1-19.6]	12.4 [10.1-17.0]	16.2 [10.0-21.8]

[1] Only asked to caregivers of children (N=24). [2] A portion =120 g of fresh and cooked, 30 g if dried, 2.5 dL of soup, and 100 g of sauce (juice excluding), based on the mean of two non-consecutive 24HDR. [3] A portion = 120 g of fresh and cooked, 30 g if dried, based on the mean of two non-consecutive 24HDR. [4] Estimated from spot urine, using the INTERSALT equation considering potassium [32, 33]. [5] One extreme high value was excluded.

Dietary assessment and anthropometry

The software GloboDiet®, which was used in menuCH to conduct the 24HR among adults, could be applied in the feasibility study without problems. Foods and beverages consumed by the interviewed children and adolescents were similar to those reported by adults in menuCH and thus already present in GloboDiet® database (>1600 foods). However, we identified 19 new food products and 15 new descriptors (often new brands). Three elements regularly consumed by children and adolescents were missing: 1) several types and brands of candies, 2) commercial fruit compotes, and 3) commercial breakfast cereals. The picture book was also adapted to both children and adolescents since pictures of the six different portion sizes were sufficiently dissimilar to correspond to young children eating small portions and young male adolescents eating large portions. Caregivers correctly understood and completed the 24-hour food diary. Both registered dietitians believed that using the food diary (prospective data collection) had increased precision in the collected dietary information, as already documented in literature [34-36]. A few caregivers spontaneously took pictures of meals together with the food diary. This helped dietitians to identify food products and brands more easily, and to determine portion size more objectively. However, the food diary increased the burden on caregivers.

The FPQ was complete by all participants or their caregiver(s). Ninety-eight per cent of participants or caregivers (50/51) would accept to take pictures of what is consumed. On average, people would accept this constraint for maximum three consecutive days. However, caregivers noted that it was difficult to organize pictures when they were absent: *i.e.,* when the child is at school, doing sports, or being with another family member(s), *etc*. Of note, staff in schools and kindergartens was reluctant or unable to complete the 24-hour food diary or report what was consumed by the child. Measuring weight and height in children and adolescents was performed without problems.

Online questionnaires

All participants and/or caregivers completed the required questionnaires. One caregiver preferred a paper copy. The questionnaire for caregivers of children aged 3 to 10 years was mostly completed by the mother without the child (75%), or both parents without the child (17%). The completion of this questionnaire took a median duration of 38 minutes (P25-P75: 21-63 minutes). The questionnaire for adolescents aged 11 to 17 years was mostly completed by the adolescent and his/her mother (52%) or the adolescents alone (41%). It took them 21 minutes (P25-P75: 18-26 minutes). The questionnaire for the adolescents' caregivers was completed by the mother (86%) or the father (14%) in 10 minutes (P25-P75: 8-13 minutes).

Bio-samples and biomarkers

All spot urine samples were collected. However, specific problems were observed in four out of 53 participants (8%). One child forgot to collect the first morning specimen. Therefore, we collected the second morning specimen (only small amount) at the CTU. One teenage collected the second urine specimen due to study protocol misunderstanding. One child aged 3 years old had no need to urinate in the morning of the interview. The first morning specimen was thus collected at the CTU at the end of the face-to-face interview. Finally, another participant collected only a small amount of urine for no specific reason.

Out of the 48 participants who accepted capillary or venous blood collection, 37 (78%) came in the morning and were fasting. Seven participants (15%) attended the face-to-face interview in the afternoon, when fasting was no longer possible. Finally, four participants (aged 5, 7, and 9 years) reported not being fasting.

Most adolescents aged 11 to 17 years (24/29, 83%) accepted venous blood collection. Age (11-12 years vs. 16-17 years) did not play a role in the acceptation. Providing Emla patches helped to reduce the pain at the puncture point. The patches were placed on time at the right place for the majority of participants. Out of the 24 collected samples, 24 could be analysed in CHUV and FSVO laboratories and 22 in Swiss Vitamin Institute (SVI). CHUV laboratory informed that two fresh blood samples had been haemolysed. Five important results in terms of health and nutrition surveillance are to be reported. First, 29% of adolescents (7/24, 3 boys and 4 girls) had ferritin below 30 ug/l. Of them, four (1 boy and 3 girls) had ferritin even below 15 ug/l. Thus, 17% of tested adolescents had very low iron reserve. Second, 3/24 adolescents (13%) had LDL-cholesterol (calculated values) above 3 mmol/l. Among those, two had LDL-cholesterol value close to 4 mmol/l: the first one probably due to familial hypercholesterolemia and the second one secondary to obesity. Third, 8% of adolescents (2/24) had plasma vitamin B12 concentration below 120 pmol/l (norms defined by SVI in female and male adults: 162 - 796 pmol/l). Fourth, there was some indication that lead in blood has decreased since 2010 (**Table 3**, adapted from [37] by FSVO). Fifth, we found no recently published norms for vitamin status in European children. Thus, we had to interpret values based on data among American children [38, 39], old studies conducted in Switzerland [40] or more recent studies but in Turkey [41] or studies in sick children [42] or adults [43-45].

Table 3. Blood lead concentration between 2010 and 2017 in children aged 10 to 18 years old from the French-speaking area of Switzerland [37].

	Previous study - 2010		**Our study - 2017**	
	Female	*Male*	*Female*	*Male*
N	21	26	9	14
Mean (ug/l)	12.1	15.4	6.6	9.6
P95 (ug/l)	16.7	32.3	16.9	14.2

All adolescents (29/29) and 19/24 children (79%) accepted capillary blood collection. Children under 5-6 years old often cried. Above this age, they could better understand the advantages and disadvantages, and gave a clearer consent or refusal. Despite instructions, the Emla patches were often placed on the wrong finger (*e.g.,* index instead of the little finger). In addition, patches produced vasoconstriction, which limited the amount of blood drops possible to be extracted. Out of the 48 collected samples, 41 could be analysed. The amount of collected capillary blood in the seven other samples was insufficient to conduct analyses. Results are mixed regarding the interest to measure capillary blood instead of venous blood. Out of 13 measured parameters, three parameters (*i.e.,* CRP, iron, and ferritin) showed a high concordance between measured values in fresh venous plasma (reference method) and frozen capillary plasma (Lin's concordance correlation coefficient r > 0.90). **Figure 2** shows a comparison between the two methods for three parameters with variable degree of correlation in 22 participants: ferritin (good), HDL-cholesterol (fair), and albumin (poor). Several explanations were produced by the start-up DBS System to explain these phenomena (*not detailed in this report summary*).

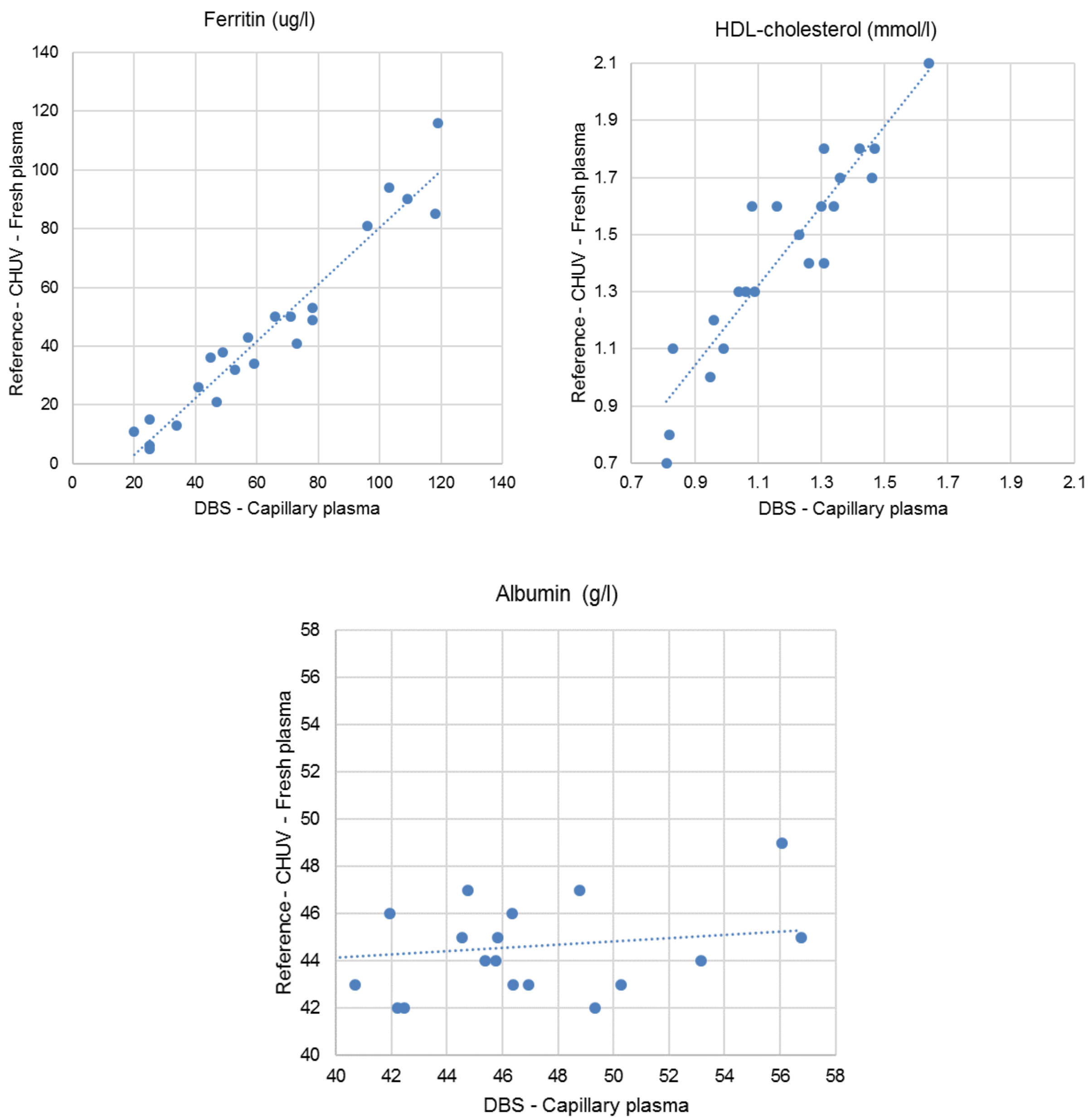


Figure 2. Correlation between ferritin (N=22, Pearson's r = 0.97, slope = 0.97 and constant = -16), HDL-cholesterol (N=22, Pearson's r = 0.92, slope = 1.39 and constant = -0.21), and albumin (N=22, Pearson's r = 0.21, slope = 0.07 and constant = 41) measured in frozen capillary plasma by DBS System (horizontal axis) and fresh plasma in CHUV laboratory (reference method, vertical axis).

Out of 24 children, 23 (96%) accepted toenail collection. The collection of toenails was less easy than expected because nails flied away while clipping and were thus lost on the floor. Sometimes, it was also hard to collect them because nails were short. Because we did not analyse collected nails, we did not know if collected quantities were sufficient and if nail polish had an impact on metal values.

Procedures to assess skin carotenoid concentration using Raman spectroscopy were quick (2-3 min for both hands), simple and well accepted by children and caregivers (100% of acceptation rate). The mean score of the two measures given by the Biozoom® scanner was fairly correlated to measured carotenoid plasma concentration in adolescents (N=22, Pearson's correlation coefficient: r = 0.69, $P < 0.001$, Spearman's correlation coefficient: r = 0.55, $P = 0.008$, **Figure 3**). This value corresponds to literature: r = 0.79 in 68 adults [27]. Additionally, the mean score by Biozoom® device was to some extent correlated to the usual intake of fruit and vegetables assessed by two non-consecutive 24HDR and a FPQ (N=52, Pearson's correlation coefficient: r = 0.34, $P = 0.013$, Spearman's correlation coefficient: r = 0.43, $P = 0.002$, *data not shown*).

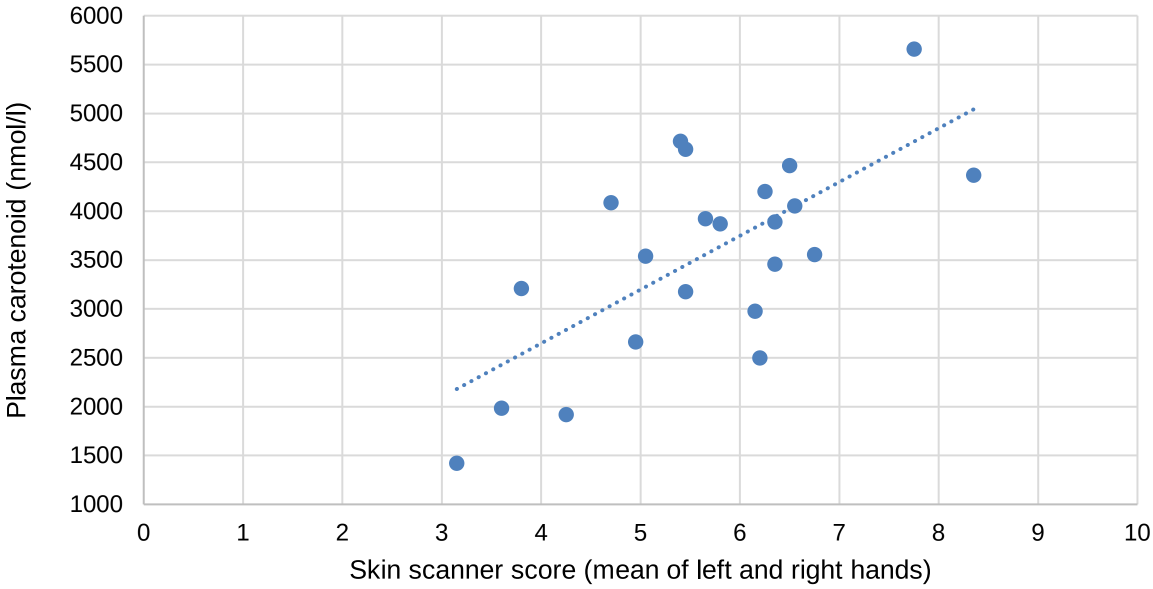


Figure 3. Comparison between mean score measured using Biozoom® skin scanner on both hand palms and carotenoid measured in plasma (N=22, Pearson's r = 0.69, $P < 0.001$).

All participants/caregivers would accept to provide saliva. Twenty per cent of them (10/51) would agree to collect 24-hour urine any weekday and 55% (28/51) would accept only if collection would be a weekend day or holiday. The most common causes for refusal were practical complication (10/51, 20%) and embarrassment (4/51, 8%). Regarding stool collection, 59% (30/51) would agree. As expected, caregivers from children (74%) were more inclined to collect stool than adolescents (46%). Thirty-seven per cent (19/51) would refuse because of embarrassment, and 4% (2/51) for practical complications due to constipation. These data must be interpreted with caution because they reflect often answers and opinions of the caregivers in the absence of the child or young adolescent (not on the phone). In addition, answers were collected after two interviews, when a trustful relationship with the study staff had been established.

Feedback to participants and compensation for participation

Because the selected parameters analysed in fresh urine in CHUV were mainly nutritional parameters and not direct health indicators (Table 1), no out-of-norms values required information to the participant, his/her caregiver(s) and his/her paediatrician. Among adolescents who accepted venous blood tests, 20/24 (83%) had to be re-contacted. This high proportion reflects the fact that reference values are not clearly established in children and adolescents. No participants/caregivers were re-contacted for extreme values based on capillary blood due to lack of accuracy and reference value for this exploratory method. Interpreting results, re-contacting caregivers and preparing letter for paediatricians was time-consuming: 1h15 per participant.

Generally speaking, caregivers were interested in all types of personalised feedback, in particular information when biomarkers were outside the reference limits. Because compensation was sent by post, it was hard to estimate how much went really to the child/adolescent or to the caregiver(s). When asked informally, most participants and caregivers would have preferred being compensated with cash instead of vouchers. Swissethics' guidelines and recommendations for the compensation in research projects did not take a position regarding passing on cash to children and adolescents [46]. After contacting the CER-VD, the president recommended not to send cash to children and adolescents and to use vouchers as we did.

Ethical consideration

Submission of research projects has been simplified since menuCH. Since January 2016, on-line submission is centralized and uniformed across cantons. BASEC provides clear information and checklists of needed documents for project submission.

7.5. Main recommendations for next national nutrition survey

Age of participants

For the next national nutrition survey, we recommend excluding children below school age (under 5 years) to facilitate bio-sample collection, especially for capillary blood and spot urine. Waiting during the face-to-face interview was also long for those young children. Regarding the cut-off age between children and adolescents, we observed that assistance of caregiver(s) was almost always required to complete the on-line questionnaire and 24HDR for participants under 14 years. We suggest having a cut-off at 14 years for all questionnaire and diet-related data, as defined by Swissethics (*i.e.,* adolescents above 14 years are considered as adults). This means that the 24-hour food diary and the questionnaire would mainly be completed by the caregiver(s) until 13 years old. However, for blood sampling, such an age cut-off should not be made. Blood sampling should be proposed to every participant aged 5 to 17 years, because we observed no differences in acceptation or puncture tolerance between young adolescents (aged 11-12 years) or older adolescents (aged 16-17 years).

Sampling and recruitment

A good recruitment methodology is key to have high participation rate and reduced risk of participation bias. For the main survey, we recommend using the same national population registry as in menuCH: *i.e.,* national sampling frame for person and household surveys [47]. For an optimal recruitment rate, more investment than only writing one letter is definitely needed to motivate people in taking part in a survey. Access to personal phone numbers or emails of potential participants is important. When they are unavailable, sending several times the invitation letter with the pre-stamped response card on which the participant and/or his/her caregiver(s) could indicate their contact details and availabilities are a good alternative to reach more participants.

The stratified random selection of people among a population registry has four main advantages. First, selection bias is limited when a stratified random sample is used (probability sampling technique) [48]. Literature [48, 49] and our results among participants recruited via flyers suggested a convenience sample (non-probability sampling technique) increases the risk of selection bias towards families with healthier eating habits. Second, participation rate can be easily calculated based on the ratio survey participants / contacted child-caregiver pairs. Third, when information about non-participants (*e.g.,* addresses, dates of birth) is available, we can track who did or did not participated in the survey to estimate participation bias and try to correct it with an appropriate weighting strategy. Because SES influences diet and its quality [50, 51], information about SES of participants and non-participants would be ideal for the weighting strategy. Fourth, the sample can be redirected during the recruitment phase in case there is an unbalanced mid-study sample. For example, if too many girls accept participating at the beginning of the recruitment, we could invite in the next wave(s) more boys and use the weighting strategy to re-balance the sample according to the original reference population [48]. However, this recruitment procedure requires legal access to national population registries. Additionally, costs related to sampling and contacting selected people in the population may be high [48].

Of note, kindergarten and public schools are good entry points to reach high participation and high representativeness of the sample if well designed. However, this recruitment method requires strong commitment in the different cantons. This requires also commitment in the institutions, which are selected for the study. Moreover, recruiting in institutions creates data clustering that needs to be accounted for in statistical analyses. There is indeed a loss of variability, since children in a same school or a same class have some common characteristics (intra-cluster correlation).

Dietary assessment and anthropometry

To ensure dietary assessment quality, 24HDR should be conducted by registered dietitians. Having health professionals leading the interviews is even more important when bio-samples are collected and caregiver(s) ask questions specific to nutritional biomarkers. GloboDiet® and the menuCH picture book can be used without major adaptations for a national nutrition survey in children and adolescents. The use of the 24-hour food diary is a key asset for increasing the precision in the data collection in young children. It is important that the on-line questionnaires includes a FPQ. The latter increase the intra-individual precision when modelling usual intake from short-term dietary measurements such as 24HDR [52-54] .

In theory, prospectively taking pictures of consumed foods during the interviewed days would be widely accepted by participants and caregivers. It could complement, or even replace, the 24-hour food diary and thus reduce burden on participants or caregivers. It would also help dietitians in data entry. An on-line survey platform is important for the next national nutrition survey 1) to share completed food diaries and/or pictures of foods between caregivers and dietitians, and 2) to have on-line access to the picture book.

Relying exclusively on a smart-phone application (*e.g.,* electronic food diary with or without digital photography) without supervision of a nutrition professional is premature for the next national nutrition survey due to several factors. First, young children do not possess smart-phones and are often away from the main caregiver while eating or drinking. This means that caregivers plus other people (*e.g.,* school staff, sports trainers, other family members) should be involved and trained on how to use the applications, which seems complicated. Second, technical and scientific advances in digital nutritional epidemiology, such as portion size estimation, food recognition, linkage with local food composition database, are still needed to precisely analyse and interpret the pictures/data [55, 56]. Third, the smart-phone application would need to be adapted to the Swiss food market, available in the three main languages, linked to the Swiss Food Composition Database [57], and validated. To our best knowledge, such an application does not exist in Switzerland yet.

Bio-samples and biomarkers

Collecting spot urine samples was relatively well collected by children aged over 4-5 years. In addition, spot urine collection, preparation for laboratories and analyses necessitate limited financial resources (*e.g.,* purchase of beakers and tubes). We recommend collecting spot urine in all children and adolescents during the main survey.

Collection of blood requires more constraints: *e.g.,* fasting participants and more staff, such as study nurse for collection and sample processing, and higher costs for analyses. However, acceptation of venous blood collection was relatively high among adolescents who took part in the feasibility study. The puncture was well tolerated. Acceptation of capillary blood was also high and well tolerated in children above 5-6 years old. However, so far the array of validated clinical and/or nutritional parameters is limited. Venous blood sampling should be preferred and capillary blood kept as a second choice in case venous blood collection is refused. For these participants, nutritional parameters such as iron and lipid status could be assessed, considering further improvement in the collection system and in the laboratory analyses by DBS System or other providers.

Toenails could be a good way to obtain biomarkers with a minimally invasive procedure, but should not be the only collected bio-sample. However, if they are collected for the main survey, clarification with laboratories should be made to define the exact nail quantity required for proper analyses and if nail polish should be removed. We also recommend asking the caregiver(s) to collect nails at home, at their convenient time (*i.e.,* when nails are long and/or free from polish) and in a relaxed atmosphere (*i.e.,* not after blood collection), especially for young children. Toenails should however not be the main type of bio-samples.

We recommend assessing skin carotenoid concentration using Raman spectroscopy in the main survey. In conclusion, we highly recommend using objective nutritional biomarkers in the next national nutrition survey to establish reference values among children (*e.g.,* vitamin status) and to complement food consumption data in the assessment of nutritional status in the population. Of note, assessing the uptake of vitamin and mineral supplements is important if nutritional biomarkers are collected.

Feedback to participants

If bio-samples are collected at a large scale, a systematic check of laboratory parameters has to be organized to detect potential health and nutritional disorders. Then, a medical doctor, if possible, a multilingual paediatrician, has to interpret these laboratory parameters together with other data collected by the dietitians and nurses. When necessary, he/she should then contact the participant/caregiver(s) and their paediatrician. This should be done as many times as medically required but as few times as possible to limit caregiver(s)' worry and survey staff's time. We realised that developing a one-size-fits-all algorithm/decision tree to interpret data is difficult due to the relative limited information we had on health background. The feasibility study showed that assessing the nutritional status of children and adolescents with biomarkers was hard and specialists in this field are scarce. To save time and costs, a solution or an algorithm/decision tree should be discussed with professionals or paediatrics associations before the main survey start.

7.6. Conclusion

Studying diet in a population-based sample of Swiss children and adolescents is important and proved to be feasible in Lausanne. Participation rate was low, yet similar to what was observed in adults participating in menuCH. In the next national nutrition survey we recommend using a stratified random sample of the national population registry and improving recruitment procedures (*e.g.,* several written reminders). Acceptation rate for bio-sample collection was high to very high for Raman spectroscopy, spot urine, capillary blood, venous blood, and toenails. We strongly recommend using objective nutritional biomarkers in the next survey to better assess nutritional status and to establish reference values for Swiss healthy children and adolescents. Detailed dietary assessment is essential to assess food consumption and is complementary to biomarkers. The tested dietary assessment tools in this feasibility study (*e.g.,* computed assisted 24HDR, 24-hour food diary and on-line FPQ) would need only minor modifications before the main survey. Personal feedback given to participants' caregiver(s) was appreciated by participants but time-consuming for survey staff; it needs further reflexion. This report will help plan and budget the next national nutrition survey.

7.7. References

1. Gernand, A.D., et al., Micronutrient deficiencies in pregnancy worldwide: health effects and prevention. Nat Rev Endocrinol, 2016. 12(5): p. 274-89.

2. Nyaradi, A., et al., The role of nutrition in children's neurocognitive development, from pregnancy through childhood. Front Hum Neurosci, 2013. 7: p. 97.

3. Soliman, A., V. De Sanctis, and R. Elalaily, Nutrition and pubertal development. Indian J Endocrinol Metab, 2014. 18(Suppl 1): p. S39-47.

4. Mikkila, V., et al., Longitudinal changes in diet from childhood into adulthood with respect to risk of cardiovascular diseases: The Cardiovascular Risk in Young Finns Study. Eur J Clin Nutr, 2004. 58(7): p. 1038-45.

5. Kelder, S.H., et al., Longitudinal tracking of adolescent smoking, physical activity, and food choice behaviors. Am J Public Health, 1994. 84(7): p. 1121-6.

6. Law, M., Dietary fat and adult diseases and the implications for childhood nutrition: an epidemiologic approach. Am J Clin Nutr, 2000. 72(5): p. 1291s-1296s.

7. Serdula, M.K., et al., Do obese children become obese adults? A review of the literature. Prev Med, 1993. 22(2): p. 167-77.

8. Freedman, D.S., et al., The relation of childhood BMI to adult adiposity: the Bogalusa Heart Study. Pediatrics, 2005. 115(1): p. 22-7.

9. Biro, F.M. and M. Wien, Childhood obesity and adult morbidities. Am J Clin Nutr, 2010. 91(5): p. 1499S-1505S.

10. European Food Safety Authority (EFSA), Scientific Opinion on nutrient requirements and dietary intakes of infants and young children in the European Union. EFSA Journal, 2013. 11(10): p. 3408.

11. Federal Commission for Nutrition (FCN), Iodine supply in Switzerland: Current Status and Recommendations. Expert report of the FCN. 2013, Federal Office of Public Health: Zurich, Switzerland.

12. Zimmermann, M.B., et al., Increasing the iodine concentration in the Swiss iodized salt program markedly improved iodine status in pregnant women and children: a 5-y prospective national study. Am J Clin Nutr, 2005. 82(2): p. 388-92.

13. Lasserre, A.M., et al., Overweight in Swiss children and associations with children's and parents' characteristics. Obesity (Silver Spring), 2007. 15(12): p. 2912-9.

14. Schneider, H., W. Venetz, and C. Gallani Berard, Overweight and obesity in Switzerland. Part 2: Overweight and obesity trends in children. 2009, Federal Office of Public Health: Basel, Switzerland.

15. Aeberli, I., et al., Stabilization of the prevalence of childhood obesity in Switzerland. Swiss Med Wkly, 2010. 140: p. w13046.

16. Suggs, L.S., S. Della Bella, and P. Marques-Vidal, Low adherence of Swiss children to national dietary guidelines. Prev Med Rep, 2016. 3: p. 244-9.

17. European Food Safety Authority (EFSA), Guidance on the EU Menu methodology. EFSA Journal, 2014. 12(12): p. 3944.

18. European Food Safety Authority (EFSA), General principles for the collection of national food consumption data in the view of a pan-European dietary survey. EFSA Journal, 2009. 7(12): p. 1435.

19. Slimani, N., et al., The standardized computerized 24-h dietary recall method EPIC-Soft adapted for pan-European dietary monitoring. Eur J Clin Nutr, 2011. 65 Suppl 1: p. S5-15.

20. Crispim, S.P., et al., Two non-consecutive 24 h recalls using EPIC-Soft software are sufficiently valid for comparing protein and potassium intake between five European centres--results from the European Food Consumption Validation (EFCOVAL) study. Br J Nutr, 2011. 105(3): p. 447-58.

21. Crispim, S.P., et al., Two non-consecutive 24 h recalls using EPIC-Soft software are sufficiently valid for comparing protein and potassium intake between five European centres--results from the European Food Consumption Validation (EFCOVAL) study. Br J Nutr, 2011. 105(3): p. 447-58.

22. European Food Safety Authority (EFSA), Guidance on the EU Menu methodology [Appendix 5.3.3: Example of a one-day food diary for toddlers and children based on the PANCAKE project]. EFSA Journal, 2014. 12(12): p. 3944.

23. Camenzind-Frey, E. and C. Zuberbühler, menuCH - Schweizerisches Fotobuch / Livre Photo Suisse / Manuale Fotografico Svizzero (Picture book for menuCH). 2013, Bern, Switzerland: Federal Office of Public Health / Federal Food Safety and Veterinary Office.

24. World Health Organization. MONICA Manual, Part III: Population Survey. Section 1: Population Survey Data Component. 4.6 Height, weight, waist and hip measurement. [cited 2016 Sep 30]; Available from: http://www.thl.fi/publications/monica/manual/part3/iii-1.htm#s4-6.

25. Meinke, M.C., et al., Influences of Orally Taken Carotenoid-Rich Curly Kale Extract on Collagen I/Elastin Index of the Skin. Nutrients, 2017. 9(7).

26. Yu, R.X., et al., Spectroscopic biofeedback on cutaneous carotenoids as part of a prevention program could be effective to raise health awareness in adolescents. J Biophotonics, 2014. 7(11-12): p. 926-37.

27. Darvin, M.E., et al., Multiple spatially resolved reflection spectroscopy for in vivo determination of carotenoids in human skin and blood. Laser Physics Letters, 2016. 13(9): p. 1-7.

28. Société Suisse de Nutrition. Disque alimentaire suisse (Swiss Food Disk). [cited 2016 Nov 20]; Available from: http://www.sge-ssn.ch/fr/disque-de-lalimentation/.

29. Swiss Society for Nutrition / Federal Food Safety and Veterinary Office. Pyramide alimentaire suisse 2011 (Swiss Food Pyramid 2011). [cited 2016 Nov 20]; Available from: http://www.sge-ssn.ch/fr/toi-et-moi/boire-et-manger/equilibre-alimentaire/pyramide-alimentaire-suisse/.

30. Chatelan, A., et al., Major Differences in Diet across Three Linguistic Regions of Switzerland: Results from the First National Nutrition Survey menuCH. Nutrients, 2017. 9(11).

31. Statistique Vaud. Bilan démographique, grands groupes d'âges et population étrangère, par commune, Vaud, 2010-2016 (Demographics in the canton of Vaud, Switzerland). [cited 2018 Jul 14]; Available from: http://www.scris.vd.ch/Default.aspx?DocID=6999&DomId=2987.

32. Leyvraz, M., et al., Urine spot samples can be used to estimate 24-h urinary sodium excretion in children. J Nutr (in press).

33. Cogswell, M.E., et al., Validity of predictive equations for 24-h urinary sodium excretion in adults aged 18-39 y. Am J Clin Nutr, 2013. 98(6): p. 1502-13.

34. Crawford, P.B., et al., Comparative advantage of 3-day food records over 24-hour recall and 5-day food frequency validated by observation of 9- and 10-year-old girls. J Am Diet Assoc, 1994. 94(6): p. 626-30.

35. Lucchiari, C., M. Masiero, and G. Pravettoni, Methods for nutrition monitoring in cancer patients: a cognitive perspective. Ecancermedicalscience, 2012. 6: p. 259.

36. Ralph, J.L., et al., Diet assessment methods: a guide for oncology nurses. Clin J Oncol Nurs, 2011. 15(6): p. E114-21.

37. Dudler, V., Plombémie infantile en Suisse (Lead in blood of Swiss children). 2018, Federal Food Safety and Veterinary Office: Bern, Switzerland.

38. Mayo Medical Laboratories. Vitamin A, Serum / Vitamin E, Serum / Vitamin K1, Serum / Vitamin B12 Assay, Serum / Ascorbic Acid (Vitamin C), Plasma / Thiamine (Vitamin B1), Whole Blood / 25-Hydroxyvitamin D2 and D3, Serum / Folate, Serum. [cited 2018 Jul 17]; Available from: https://www.mayomedicallaboratories.com/test-catalog/search.php?s=q=vitamin%26access=p%26entqr=1%26sort=date:D:L:d1%26output=xml_no_dtd%26client=MayoMedLabs%26ud=1%26oe=UTF-8%26ie=UTF-8%26numgm=6%26as_sitesearch=http://www.mayomedicallaboratories.com/test-catalog/Overview%26site=MCSITestCatalog%26getfields=*%26ulang=%26ip=192.168.232.100%26entqrm=0%26entsp=a__MedLab%26wc=200%26wc_mc=1%26start=0.

39. Hicks, J.M., et al., Vitamin B12 and folate. Pediatric reference ranges. Arch Pathol Lab Med, 1993. 117(7): p. 704-6.

40. Winklhofer-Roob, B.M., M.A. van't Hof, and D.H. Shmerling, Reference values for plasma concentrations of vitamin E and A and carotenoids in a Swiss population from infancy to adulthood, adjusted for seasonal influences. Clin Chem, 1997. 43(1): p. 146-53.

41. Akin, F., et al., Vitamin B12 levels of subjects aged 0-24 year(s) in Konya, Turkey. J Health Popul Nutr, 2014. 32(4): p. 615-22.

42. Conway, S.P., et al., Vitamin K status among children with cystic fibrosis and its relationship to bone mineral density and bone turnover. Pediatrics, 2005. 115(5): p. 1325-31.

43. World Health Organization (WHO), Serum and red blood cell folate concentrations for assessing folate status in populations. 2015, WHO: Geneva, Switzerland.

44. Thane, C.W., L.Y. Wang, and W.A. Coward, Plasma phylloquinone (vitamin K1) concentration and its relationship to intake in British adults aged 19-64 years. Br J Nutr, 2006. 96(6): p. 1116-24.

45. Sadowski, J.A., et al., Phylloquinone in plasma from elderly and young adults: factors influencing its concentration. Am J Clin Nutr, 1989. 50(1): p. 100-8.

46. Swissethics. Rémunération des patients participant à un projet de recherche (Study participant compensation). [cited 2018 Jul 17]; Available from: https://www.swissethics.ch/doc/leitfaden_pos/entschaedigungen_pkl_f.pdf.

47. Federal Statistical Office. Stichprobenrahmen für Personen- und Haushaltserhebungen (Swiss persons and households registry). [cited 2017 Apr 28]; Available from: https://www.bfs.admin.ch/bfs/de/home/grundlagen/volkszaehlung/volkszaehlung-teil-gesamtsystem/stichprobenrahmen.html.

48. Bornstein, M.H., J. Jager, and D.L. Putnick, Sampling in Developmental Science: Situations, Shortcomings, Solutions, and Standards. Dev Rev, 2013. 33(4): p. 357-370.

49. Coggon, D., R. G., and D.J.P. Barker, Measurement error and bias. In: Epidemiology for the uninitiated. 5th ed. 2003, The BMJ: London, United Kingdom.

50. Wang, D.D., et al., Improvements In US Diet Helped Reduce Disease Burden And Lower Premature Deaths, 1999-2012; Overall Diet Remains Poor. Health Aff (Millwood), 2015. 34(11): p. 1916-22.

51. Darmon, N. and A. Drewnowski, Does social class predict diet quality? Am J Clin Nutr, 2008. 87(5): p. 1107-17.

52. Subar, A.F., et al., The food propensity questionnaire: concept, development, and validation for use as a covariate in a model to estimate usual food intake. J Am Diet Assoc, 2006. 106(10): p. 1556-63.

53. Souverein, O.W., et al., Comparing four methods to estimate usual intake distributions. Eur J Clin Nutr, 2011. 65 Suppl 1: p. S92-101.

54. Laureano, G.H., et al., Comparison of the ISU, NCI, MSM, and SPADE Methods for Estimating Usual Intake: A Simulation Study of Nutrients Consumed Daily. Nutrients, 2016. 8(3): p. 166.

55. McClung, H.L., et al., Dietary Intake and Physical Activity Assessment: Current Tools, Techniques, and Technologies for Use in Adult Populations. Am J Prev Med, 2018. 55(4): p. e93-e104.

56. Martin, C.K., et al., Measuring food intake with digital photography. J Hum Nutr Diet, 2014. 27 Suppl 1: p. 72-81.

57. Federal Food Safety and Veterinary Office. Swiss Food Composition Database. [cited 2017 Jul 13]; Available from: http://naehrwertdaten.ch/request?xml=MessageData&xml=MetaData&xsl=Start&lan=en&pageKey=Start.

8. Precision nutrition in public health

Title of the manuscript: Precision nutrition: Hype or hope for public health interventions to reduce obesity?

Authors: Angeline Chatelan[1], Murielle Bochud[1], Katherine L. Frohlich[2].

Affiliations: [1] Institute of Social and Preventive Medicine (IUMSP), Lausanne University Hospital (CHUV), Lausanne, Switzerland, [2] Département de médecine sociale et préventive, Ecole de Santé Publique & Institut de recherche en santé publique de l'Université de Montréal, Université de Montréal, Canada.

Author contributions: AC conceived the manuscript under the supervision of KLF. MB provided inputs to the manuscript. All authors read and approved the final manuscript.

Publication status: Manuscript accepted in International Journal of Epidemiology.

8.1. Abstract

High-income countries are experiencing an obesity epidemic that follows a socio-economic gradient, affecting groups of lower socio-economic status disproportionately. Recent clinical findings have suggested new perspectives for the prevention and treatment of obesity using personalized dietary approaches. Precision nutrition (PN), also called personalized nutrition, has been developed to deliver more preventive and practical dietary advice than 'one-size-fits-all' guidelines. With interventions becoming increasingly plausible at a large scale thanks to artificial intelligence and smart-phone applications, some have begun to view PN as a novel way to deliver the right dietary intervention to the right population. We argue that large-scale PN, if taken alone, might be of limited interest from a public health perspective. Building on Geoffrey Rose's theory regarding the differences in individual and population causes of disease, we show that large-scale PN can only address some individual causes of obesity (causes of cases). This individual-centred approach is likely to have a small impact on the distribution of obesity at a population level because it ignores the population causes of obesity (causes of incidence). The latter are embedded in the populations' social, cultural, economic, and political contexts that make environments obesogenic. Additionally, the most socially privileged groups in the population are the most likely to respond to large-scale PN interventions. This could have the undesirable effect of widening social inequalities in obesity. We caution public health actors that interventions based only on large-scale PN are unlikely, despite current expectations, to improve dietary intake or reduce obesity at a population level.

8.2. Key messages

- Some public health actors have begun to view large-scale precision nutrition as a novel opportunity to provide the right dietary intervention to the right population at the right time.
- Large-scale precision nutrition is an individual-centred approach focusing on behavioural modification in large numbers, and not a true population approach as defined by Geoffrey Rose.
- Large-scale precision nutrition is likely to have a limited impact on obesity at a population level as it neglects population causes of obesity that are rooted in obesogenic environments.
- Early adoption and achievement of improved dietary habits based on precision nutrition are more likely among more socially privileged members of the population, which would exacerbate socio-economic inequalities in diet and obesity.
- If taken alone, interventions based on large-scale precision nutrition are unlikely to improve dietary intake or reduce obesity at a population level.

8.3. Introduction

Most high-income countries are experiencing an obesity epidemic since 1975 [1]. For example, in the United States (U.S.), more than one in three adults and one in six children were estimated to be obese in 2015 [2]. Obesity has been linked to numerous non-communicable diseases such as diabetes, cardiovascular disease, osteoarthritis, and certain forms of cancer [3-5]. According to the 2016 Global Burden of Disease [6], an unbalanced diet, obesity, and high fasting plasma glucose were among the top six leading risk factors for disability-adjusted life-years in high-income countries. In these countries, the incidence and prevalence of obesity follows a socio-economic gradient, whereby individuals with lower education, occupation and income are disproportionally affected [7-9]. In Spain, Italy and France for instance, the least educated women are over four times as likely to be obese as the most educated ones [10].

Diet is a major modifiable determinant of obesity. Multiple public health interventions to improve population dietary intake have been implemented to date. Some individual-centred interventions have aimed at providing information about healthy eating. They used, for example, mass campaigns to disseminate dietary guidelines (e.g.,'5 a day') and food guides (*e.g.,* MyPlate in the U.S.) [11-13]. More recent interventions have focused on shaping the food environment through structural measures. Classical examples are compulsory nutritional standards for school meals [14, 15] or taxes on sugar-sweetened beverages [16-18]. So far outcomes have been disappointing. People largely fail to follow the dietary guidelines [19-22].

As for obesity, the prevalence has not declined [2, 23], and social inequalities in diet [24] and obesity [10, 25, 26] have persisted or even increased.

Recent research findings [27-35], particularly by Zeevi and co-researchers [36], have suggested new perspectives for the prevention and treatment of obesity-related diseases using personalized dietary approaches. Precision nutrition (PN), also called personalized nutrition, is based on the postulate that the optimal diet is not the same for everyone. In brief, PN aims at delivering tailored nutritional recommendations based on combined information from individuals' gut microbiota, genetic, physiological, and behavioural backgrounds [37-42].

Following these promising results in clinical research [27-36], some large public research funders, such as the EU Horizon 2020 program [43], have encouraged researchers to test solutions providing tailored nutritional advice to large numbers of people, including healthy individuals. An international trial, Food4Me, was recently launched in 1600 volunteers to test the opportunities and challenges of PN in the general population [44]. Within this context, some [39, 42, 45, 46] have begun to consider PN as an emerging tool for public health to reduce obesity and obesity-related diseases, notably because precision approaches have a marked preventive component.

In parallel, advances in 'omics' technologies and wearable devices facilitate less costly collection and analysis of massive data. This makes scalable delivery of tailored nutritional advice increasingly plausible [38, 39, 42]. Thanks to these technical developments and the clinical context explained above, PN could be viewed as a novel opportunity to provide the right dietary intervention to the right population at the right time, and at a large scale [47-49]. In this paper, we explore the promises and potential limitations of interventions based on large-scale PN. We question their relevance in balancing individuals' diet and addressing obesity at a population level. We build our argument on Geoffrey Rose's theory [50, 51] regarding the differences in individual and population causes of disease. We finally argue that large-scale PN could possibly have the unintended effect of exacerbating social inequalities in obesity.

8.4. What is large-scale precision nutrition?

Modelled after PN in clinical settings [36], large-scale PN relies on the collection and analysis of several types of data from eating behaviour, physical activity, deep phenotyping, nutrigenomics, microbiomics/metagenomics, and metabolomics [37-42] (**Table 1**). These data serve to define the appropriate diet for each individual, or more realistically, each population sub-stratum [49, 52]. Different amounts of data can be collected and analysed depending on the infrastructure availability and financial resources. For example, in the Food4Me trial, the intervention involved the delivery of personalized nutrition advice based on data from: 1) current diet, or; 2) diet plus phenotypic traits such as waist circumference and serum glucose, total cholesterol, carotenes, and omega 3 index, or; 3) diet, phenotype plus genotype (*i.e.,* specific variants on five diet-responsive genes) [44].

Table 1. Potential sources of data for tailored nutritional advice in large-scale precision nutrition interventions.

<table>
<tr><th>Data</th><th>Aims of data collection</th><th>Methods to produce data</th><th>Infrastructures and tools to collect, analyse and store data</th></tr>
<tr><td>Eating behaviour</td><td>To evaluate :
- Dietary intake (e.g., food consumption, use of nutrient supplements)
- Eating behaviour</td><td>Dietary assessment on several days using:
- Online food diary
- Smart-phone applications (self-description and quantification of consumed foods)
- Digital photography (semi-automatic identification and quantification of consumed foods)</td><td rowspan="6">- Dried blood spot testing
- Saliva swaps
- Stool kits
- Shipment material
- Local pharmacy networks
- Accelerometers
- Smart-phone and other digital technologies
- Bio-banks
- Linkage with electronic health record
- Biomedical laboratories
- Artificial intelligence, etc.</td></tr>
<tr><td>Physical activity</td><td>To measure physical activity level
To estimate energy expenditure</td><td>Accelerometry techniques using:
- Wearable/portable devices (e.g., wristband)
- Online questionnaire</td></tr>
<tr><td>Deep phenotyping</td><td>To assess :
- Body composition
- Nutritional status
- Other risk factors for diet-related diseases</td><td>Anthropometric measurements (e.g., weight, waist circumference, bone densitometry)
Clinical chemistry from various bio-samples (e.g., plasma, urine, saliva) to assess visceral fat distribution, insulin resistance, LDL-cholesterol, nutrient-deficiencies, etc.</td></tr>
<tr><td>Nutrigenomics</td><td>To look for genetic variants associated with diet-related diseases and/or responsive to dietary changes</td><td>DNA extraction and genotyping of selected loci from whole-blood samples</td></tr>
<tr><td>Microbiomics/ metagenomics</td><td>To understand the interplay between diet and gut microbiota</td><td>Faeces collection to sequence the microorganisms present in the gut for microbial profiling and detection of dysbiosis</td></tr>
<tr><td>Metabolomics</td><td>To understand how the body metabolizes/utilizes nutrients</td><td>Complex chemical analyses from bio-samples (e.g., serum, plasma, urine) using :
- Nuclear magnetic resonance spectroscopy
- Mass spectrometry-based techniques</td></tr>
</table>

Once the desired level of precision/information is defined, data can be collected at a large scale using personal smart-phones and other relatively inexpensive and reliable wearable devices, such as electronic food diary and wristband for accelerometry [38, 39]. In parallel, new tools (Table 1), such as dried blood spot testing [42], already routinely used for the Guthrie test in new-borns [53], and simple stool kits [36, 54], enable the bio-sample collection from home or a local pharmacy. The Food4Me intervention was entirely internet-delivered, for instance. Participants themselves collected both bio-samples using the saliva swaps for genotyping and dried blood spots for phenotyping. They followed online demonstrations, and sent their biological material by conventional mail [44]. The advances of laboratory analytic techniques (*e.g.*, DNA sequencing, mass spectrometry) [39, 42], bioinformatics, and artificial intelligence (*e.g.*, machine-learning algorithms, deep learning) [36, 38, 55, 56] render the analysis and interpretation of large datasets less and less expensive and time-consuming.

Lastly, smart-phone applications allow large-scale dissemination of personalized advice directly to individuals. For instance, the applications delivered by the companies DayTwo [57] and Viome [58] can provide a personal score for foods or recipes regarding their potential positive or negative impact on blood glucose level. The enterprise habit [59] even offers detailed menu plans to comply with personalized recommended intake in terms of protein, carbohydrate and fat.

8.1. Large-scale precision nutrition: promises and challenges

The central promise of large-scale PN is personalized interventions based on more: 1) preventive (predictive and accurate); 2) practical (understandable and implementable); and 3) dynamic nutritional advice than 'one-size-fits-all' guidelines [39]. First, PN advocates presume that nutritional advice is likely to be more predictive because the personal risk of developing specific diseases (*e.g.*, based on polygenic risk scores) and biomedical context can be considered [40, 49, 60]. Advice could also be more accurate due to more precise dietary intake and nutritional status assessment [61-65] and better anticipation of interpersonal variability in food metabolic response [36, 66, 67]. Second, personalised nutritional advice may be easily understood as messages could be delivered in a simpler way using modern communication techniques [68, 69]. Advice may also be more implementable as adapted to actual food consumption, personal food preferences and lifestyle [68-70]. Third, nutritional advice would evolve following the personal dietary and biomedical evolutions of each individual as automatically processed and refined over time through new data [39]. In sum, large-scale PN promises better individual risk identification through comprehensive screening and behavioural modification in line with these identified risks.

At present, large-scale PN faces two main challenges, however. On the one hand, its application at a large scale raises organisational, legal and ethical questions, notably regarding biobank management, data protection, and informed consent [42, 52, 71]. However, these technical challenges are currently being addressed by some countries that have launched large-scale precision medicine projects, such as the Precision Medicine Initiative in one million U.S. residents [72], and the human biomonitoring project (HBM4EU) in 28 European countries [73]. On the other hand, the effectiveness associated with both identifying the individual risk and delivering personal messages for prevention and treatment of obesity-related disease is disputed [4, 38, 40, 74-77]. The 2018 Lancet review by Wang and Hu [38] concluded that evidence is currently lacking to support the additional benefits of PN over 'one-size-fits-all' nutrition intervention in the prevention and treatment of type 2 diabetes. Evidence regarding effectiveness and cost-effectiveness of large-scale PN in the general population is even scarcer. To date, the Food4Me trial has determined that participants receiving personalized advice had a healthier diet compared with controls receiving standard guidelines after the 6-month intervention (completion rate: 79%) [78]. However, no significant changes in weight or waist circumference were observed, even when phenotypic or genotypic data were considered to personalise diet. The question of effectiveness on population health will probably remain open for some years.

8.2. Obese individuals and obese populations

In public health, two main traditional strategies have existed for preventive interventions: high-risk and population approaches [50, 51]. The traditional population approach seeks an improvement of overall population health by shifting the distribution of exposure risk in a favourable direction in the entire population (**Figure 1**A). With the assumption that 'a large number of people at a small risk may give rise to more cases of disease than the small number who are at a high risk', the population approach contrasts with the high-risk approach [50]. The high-risk approach proposes targeted interventions addressed only to individuals screened for their higher probability of developing the disease [50].

Large-scale PN targets the whole population in the spirit of a traditional population approach. Both preventive strategies can be used for primary and secondary prevention. However, large-scale PN interventions substantially differ from the traditional population interventions in the way to achieve the distribution shift. The former targets individual risk with precision behavioural measures in large numbers, while the latter targets overall population risk with structural/environmental measures, as shown below.

In the 1985 seminal article Sick Individuals and Sick Populations [50], still considered relevant for modern public health [79], Geoffrey Rose suggested a distinction be made between two kinds of disease determinants. First, the causes of cases explain why individuals become sick (*i.e.,* individual risk). Second, the causes of incidence explain why certain populations become sick, whilst others do not (*i.e.,* population risk). Rose [50, 51], and later Schwartz and Diez-Roux [80], demonstrated that the causes of cases and incidence are not necessarily the same, even if they are often related. Using empirical examples for hypertension and hypercholesterolemia, Rose showed that causes of cases originate generally from the individual variation in genetic, social, and behavioural factors, or a mixture of them (*i.e.,* what we call today gene-environment interactions) [51]. As for the causes of incidence, they originate, instead, from the population variation in collective and societal characteristics [51].

Returning to the issue of obesity, Rose would argue that the causes of why some individuals become obese differ from the causes of why some populations become obese. **Table 2** provides examples of the distinction between causes of obesity in individuals and those in populations, knowing that inadequate diet and lack of physical activity are common causes at both individual and population levels. Based on the determinants listed in Table 2, we observe that the causes of incidence are largely related to the living conditions encouraging excessive food intake and discouraging physical activity. Others have grouped these determinants under the umbrella term of obesogenic environments [81-88]. As for large-scale PN, it accounts only for some of the causes of obesity in individuals: *e.g.*, genetic predisposition, gut microbial dysbiosis, and lack of food and nutrition literacy regarding the meaning of healthy eating. By definition, as PN is an individualized approach, it does not address any causes of incidence. That is why we define large-scale PN as an individual-centred approach in large numbers rather than a true population approach.

Table 2. Non-exhaustive list of determinants of obesity in individuals vs. those of obese populations in most high-income countries.

	Causes of cases - Individual risk ***Why some individuals in a population become obese?***	**Causes of incidence - Population risk** ***Why some populations become obese while others do not?***
Common causes	• Quantitative and qualitative imbalance in diet • Lack of physical activity	
Distinctive causes	• Genetic predisposition • Diseases, metabolic and endocrine disorders • Medications associated with weight gain • Lack of richness and diversity in gut microbiota • Age • Lack of food and nutrition literacy • Psychological factors	• Food markets making high-energy and ultra-processed foods widely available, low-priced, delivered in large portion sizes, and/or prominently marketed • Agricultural policies and subsidies promoting the production of less healthy foods • Built environment and transportation policies promoting physical inactivity • School and workplace environment not encouraging healthy eating and physical activity • Loss of traditional culture around food, cooking and meals • Values associated with slimness and fatness

Individual-centred interventions targeting behaviour change in large numbers can bring benefits to some individuals or sub-strata in the population. For example, it could allow early detection of rare forms of monogenic obesity, such as leptin deficiency due to LEP gene mutations [89, 90]. However, such interventions are less valuable for overall population health, especially in the case of common diseases with reduced penetrance, such as obesity [51, 91]. We will now discuss these limitations.

8.3. Limitations of individual-centred strategies for population health

Individual-centred strategies often offer temporary and palliative, rather than radical success at a population level because they do not alter the conditions that affect the overall distribution [50, 79]. In other words, helping individuals to reduce their individual level of risk exposure does not address the root of the problem determining population risk exposure [51]. For obesity, the root of the problem of inadequate dietary intake in most high-income populations is mainly the obesogenic food environment, as mentioned previously.

High-energy and ultra-processed foods rich in sodium, added sugars, and saturated fats are widely available in shops and restaurants, and hence in households [92, 93]. This is particularly applicable for people of lower socio-economic status (SES), who tend to experience a more prominent obesogenic food environment in their neighbourhoods [85, 94, 95]. For example, lack of access to shops/supermarkets to buy fresh healthy products and over-exposure to fast-food restaurants have been documented in the U.S.' poorer neighbourhoods [85, 94, 95]. Moreover, high-energy and ultra-processed foods tend to cost less than healthier alternatives [96-99]. High-energy and ultra-processed foods are also heavily advertised [100, 101], promoting their over-consumption, especially in children [102, 103]. In addition, food is sold in large portion sizes encouraging overeating [87]. Of note, social and cultural norms (*e.g.*, reduction of time and/or skills to shop, prepare and eat food, and frequent snacking) tend to favour imbalanced diets and excessive food intake [104, 105]. These social, cultural, economic and political barriers hinder healthy eating on a daily basis. If these barriers persist at a population level, the weight loss success of some individuals, thanks to large-scale PN, might be attenuated by the future weight gain of their neighbours or children who are exposed to the same unchanged obesogenic environments. This puts them continually at risk of obesity [106].

Similarly, if the root causes of disease in the population are not addressed, individual-centred strategies tend to be behaviourally and culturally difficult to maintain over time [50, 79]. Namely, implementing behaviour change at an individual level becomes challenging when 'social norms' (*i.e.,* peers and environment) are not altered. Deviation from norms necessitates constant effort to sustain alternative behaviours [107-110]. This might enlighten why individual-centred programs aimed at changing eating behaviour and/or maintaining weight loss in *a priori* motivated people have regularly yielded disappointing results in the long term [111-113].

PN advocates could argue that knowing the higher personal risk of obesity might further motivate people to change their diet. A systematic review of seven randomized and quasi-randomized controlled trials [114], and a more recent trial [115], however, did not support this hypothesis. They found that communicating DNA-based risk estimates for common complex diseases did not enhance eating behaviour compared to non-DNA based risk estimates or no risk estimates at all. It seems, indeed, that targeting individual eating behaviour with rational advice on food choices without simultaneously tackling the social, cultural, economic and political conditions in which behaviours occur is unlikely to generate large, long-term dietary changes at a population level.

Together with efficacy, public health interventions aim at maximizing equity or at least mitigating inequity [91, 116]. In other words, desirable population interventions should have a large mean effect size together with a decreased standard deviation (Figure 1B). Applied to large-scale PN, desirable interventions should reduce the gap between those with the best and worse dietary intake. This means that they should have the most impact on groups with poorer dietary intake, often those of lower SES [24, 117, 118]. However, several reviews have shown that individual-centred public health interventions targeting behavioural changes to improve nutrition [119, 120] or health [121, 122] provide less benefit to lower SES groups. For example, Sumar and McLaren [123] demonstrated that public information campaigns about the importance of folic acid intake among child-bearing aged women (*i.e.,* an intervention requiring individual decisions to change behaviour) were more likely to increase socio-economic inequalities in folate status than staple food fortification with folic acid (*i.e.,* an intervention at a policy level requiring no individual decision-making).

Inequalities resulting from individual-centred interventions targeting the entire population can be understood through the ‘capability approach’, developed by Amartya Sen [124, 125]. He stated that people with the same amount of resources at hand are not equal in capacity, that is, in what they are able to actually achieve with these resources. Specifically to health, Link and Phelan’s fundamental cause theory [126, 127] states that individuals of higher SES have a wider range of ‘flexible resources’ with regard to knowledge, wealth, power and social networks than individuals of lower SES. Thanks to these resources they can better understand information, afford, and become motivated to engage in a larger range of activities focusing on their health improvement. In essence, control over the determinants of diet and the motivation to act on it is unequally distributed within a population.

These theories, plus the role of obesogenic neighbourhoods, may partly explain why individuals of higher SES have already taken the most advantage of previous public health individual-centred interventions and thus have lower obesity prevalence than less privileged individuals [10, 25, 26]. From this observation, and building on the fundamental cause theory [126, 127], we believe that smart-phone applications delivering tailored nutritional advice, albeit free, may be more or less attractive and differentially used according to SES. Early adoption and achievement of improved dietary habits is hence more likely among more socially privileged members of the population. This could exacerbate socio-economic inequalities in diet and in obesity. This is not only an equity concern, but also one of efficacy. Indeed, if mostly privileged groups in the population improve their eating habits, this would have a limited impact on overall population health, since they already demonstrate a lower risk of obesity and obesity-related disease.

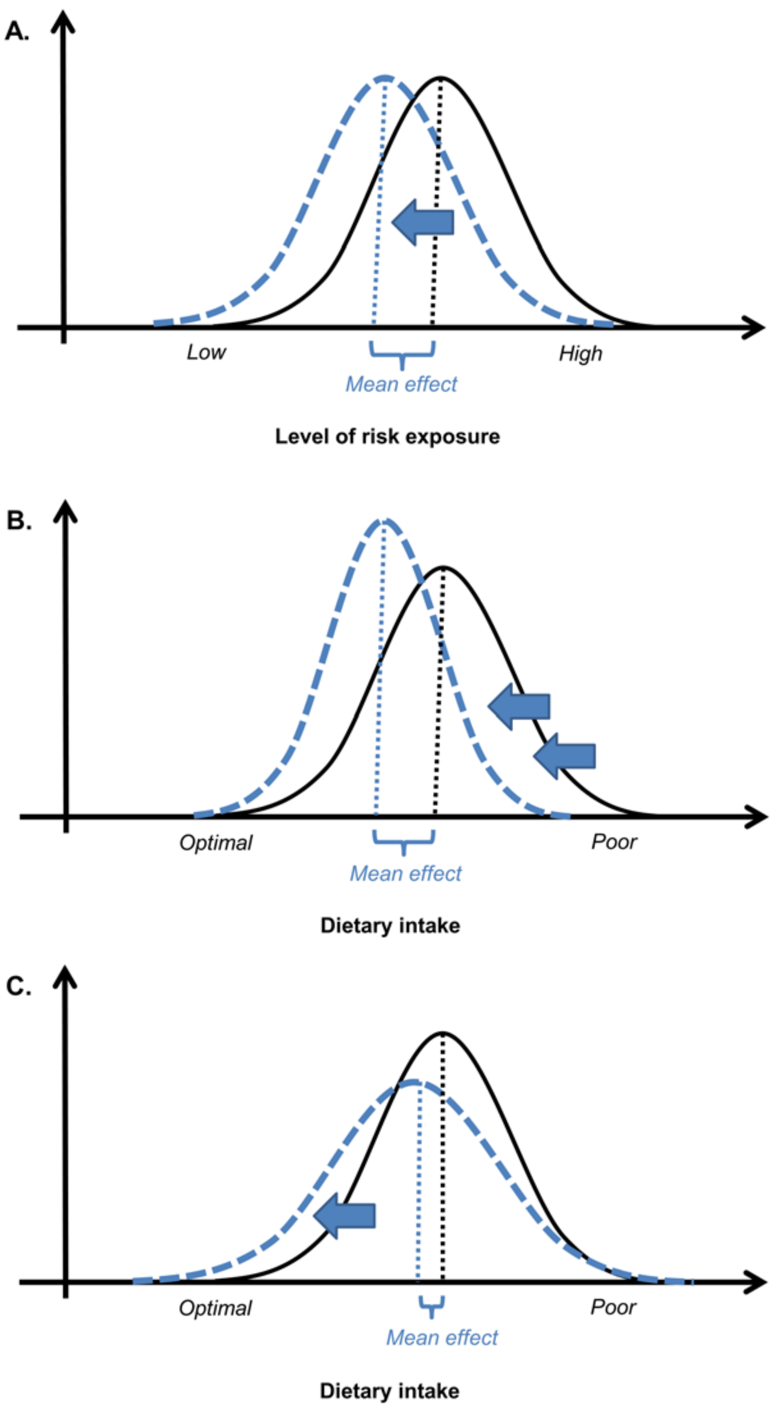


Figure 1. Impact of public health interventions on health. **A**. Intended effect of Rose's population strategy on risk of exposure (*i.e.,* large mean effect and unchanged standard deviation after the intervention). **B**. Desirable impact of public health interventions on dietary intake (*i.e.,* large mean effect and decreased standard deviation after the intervention). **C**. Probable impact of large-scale precision nutrition on dietary intake (*i.e.,* small mean effect and increased standard deviation after intervention). *Solid line: Distribution of risk/dietary intake before the intervention. Dash line: Distribution of risk/dietary intake after the intervention.*

8.4. Conclusion

Some public health actors have become enthused by the central promise of PN to better identify the individual risks and suggest targeted dietary modification. They expect PN applied at a large scale to improve populations' diet and health. We showed, however, that individual-centred interventions directed to behaviour change, such as large-scale PN, are likely to have a limited and unequal impact on diet and obesity incidence at a population level (Figure 1C), particularly if the obesogenic environments are not addressed in the first place.

We nevertheless believe that knowledge and technologies from large-scale PN (Table 1) may provide improved solutions to two recurring concerns in nutritional epidemiology: 1) the accurate assessment of food and nutrients intakes together with physical activity in relation to energy intake and expenditure, and 2) the long-term monitoring of nutritional status at individual and population levels. This may improve or validate our understanding of the impact of dietary intakes and changes on the personal risk of diseases and related biological pathways [36, 38, 41, 65, 128]. Similarly, methods used in large-scale PN could complement traditional subjective and/or memory-based dietary assessment methods, such as food frequency questionnaire and 24-hour dietary recalls [38, 39, 41, 61, 63, 64]. Overall, this may help confirm or refine dietary guidelines for specific population sub-strata. Despite the potential for causal inference and population surveillance, we conclude that PN at a large scale would be of limited interest for public health interventions in the prevention of common polygenic diseases, such as obesity. The impact of large-scale PN on populations' health is likely to be minor and unevenly distributed in the populations in the absence of complementary social and structural/environmental measures.

8.5. References

1. World Health Organization. Obesity and overweight. Key facts. [cited 2018 Apr 5]; Available from: http://www.who.int/mediacentre/factsheets/fs311/en/.
2. Hales, C.M., et al., Trends in Obesity and Severe Obesity Prevalence in US Youth and Adults by Sex and Age, 2007-2008 to 2015-2016. JAMA, 2018. 319(16): p. 1723-1725
3. Pi-Sunyer, X., The medical risks of obesity. Postgrad Med, 2009. 121(6): p. 21-33.
4. Goodarzi, M.O., Genetics of obesity: what genetic association studies have taught us about the biology of obesity and its complications. Lancet Diabetes Endocrinol, 2018. 6(3): p. 223-236.
5. Must, A., et al., The disease burden associated with overweight and obesity. JAMA, 1999. 282(16): p. 1523-9.
6. G.B.D. Risk Factors Collaborators, Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet, 2017. 390(10100): p. 1345-1422.
7. Drewnowski, A., Obesity, diets, and social inequalities. Nutr Rev, 2009. 67 Suppl 1: p. S36-9.
8. Robertson, A., T. Lobstein, and C. Knai, Obesity and socio-economic groups in Europe: Evidence review and implications for action. Report SANCO/2005/C4-NUTRITION-03. 2007, European Commission: Brussels, Belgium.
9. Siddiqi, A., et al., Cross-national comparison of socioeconomic inequalities in obesity in the United States and Canada. Int J Equity Health, 2015. 14: p. 116.
10. Devaux, M. and F. Sassi, Social inequalities in obesity and overweight in 11 OECD countries. Eur J Public Health, 2013. 23(3): p. 464-9.
11. Food and Agriculture Organization (FAO). Plates, pyramids, planet. Developments in national healthy and sustainable dietary guidelines: a state of play assessment. [cited 2018 Sep 4]; Available from: https://www.un.org/nutrition/home.
12. United States Department of Agriculture. 2015-2020 Dietary Guidelines for Americans. [cited 2018 Apr 5]; Available from: https://www.choosemyplate.gov/dietary-guidelines.
13. Public Health England. The Eatwell Guide. [cited 2018 Apr 5]; Available from: https://www.gov.uk/government/publications/the-eatwell-guide.
14. United States Department of Agriculture, Nutrition Standards in the National School Lunch and School Breakfast Programs. 2012: Federal Register, Vol. 77, No. 17.
15. United Kingdom Department of Education, The Requirements for School Food Regulations 2014: No. 1603.
16. Backholer, K., M. Blake, and S. Vandevijvere, Sugar-sweetened beverage taxation: an update on the year that was 2017. Public Health Nutr, 2017. 20(18): p. 3219-3224.

17. Silver, L.D., et al., Changes in prices, sales, consumer spending, and beverage consumption one year after a tax on sugar-sweetened beverages in Berkeley, California, US: A before-and-after study. PLoS Med, 2017. 14(4): p. e1002283.

18. Colchero, M.A., M. Molina, and C.M. Guerrero-Lopez, After Mexico Implemented a Tax, Purchases of Sugar-Sweetened Beverages Decreased and Water Increased: Difference by Place of Residence, Household Composition, and Income Level. J Nutr, 2017. 147(8): p. 1552-1557.

19. Rehm, C.D., et al., Dietary Intake Among US Adults, 1999-2012. JAMA, 2016. 315(23): p. 2542-53.

20. Bates, B., et al., National Diet and Nutrition Survey: Results from Years 1, 2, 3 and 4 (combined) of the Rolling Programme (2008/2009 - 2011/2012). 2014, Public Health England / Food Standard Agency: London, United Kingdom.

21. Diethelm, K., et al., Food intake of European adolescents in the light of different food-based dietary guidelines: results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. Public Health Nutr, 2012. 15(3): p. 386-98.

22. Chatelan, A., et al., Major Differences in Diet across Three Linguistic Regions of Switzerland: Results from the First National Nutrition Survey menuCH. Nutrients, 2017. 9(11).

23. N. C. D. Risk Factor Collaboration, Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. Lancet, 2017. 390(10113): p. 2627-2642.

24. Wang, D.D., et al., Improvements In US Diet Helped Reduce Disease Burden And Lower Premature Deaths, 1999-2012; Overall Diet Remains Poor. Health Aff (Millwood), 2015. 34(11): p. 1916-22.

25. Stamatakis, E., et al., Overweight and obesity trends from 1974 to 2003 in English children: what is the role of socioeconomic factors? Arch Dis Child, 2005. 90(10): p. 999-1004.

26. Singh, G.K., et al., Dramatic increases in obesity and overweight prevalence and body mass index among ethnic-immigrant and social class groups in the United States, 1976-2008. J Community Health, 2011. 36(1): p. 94-110.

27. Qi, Q., et al., Sugar-sweetened beverages and genetic risk of obesity. N Engl J Med, 2012. 367(15): p. 1387-96.

28. Price, N.D., et al., A wellness study of 108 individuals using personal, dense, dynamic data clouds. Nat Biotechnol, 2017. 35(8): p. 747-756.

29. Wang, T., et al., Genetic variation of fasting glucose and changes in glycemia in response to 2-year weight-loss diet intervention: the POUNDS LOST trial. Int J Obes (Lond), 2016. 40(7): p. 1164-9.

30. Qi, Q., et al., Insulin receptor substrate 1 gene variation modifies insulin resistance response to weight-loss diets in a 2-year randomized trial: the Preventing Overweight Using Novel Dietary Strategies (POUNDS LOST) trial. Circulation, 2011. 124(5): p. 563-71.

31. Huang, T., et al., Genetic susceptibility to diabetes and long-term improvement of insulin resistance and beta cell function during weight loss: the Preventing Overweight Using Novel Dietary Strategies (POUNDS LOST) trial. Am J Clin Nutr, 2016. 104(1): p. 198-204.

32. Corella, D., et al., Association of the LCT-13910C>T polymorphism with obesity and its modulation by dairy products in a Mediterranean population. Obesity (Silver Spring), 2011. 19(8): p. 1707-14.

33. Goni, L., et al., A genetic risk tool for obesity predisposition assessment and personalized nutrition implementation based on macronutrient intake. Genes Nutr, 2015. 10(1): p. 445.

34. Wu, G.D., et al., Comparative metabolomics in vegans and omnivores reveal constraints on diet-dependent gut microbiota metabolite production. Gut, 2016. 65(1): p. 63-72.

35. Ortega-Azorin, C., et al., Amino acid change in the carbohydrate response element binding protein is associated with lower triglycerides and myocardial infarction incidence depending on level of adherence to the Mediterranean diet in the PREDIMED trial. Circ Cardiovasc Genet, 2014. 7(1): p. 49-58.

36. Zeevi, D., et al., Personalized Nutrition by Prediction of Glycemic Responses. Cell, 2015. 163(5): p. 1079-1094.

37. Ferguson, L.R., et al., Guide and Position of the International Society of Nutrigenetics/Nutrigenomics on Personalised Nutrition: Part 1 - Fields of Precision Nutrition. J Nutrigenet Nutrigenomics, 2016. 9(1): p. 12-27.

38. Wang, D.D. and F.B. Hu, Precision nutrition for prevention and management of type 2 diabetes. Lancet Diabetes Endocrinol, 2018.

39. de Toro-Martin, J., et al., Precision Nutrition: A Review of Personalized Nutritional Approaches for the Prevention and Management of Metabolic Syndrome. Nutrients, 2017. 9(8).

40. Heianza, Y. and L. Qi, Gene-Diet Interaction and Precision Nutrition in Obesity. Int J Mol Sci, 2017. 18(4).

41. Ferguson, J.F., et al., Nutrigenomics, the Microbiome, and Gene-Environment Interactions: New Directions in Cardiovascular Disease Research, Prevention, and Treatment: A Scientific Statement From the American Heart Association. Circ Cardiovasc Genet, 2016. 9(3): p. 291-313.

42. Kohlmeier, M., et al., Guide and Position of the International Society of Nutrigenetics/Nutrigenomics on Personalized Nutrition: Part 2 - Ethics, Challenges and Endeavors of Precision Nutrition. J Nutrigenet Nutrigenomics, 2016. 9(1): p. 28-46.

43. European Commission. EU Programmes 2014-2020. Horizon2020. TOPIC: Personalized Nutrition. [cited 2018 Apr 5]; Available from: http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/dt-sfs-14-2018.html.

44. Celis-Morales, C., et al., Design and baseline characteristics of the Food4Me study: a web-based randomised controlled trial of personalised nutrition in seven European countries. Genes Nutr, 2015. 10(1): p. 450.

45. Newell, A., et al., Addressing the obesity epidemic: a genomics perspective. Prev Chronic Dis, 2007. 4(2): p. A31.

46. Claus, S.P., Development of personalized functional foods needs metabolic profiling. Curr Opin Clin Nutr Metab Care, 2014. 17(6): p. 567-73.

47. Khoury, M.J., M.F. Iademarco, and W.T. Riley, Precision Public Health for the Era of Precision Medicine. Am J Prev Med, 2016. 50(3): p. 398-401.

48. Vaithinathan, A.G. and V. Asokan, Public health and precision medicine share a goal. J Evid Based Med, 2017. 10(2): p. 76-80.

49. Belsky, D.W., T.E. Moffitt, and A. Caspi, Genetics in population health science: strategies and opportunities. Am J Public Health, 2013. 103 Suppl 1: p. S73-83.

50. Rose, G., Sick individuals and sick populations. Int J Epidemiol, 1985. 14(1): p. 32-8.

51. Rose, G., The Strategy of Preventive Medicine. 1992, Oxford, United Kingdom: Oxford University Press.

52. Burton, H., et al., Time to revisit Geoffrey Rose: strategies for prevention in the genomic era? Ital J Public Health, 2012. 9(4).

53. Guthrie, R. and A. Susi, A Simple Phenylalanine Method for Detecting Phenylketonuria in Large Populations of Newborn Infants. Pediatrics, 1963. 32: p. 338-43.

54. Human Microbiome Project Consortium, Structure, function and diversity of the healthy human microbiome. Nature, 2012. 486(7402): p. 207-14.

55. Rimbach, G. and A.M. Minihane, Nutrigenetics and personalised nutrition: how far have we progressed and are we likely to get there? Proc Nutr Soc, 2009. 68(2): p. 162-72.

56. Beam, A.L. and I.S. Kohane, Big Data and Machine Learning in Health Care. JAMA, 2018. 319(13): p. 1317-1318.

57. DayTwo. DayTwo: Personalized Nutrition Based On Your Gut Microbiome. [cited 2018 Apr 5]; Available from: www.daytwo.com.

58. Viome. Viome: Gut Microbiome and Wellness. [cited 2018 Apr 5]; Available from: www.viome.com.

59. Habit. Habit: Personalized Nutrition Designed for Better Health & Weight Loss. [cited 2018 Apr 5]; Available from: https://habit.com/.

60. Weber, G.M., K.D. Mandl, and I.S. Kohane, Finding the missing link for big biomedical data. JAMA, 2014. 311(24): p. 2479-80.

61. Garcia-Perez, I., et al., Objective assessment of dietary patterns by use of metabolic phenotyping: a randomised, controlled, crossover trial. Lancet Diabetes Endocrinol, 2017. 5(3): p. 184-195.

62. Vernocchi, P., et al., Integration of datasets from different analytical techniques to assess the impact of nutrition on human metabolome. Front Cell Infect Microbiol, 2012. 2: p. 156.

63. Lloyd, A.J., et al., Data-driven strategy for the discovery of potential urinary biomarkers of habitual dietary exposure. Am J Clin Nutr, 2013. 97(2): p. 377-89.

64. Martin, C.K., et al., Validity of the Remote Food Photography Method (RFPM) for estimating energy and nutrient intake in near real-time. Obesity (Silver Spring), 2012. 20(4): p. 891-9.

65. Vazquez-Fresno, R., et al., Metabolomic pattern analysis after Mediterranean diet intervention in a nondiabetic population: a 1- and 3-year follow-up in the PREDIMED study. J Proteome Res, 2015. 14(1): p. 531-40.

66. Connaugton, R.M., et al. An anti-inflammatory nutritional intervention selectively improves insulin sensitivity in overweight and obese adolescents wherein baseline metabotype predicts response. In: Irish Section Meeting, Changing Dietary Behaviour: Physiology Through to Practice. 2014.

67. Sevilla-Villanueva, B., et al., Evaluation of Adherence to Nutritional Intervention Through Trajectory Analysis. IEEE J Biomed Health Inform, 2017. 21(3): p. 628-634.

68. Nielsen, D.E. and A. El-Sohemy, A randomized trial of genetic information for personalized nutrition. Genes Nutr, 2012. 7(4): p. 559-66.

69. Brug, J., M. Campbell, and P. van Assema, The application and impact of computer-generated personalized nutrition education: a review of the literature. Patient Educ Couns, 1999. 36(2): p. 145-56.

70. Afshin, A., et al., Information Technology and Lifestyle: A Systematic Evaluation of Internet and Mobile Interventions for Improving Diet, Physical Activity, Obesity, Tobacco, and Alcohol Use. J Am Heart Assoc, 2016. 5(9).

71. Stewart-Knox, B., et al., Factors influencing European consumer uptake of personalised nutrition. Results of a qualitative analysis. Appetite, 2013. 66: p. 67-74.

72. Collins, F.S. and H. Varmus, A new initiative on precision medicine. N Engl J Med, 2015. 372(9): p. 793-5.

73. German Environment Agency. Human Biomonitoring for Europe. HBM4EU. [cited 2018 Apr 5]; Available from: https://www.hbm4eu.eu/.

74. Gardner, C.D., et al., Effect of Low-Fat vs Low-Carbohydrate Diet on 12-Month Weight Loss in Overweight Adults and the Association With Genotype Pattern or Insulin Secretion: The DIETFITS Randomized Clinical Trial. JAMA, 2018. 319(7): p. 667-679.

75. Livingstone, K.M., et al., FTO genotype and weight loss: systematic review and meta-analysis of 9563 individual participant data from eight randomised controlled trials. BMJ, 2016. 354: p. i4707.

76. Look, A.R.G., Prospective Association of GLUL rs10911021 With Cardiovascular Morbidity and Mortality Among Individuals With Type 2 Diabetes: The Look AHEAD Study. Diabetes, 2016. 65(1): p. 297-302.

77. Tyrrell, J., et al., Gene-obesogenic environment interactions in the UK Biobank study. Int J Epidemiol, 2017. 46(2): p. 559-575.

78. Celis-Morales, C., et al., Effect of personalized nutrition on health-related behaviour change: evidence from the Food4Me European randomized controlled trial. Int J Epidemiol, 2017. 46(2): p. 578-588.

79. Doyle, Y.G., A. Furey, and J. Flowers, Sick individuals and sick populations: 20 years later. J Epidemiol Community Health, 2006. 60(5): p. 396-8.

80. Schwartz, S. and A.V. Diez-Roux, Commentary: causes of incidence and causes of cases--a Durkheimian perspective on Rose. Int J Epidemiol, 2001. 30(3): p. 435-9.

81. Hill, J.O. and J.C. Peters, Environmental contributions to the obesity epidemic. Science, 1998. 280(5368): p. 1371-4.

82. Egger, G. and B. Swinburn, An ‘ecological’ approach to the obesity pandemic. BMJ, 1997. 315(7106): p. 477-80.

83. Swinburn, B., G. Egger, and F. Raza, Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. Prev Med, 1999. 29(6 Pt 1): p. 563-70.

84. Drewnowski, A., Obesity and the food environment: dietary energy density and diet costs. Am J Prev Med, 2004. 27(3 Suppl): p. 154-62.

85. Papas, M.A., et al., The built environment and obesity. Epidemiol Rev, 2007. 29: p. 129-43.

86. Booth, K.M., M.M. Pinkston, and W.S. Poston, Obesity and the built environment. J Am Diet Assoc, 2005. 105(5 Suppl 1): p. S110-7.

87. Osei-Assibey, G., et al., The influence of the food environment on overweight and obesity in young children: a systematic review. BMJ Open, 2012. 2(6).

88. Glanz, K., et al., Healthy nutrition environments: concepts and measures. Am J Health Promot, 2005. 19(5): p. 330-3, ii.

89. Fruhbeck, G., D.N. Kiortsis, and V. Catalan, Precision medicine: diagnosis and management of obesity. Lancet Diabetes Endocrinol, 2018. 6(3): p. 164-166.

90. Shabana and S. Hasnain, The p. N103K mutation of leptin (LEP) gene and severe early onset obesity in Pakistan. Biol Res, 2016. 49: p. 23.

91. Keyes, K.M. and S. Galea, Population Health Science. 2016, New York, United States: Oxford University Press.

92. Pan American Health Organization (PAHO), Ultra-processed Food and Drink Products in Latin America: Trends, Impact on Obesity, Policy Implications. Chapter 3. Ultra-processed product sales. 2015, PAHO: Washington DC, United States of America.

93. Monteiro, C.A., et al., Household availability of ultra-processed foods and obesity in nineteen European countries. Public Health Nutr, 2018. 21(1): p. 18-26.

94. Lovasi, G.S., et al., Built environments and obesity in disadvantaged populations. Epidemiol Rev, 2009. 31: p. 7-20.

95. Cummins, S. and S. Macintyre, Food environments and obesity—neighbourhood or nation? Int J Epidemiol, 2006. 35(1): p. 100-104.

96. Rao, M., et al., Do healthier foods and diet patterns cost more than less healthy options? A systematic review and meta-analysis. BMJ Open, 2013. 3(12).

97. Jones, N.R., et al., The growing price gap between more and less healthy foods: analysis of a novel longitudinal UK dataset. PLoS One, 2014. 9(10): p. e109343.

98. Drewnowski, A. and N. Darmon, The economics of obesity: dietary energy density and energy cost. Am J Clin Nutr, 2005. 82(1 Suppl): p. 265S-273S.

99. Andrieu, E., N. Darmon, and A. Drewnowski, Low-cost diets: more energy, fewer nutrients. Eur J Clin Nutr, 2006. 60(3): p. 434-6.

100. Batada, A., et al., Nine out of 10 food advertisements shown during Saturday morning children's television programming are for foods high in fat, sodium, or added sugars, or low in nutrients. J Am Diet Assoc, 2008. 108(4): p. 673-8.

101. Sixsmith, R. and A. Furnham, A content analysis of British food advertisements aimed at children and adults. Health Promotion Int, 2010. 25(1): p. 24-32.

102. Dovey, T.M., et al., Responsiveness to healthy television (TV) food advertisements/commercials is only evident in children under the age of seven with low food neophobia. Appetite, 2011. 56(2): p. 440-6.

103. Halford, J.C., et al., Beyond-brand effect of television (TV) food advertisements/commercials on caloric intake and food choice of 5-7-year-old children. Appetite, 2007. 49(1): p. 263-7.

104. Smith, L.P., S.W. Ng, and B.M. Popkin, Trends in US home food preparation and consumption: analysis of national nutrition surveys and time use studies from 1965-1966 to 2007-2008. Nutr J, 2013. 12: p. 45.

105. Higgs, S. and J. Thomas, Social influences on eating. Curr Opin Behav Sci, 2016. 9: p. 1-6.

106. Syme, S.L., Strategies for health promotion. Prev Med, 1986. 15(5): p. 492-507.

107. Frohlich, K.L., B. Poland, and M. Sharek, Contrasting Entry Points for Intervention in Health Promotion Practice: Situating and Working with Context. In: Health Promotion in Canada. New Perspectives on Theory, Practice, Policy, and Research, I. Rootman, et al., ed. 2017, Canadian Scholars: Toronto, Canada.

108. Higgs, S., Social norms and their influence on eating behaviours. Appetite, 2015. 86: p. 38-44.

109. Delormier, T., K.L. Frohlich, and L. Potvin, Food and eating as social practice--understanding eating patterns as social phenomena and implications for public health. Sociol Health Illn, 2009. 31(2): p. 215-28.

110. Hargreaves, K., et al., The social context of change in tobacco consumption following the introduction of 'smokefree' England legislation: a qualitative, longitudinal study. Soc Sci Med, 2010. 71(3): p. 459-466.

111. Dombrowski, S.U., et al., Long term maintenance of weight loss with non-surgical interventions in obese adults: systematic review and meta-analyses of randomised controlled trials. BMJ, 2014. 348: p. g2646.

112. Mead, E., et al., Diet, physical activity and behavioural interventions for the treatment of overweight or obese children from the age of 6 to 11 years. Cochrane Database Syst Rev, 2017. 6: p. CD012651.

113. Douketis, J.D., et al., Systematic review of long-term weight loss studies in obese adults: clinical significance and applicability to clinical practice. Int J Obes, 2005. 29: p. 1153.

114. Hollands, G.J., et al., The impact of communicating genetic risks of disease on risk-reducing health behaviour: systematic review with meta-analysis. BMJ, 2016. 352: p. i1102.

115. Godino, J.G., et al., Lifestyle Advice Combined with Personalized Estimates of Genetic or Phenotypic Risk of Type 2 Diabetes, and Objectively Measured Physical Activity: A Randomized Controlled Trial. PLoS Med, 2016. 13(11): p. e1002185.

116. Benach, J., et al., A new typology of policies to tackle health inequalities and scenarios of impact based on Rose's population approach. J Epidemiol Community Health, 2013. 67(3): p. 286-91.

117. Darmon, N. and A. Drewnowski, Does social class predict diet quality? Am J Clin Nutr, 2008. 87(5): p. 1107-17.

118. Giskes, K., et al., A systematic review of studies on socioeconomic inequalities in dietary intakes associated with weight gain and overweight/obesity conducted among European adults. Obes Rev, 2010. 11(6): p. 413-29.

119. Adams, J., et al., Why Are Some Population Interventions for Diet and Obesity More Equitable and Effective Than Others? The Role of Individual Agency. PLoS Med, 2016. 13(4): p. e1001990.

120. Lorenc, T., et al., What types of interventions generate inequalities? Evidence from systematic reviews. J Epidemiol Community Health, 2013. 67(2): p. 190-3.

121. Beauchamp, A., et al., The effect of obesity prevention interventions according to socioeconomic position: a systematic review. Obes Rev, 2014. 15(7): p. 541-54.

122. Frohlich, K.L. and L. Potvin, Transcending the known in public health practice: the inequality paradox: the population approach and vulnerable populations. Am J Public Health, 2008. 98(2): p. 216-21.

123. Sumar, N. and L. McLaren, Impact on social inequalities of population strategies of prevention for folate intake in women of childbearing age. Am J Public Health, 2011. 101(7): p. 1218-24.

124. Sen, A., Inequality re-examined. 1992, Cambridge, United States: Harvard University Press.

125. Frohlich, K.L., The social determinants of what? Int J Public Health, 2010. 55(4): p. 235-6.

126. Link, B.G. and J. Phelan, Social conditions as fundamental causes of disease. J Health Soc Behav, 1995. Spec No: p. 80-94.

127. Phelan, J.C., B.G. Link, and P. Tehranifar, Social conditions as fundamental causes of health inequalities: theory, evidence, and policy implications. J Health Soc Behav, 2010. 51 Suppl: p. S28-40.

128. Esko, T., et al., Metabolomic profiles as reliable biomarkers of dietary composition. Am J Clin Nutr, 2017. 105(3): p. 547-554.

9. Other projects

9.1. Sodium intake and blood pressure in children

I acted as a second reviewer for a systematic review and meta-analysis about the effect of sodium intake on blood pressure in children and adolescents. For this project, I selected, assessed, and extracted data from more than 120 full-texts with a colleague, Magali Leyvraz.

Published manuscripts:

Leyvraz M, Taffé P, Chatelan A, Paradis G, Tabin R, Bovet P, Bochud M, Chiolero A. Sodium intake and blood pressure in children and adolescents: protocol for a systematic review and meta-analysis. BMJ Open. 2016 Sep 21;6(9).

Leyvraz M, Chatelan A, Da Costa BR, Taffé P, Paradis G, Bovet P, Bochud M, Chiolero A. Sodium intake and blood pressure in children and adolescents: A systematic review and meta-analysis of experimental and observational studies. Int J Epidemiol. 2018 (in press).

Leyvraz M, Bloetzer C, Chatelan A, Bochud M, Burnier M, Santschi V, Paradis G, Tabin R, Bovet P, Chiolero A. Sodium intake and blood pressure in children with clinical conditions: A systematic review with meta-analysis. JCH. 2018 (in press).

Abstract of the second article

High sodium intake is a cause of elevated blood pressure in adults. In children and adolescents, less evidence is available and findings are equivocal. We systematically reviewed the evidence from experimental and observational studies on the association between sodium intake and blood pressure in children and adolescents. A systematic search of the Medline, Embase, CINAHL and CENTRAL databases up to March 2017 was conducted and supplemented by a manual search of bibliographies and unpublished studies. Experimental and observational studies involving children or adolescents between 0 and 18 years of age were included. Random-effects meta-analyses were performed by pooling data across all studies, separately for experimental and observational studies, and restricting to studies with sodium intake and blood pressure measurement methods of high quality. Subgroup meta-analyses, sensitivity analyses and meta-regressions were conducted to investigate sources of heterogeneity and confounding. The dose-response relationship was also investigated. Of the 6572 publications identified, 85 studies (14 experimental; 71 observational, including 60 cross-sectional, 6 cohort and 5 case-control studies) with 58 531 participants were included. In experimental studies, sodium reduction interventions decreased systolic blood pressure by 0.6 mm Hg [95% confidence interval (CI): 0.5, 0.8] and diastolic blood pressure by 1.2 mm Hg (95% CI: 0.4, 1.9). The meta-analysis of 18 experimental and observational studies (including 3406 participants) with sodium intake and blood pressure measurement methods of high

quality showed that, for every additional gram of sodium intake per day, systolic blood pressure increased by 0.8 mm Hg (95% CI: 0.4, 1.3) and diastolic blood pressure by 0.7 mm Hg (95% CI: 0.0, 1.4). The association was stronger among children with overweight and with low potassium intake. A quasi-linear relationship was found between sodium intake and blood pressure. Sodium intake is positively associated with blood pressure in children and adolescents, with consistent findings in experimental and observational studies. Since blood pressure tracks across the life course, our findings support the reduction of sodium intake during childhood and adolescence to lower blood pressure and prevent the development of hypertension.

9.2. Weighting strategy for menuCH data

I tested whether there was a seasonal effect on the consumption of 24 food groups. Results are presented in **Figure 1** and were used to demonstrate the necessity to account for seasonality in the weighting strategy.

Abstract and poster:

Chatelan A, Zuberbuehler C, Camenzind-Frey E, Bochud M. SUN-P126: Should we Adjust for Seasonality in Food Consumption Surveys? Clin Nutr. 35: S90

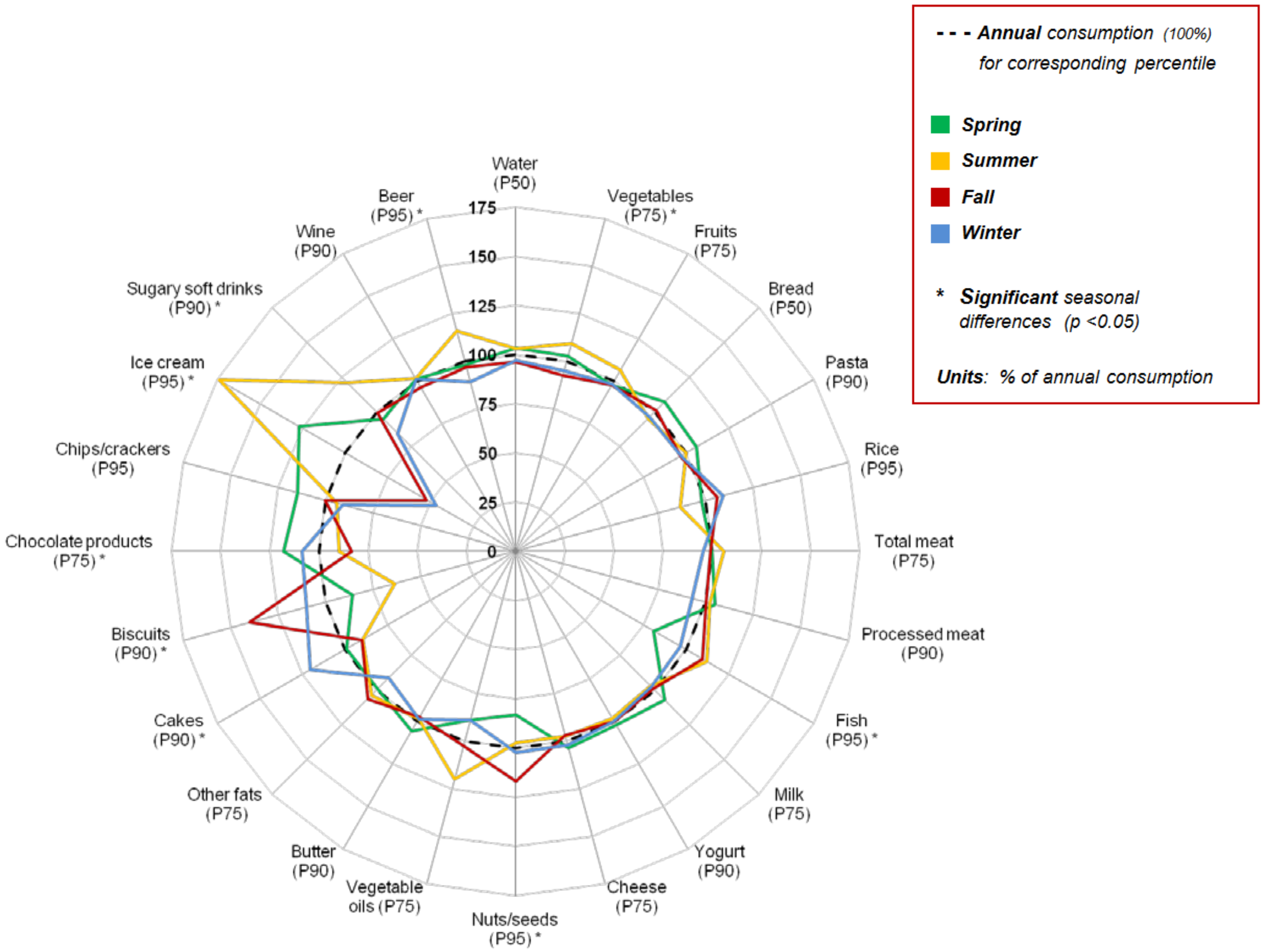


Figure 1. Seasonal variations for 24 food groups. *Seasonal daily intakes are presented in proportion to the annual intakes for the corresponding percentile (100%). Percentiles were adjusted for sex, age, weekdays, BMI, linguistic regions, smoking, education, household size and income. Relevant adjusted P50 to P95 have been chosen according to data distribution as most foods were not consumed by everyone in the two recorded days.*

I also collaborated with the statistician who established the weighting strategy. I conducted literature research and proposed a methodology to weight 24HDR by weekdays and seasons.

menuCH weighting strategy:

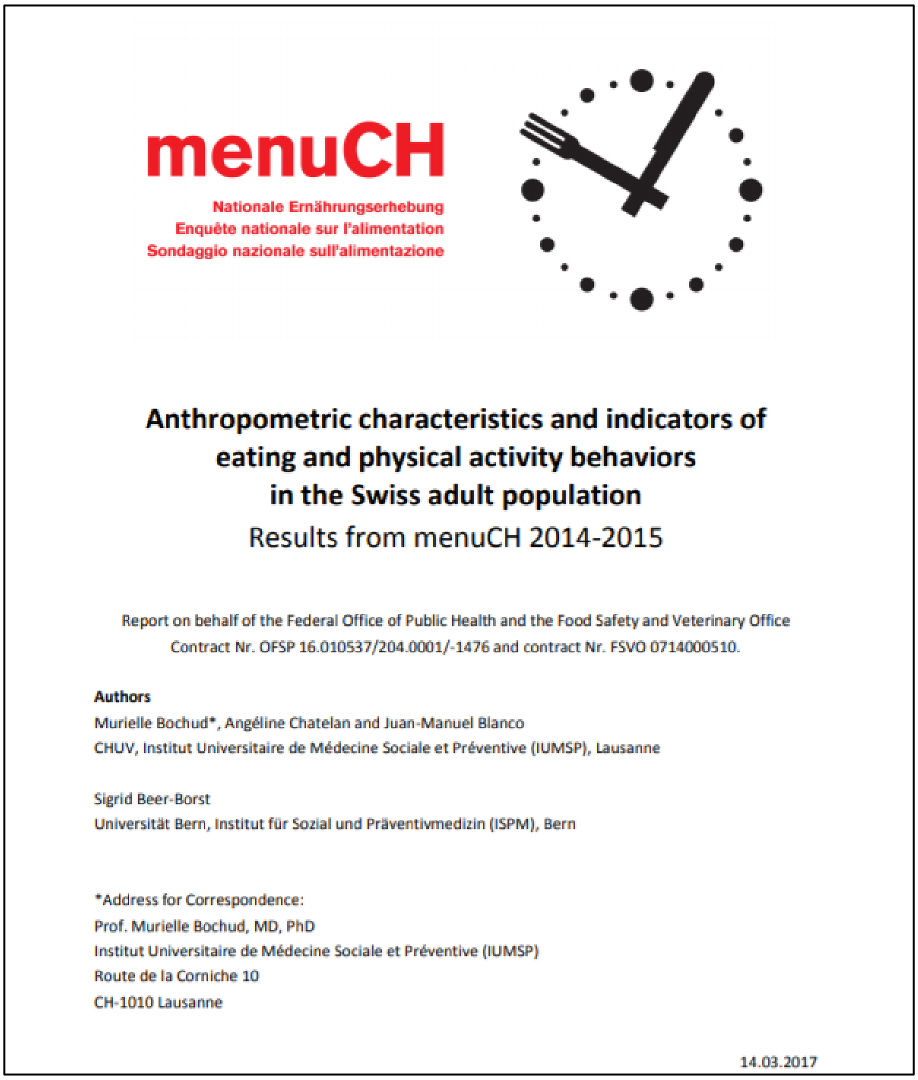
Pasquier J, Chatelan A, Bochud M (2017) Weighting strategy. Documentation on behalf of the Food Safety and Veterinary Office. Published online 12.04.2017. Available from: https://menuch.iumsp.ch/index.php/catalog/4

9.3. Report presenting menuCH results to the public

The 80-page report by Bochud et al. (**Figure 2**) presents menuCH main results in terms of anthropometry, eating and physical activity behaviours. My role in this report was to prepare data for a few analyses and proofread the report.

Public report:

Bochud M, Chatelan A, Blanco JM, Beer-Borst S (2017) Anthropometric characteristics and indicators of eating and physical activity behaviours in the Swiss adult population. Results from menuCH 2014-2015. Report on behalf of the Federal Office of Public Health and the Food Safety and Veterinary Office. Published online 16.03.2017. Available from: https://www.blv.admin.ch/blv/de/home/lebensmittel-und-ernaehrung/ernaehrung/menuch/menu-ch-ergebnisse-essverhalten.html



menuCH

Nationale Ernährungserhebung
Enquête nationale sur l'alimentation
Sondaggio nazionale sull'alimentazione

Anthropometric characteristics and indicators of eating and physical activity behaviors in the Swiss adult population

Results from menuCH 2014-2015

Report on behalf of the Federal Office of Public Health and the Food Safety and Veterinary Office
Contract Nr. OFSP 16.010537/204.0001/-1476 and contract Nr. FSVO 0714000510.

Authors
Murielle Bochud*, Angéline Chatelan and Juan-Manuel Blanco
CHUV, Institut Universitaire de Médecine Sociale et Préventive (IUMSP), Lausanne

Sigrid Beer-Borst
Universität Bern, Institut für Sozial und Präventivmedizin (ISPM), Bern

*Address for Correspondence:
Prof. Murielle Bochud, MD, PhD
Institut Universitaire de Médecine Sociale et Préventive (IUMSP)
Route de la Corniche 10
CH-1010 Lausanne

14.03.2017

Figure 2. Report on menuCH main results by Bochud et al.

Abstract

The prevalence of overweight and obesity was 41.6% and 13.9% in men, 19.7% and 11.3% in women, respectively. A considerable proportion (almost half) of the respondents indicated that they took vitamin or mineral supplements. Cooking habits were different according to age groups. Older people (65 to 75 age group) cooked at noon whereas the younger generation (18 to 49 year olds) rather at night. More than 70% of survey participants reported having lunch out of home. The majority of the population (>80%) takes a snack at least once per day. The majority of the population (87.0%) reported being trained, regularly physically active or irregularly active, thereby meeting current recommendations.

9.4. menuCH data dissemination

I worked on the establishment of a menuCH data repository, in collaboration with the our internal unit for Public Health Documentation and Data Management, and with the Federal Food Safety and Veterinary Office. I established metadata (including codebook of 6 datasets and 354 variables) for the survey open access data repository (**Figure 3**).

menuCH data repository:

menuCH Data Repository. An online microdata library. Available from: https://menuch.iumsp.ch

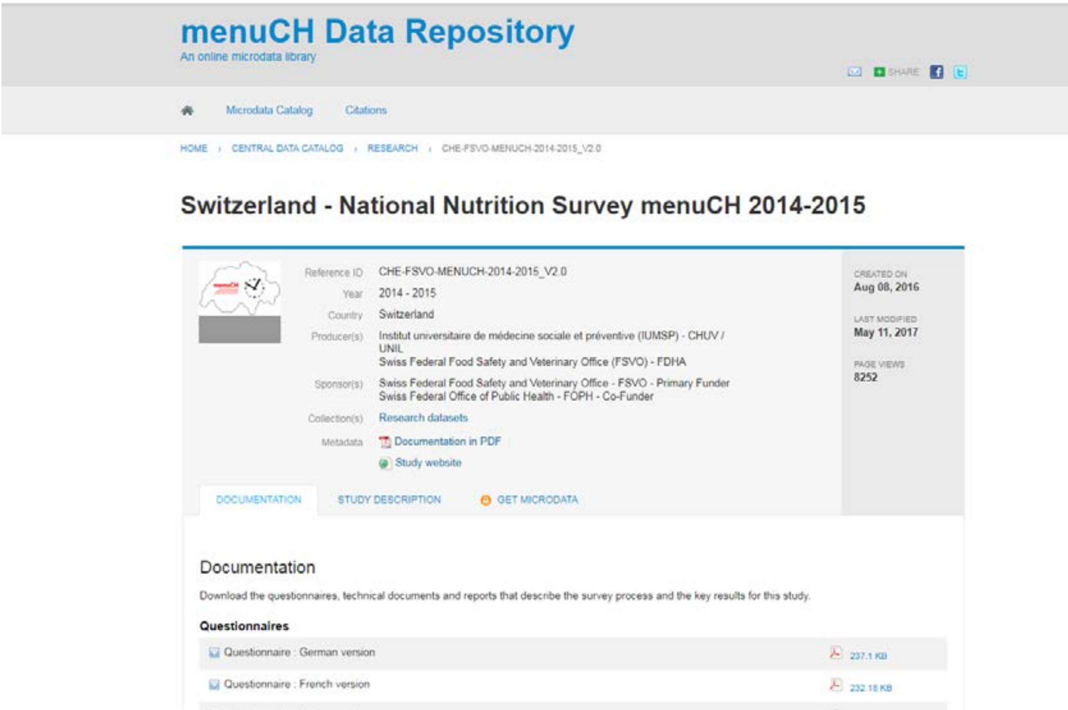


Figure 3. Print screen of the online Data Repository.

9.5. Sugar intake in the Swiss population

I was asked by World Health Organization-Europe to co-write a manuscript about total, added and free sugar consumption in Switzerland. For this project, I defined the methodology (*e.g.*, definition and calculation of total, added and free sugars), conducted statistical analyses, and drafted sections of the manuscript.

Drafted manuscript:

Chatelan A, Jewell J, Gaillard P, Kruseman M, Keller A. Total, added and free sugar consumption in Switzerland: Results from the First National Nutrition Survey menuCH.

Abstract

World Health Organization (WHO) recommends reducing free sugars to less than 10% of total energy intake (TEI) due to their potential implications in weight gain and dental caries. The objective of this manuscript was to 1) estimate the intake of total, added and free sugars, 2) define their main food group sources (30 food groups), and 3) assess adherence to WHO guidelines in the Swiss adult population. All non-institutional persons aged 18-75 years from the first Swiss national nutrition survey 2014-2015 were studied. Diet was assessed with two non-consecutive 24-hour dietary recalls. Added and free sugar content in food was systematically estimated by two dietitians using available information from manufacturer and/or standard recipe/composition. Usual daily intake distributions were modelled and weighted for sampling design, non-response, weekdays and seasons. Total, added and free sugar intake was respectively 107g, 53g and 65g, representing 19%, 9%, and 11% of TEI. Sugar consumption was higher among younger adults and lower among people living in the Italian-speaking region. The 3 main food sources of free sugars were 1) sweets (47% of total free sugars), in particular sweet spreads (15%) and cakes/cookies (11%), 2) non-alcoholic beverages (29%), mainly fruit and vegetable juices (13%), and sugar-sweetened beverages (12%), and 3) dairy (9%), with yoghurt accounting for 7%. Respectively, 44% of women and 45% of men had free sugar intake below 10% of TEI. There were 36%, 45%, and 53% of people aged 18-29, 30-64, 65-75 years with free sugar intake below 10% of TEI. The prevalence of Swiss people with free sugar intake <5% of TEI was 8%. Adherence to WHO free sugar guidelines was generally low in Switzerland, particularly among young adults. These findings are in agreement with the few published data from other western European countries.

9.6. 2017-2024 Swiss Nutrition Policy

Within the context of Health 2020, the 2017-2024 Swiss Nutrition Policy is intended to make an important contribution to the national policy for preventing non-communicable diseases (NDC, 2017-2024 NCD Policy). As an academic institution with nutrition expertise, our institute was consulted for the elaboration of the 2017-2024 National Nutrition Policy and its related Action Plan, with other parties, including food industry.

I took part in a workshop organized in September 2017 to discuss the proposed Action Plan. I suggested public health measures to improve dietary intake and nutritional status of the Swiss population and in particular commented the actions related to national nutrition monitoring and research. On June 5 2018, the Federal Food Safety and Veterinary Office invited academics for the launching of the 2017-2024 Swiss Nutrition Action Plan (**Figure 4**), where the strategy and related public health actions and measures were presented.

Inputs given for:

Federal Food Safety and Veterinary Office (FSVO), Stratégie suisse de nutrition 2017-2024 (Swiss Nutrition Policy 2017-2024). 2017, FSVO: Bern, Switzerland

Federal Food Safety and Veterinary Office (FSVO), Plan d'action de la Stratégie suisse de sutrition 2017-2024 (Action Plan of the Swiss Nutrition Policy 2017-2024). 2018, FSVO: Bern, Switzerland.

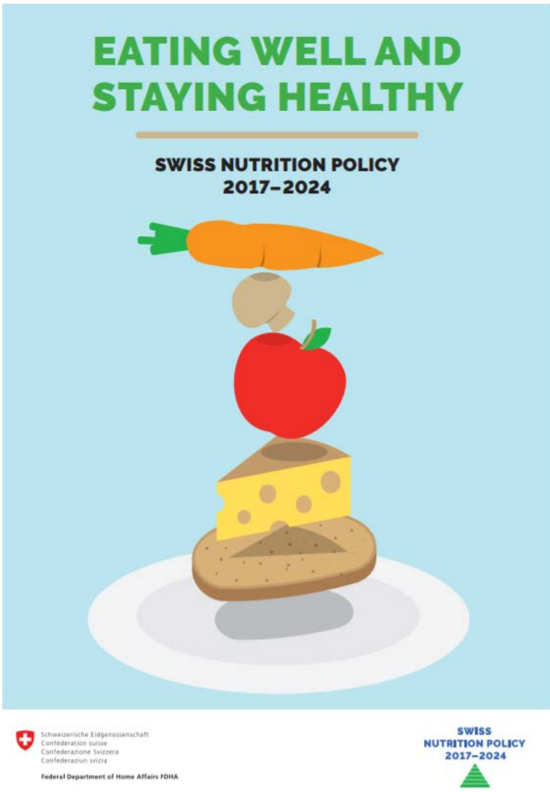


Figure 4. Cover of the 2017-2024 Swiss Nutrition Policy.

10. Discussion

The research work conducted as part of this thesis allows gaining more insight into dietary intake and nutritional status of the Swiss population thanks to the first national nutrition survey, menuCH. The thesis also provides recommendations for future national nutrition-related research and policies. This second point will be further discussed in Chapters 10.3 and 10.4.

10.1. Summary of results

In **Chapter 3**, we showed that conducting the menuCH survey pilot among 276 adults presented significant challenges, notably due to the different languages. The pilot study highlighted the importance of training dietitians and performing quality controls as fundamental prerequisites to reliably collect data in the main study. Additionally, the pilot study showed that more resources were needed to increase participation rate and to clean the data collected with the 24-hour dietary recalls (24HDR).

Chapter 4 summarized the public results of the menuCH main study among 2 086 adults residing in Switzerland. The results indicated that overall the population sample poorly complied with the national food-based dietary guidelines, *i.e.,* the Swiss Food Pyramid. The average diet was insufficient in plant-based products (*e.g.*, fruit and vegetables, nuts, vegetable oils) and too rich in ultra-processed and/or animal-based foods (*e.g.*, soft drinks, meat). **Chapter 5** described for the first time the menuCH methodology and data to the research community. It also showed that food consumption patterns substantially differed between the German-, French- and Italian-speaking parts of Switzerland for 18 out of 31 food groups. However, adherence to the dietary guidelines was uniformly low across the three linguistic regions. Both Chapters 4 and 5 highlighted that there is a need to improve dietary behaviours in the country.

Exploiting the same menuCH data, we showed in **Chapter 6** that regularly consuming a 'prudent' breakfast, rich in fruit, unprocessed and unsweetened cereal flakes, nuts/seeds and yogurt, was associated with reduced abdominal obesity (-1 cm in waist circumference). We also demonstrated that the association was partly explained by a healthier diet during the rest of the day. Understanding the impact of breakfast composition on cardio-metabolic risk factors and suggesting meal-based dietary recommendations might improve dietary intake in the Swiss population.

Chapter 7 showed that examining diet and nutritional status was feasible in a small population-based sample of 53 children and adolescents aged 3 to 17 years. The child-specific dietary assessment tools were well accepted. Compliance to bio-sample collection (*e.g.*, spot urine, venous and capillary blood, and nails) was relatively high in the different age categories.

Including this age group, improving recruitment methods, and using objective nutritional biomarkers in the next national nutrition survey were the main recommendations of the feasibility study.

Although novel digital technologies to collect dietary intake information (*e.g.,* electronic food diary), biomarkers, and 'omics' data are interesting tools for surveillance and epidemiological research (Chapters 1.3.1 and 7), we warned that using these tools to provide large-scale personalized dietary advice might be insufficient to improve population dietary intake (**Chapter 8**). Public health benefits of such type of individual-centred interventions to reduce obesity might be small at the population level. Positive effect on dietary intake could also be unequally distributed in the population, increasing thus socio-economic inequalities in diet and obesity.

10.2. Strengths and limitations of the thesis

The research work conducted during this thesis, in particular the analyses of the first national nutrition survey, has considerably increased the knowledge about dietary intake and eating habits of the Swiss population. Since menuCH was the first national nutrition survey in the country, a lot of preparatory work was needed before delivering results, but a lot of knowledge was gained during this process. For example, expertise was developed regarding:

- Grouping foods reported in 24HDR according to their nutritional value and the Swiss Food Pyramid (Chapters 4 and 5),
- Methods to estimate misreporting (Chapter 5),
- Weighting dietary intake to correct for uneven distribution of 24HDR over seasons and weekdays (Chapter 9.2),
- Modelling usual intake from two 24HDR (Chapters 5 and 6), and
- Disseminating cleaned and secured datasets to researchers via on-line data repository (Chapter 9.4).

The survey menuCH *per se* had several strengths. Recruitment was based on stratified random population-based sampling frame [1] including the seven major areas of Switzerland (Lake Geneva, Midlands, Northwest, Zurich, East, Central, and South). Data collection by trained dietitians, in particular the two non-consecutive 24HDR using GloboDiet®, was of good quality and underreporting was limited. In addition, Swiss data allowed comparison with data collected in other high-income countries in Western Europe and North America, since these countries also used two non-consecutive automated, multiple-pass 24HDR (Chapters 5 and 6).

However, several limitations exist in the currently available data. First, menuCH captured rich information on food consumption and portion sizes thanks to the 24HDR but poorly estimated the consumption probability of episodically consumed foods (*e.g.*, legumes, nuts, fish) due to the lack of a Food Propensity Questionnaire (FPQ) [2]. A FPQ informs about the probability/frequency of consumption for selected foods [2, 3]. It also allows accounting for day-to-day variations (within-person variation) when modelling usual intake with appropriate software [2, 4-7] (Chapters 5 and 6). Statistically speaking, usual intake of a certain food group is estimated using the probability of eating this food group and the usually consumed amounts on consumption days (**Figure 1**) [6, 8]. Having data on both short-term (24HDR) and long-term (FPQ) diet allows thus a better estimation of usual intake at the population level, especially for rarely consumed foods. Above all, this allows better estimation of usual intake at the individual level because the information is based on more than two unique days.

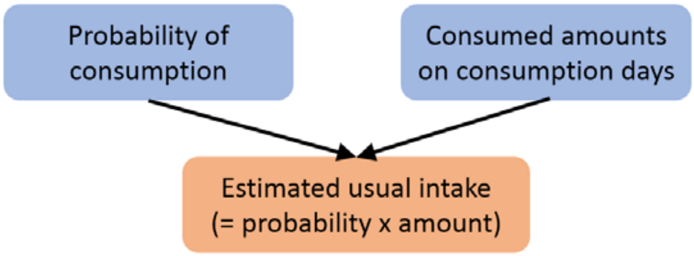


Figure 1. Simplified description of the models used to estimate usual intake.

Second, menuCH did not collect bio-samples. Similarly, there is no information about participants' risk factors (*e.g.*, LDL cholesterol) or health outcomes (*e.g.*, being diabetic), except the measured body mass index. This limits the assessment of the population's nutritional status (Chapter 1.3). Third, menuCH did not survey children and adolescents (Chapter 7). Fourth, participation rate was low: 15% of the original selected sample, or 38% of people with at least one contact with a recruiter. This increases the risk of participation bias (also called non-response bias): *i.e.,* participants are not representative of the targeted population. In menuCH, we found differences in sex, nationality and household composition between participants and non-participants (Chapters 3 and 5). In the absence of detailed information about non-participants' socio-economic conditions, we were unable to document but we highly suspected that vulnerable populations were underrepresented. Vulnerable populations are typically those living in deprived socio-economic areas or in remote rural locations, illiterates, or migrants [9, 10]. These populations are known to have lower response rates in epidemiological research, and are therefore called 'hard-to-reach populations' [9, 10].

Fifth, menuCH is cross-sectional. This study design is appropriate for nutrition monitoring and surveillance (*i.e.,* descriptive epidemiology, Chapter 1.4). Nevertheless, cross-sectional data are less relevant for analytical epidemiology, which tries to identify the most protective dietary patterns and foods (exposure) for health (outcome). In this context, ascertaining the temporal order of exposure (first) and outcome (second) is essential for causal inference.

10.3. Implications for further research

The goal for the next national nutrition surveys would be the regular monitoring of dietary intake and nutritional status of the entire Swiss population, with improved precision and accuracy at both individual and population levels, and in a cost-effective manner. In response to the limitations of the first national nutrition survey mentioned above, I have nine suggestions for Switzerland:

1. To include children and adolescents aged 5 to 17 years,
2. To improve recruitment methods,
3. To reduce burden on participants for data collection,
4. To assess long-term food and nutrient intake at the individual level with more precision and accuracy,
5. To use objective nutritional biomarkers,
6. To apply a longitudinal design,
7. To collect information about health outcomes, potentially via linkage with routinely collected data,
8. To use 'omics' data, and
9. To use novel technological developments, including smartphone applications (if validated and adapted to the Swiss context).

I discuss each suggestion below. In the feasibility study (Chapter 7), we stated that stratified random sampling from the population registry would be the preferred recruitment method. For the next national nutrition survey, we could randomly select one adult and one child in sampled households with children using the same national sampling frame for person and household surveys [22] as in menuCH.

In menuCH (Chapters 3 and 5) and the feasibility study (Chapter 7), we showed that invitation letters only were insufficient to reach a high participation rate. Enhanced recruitment procedures, such as improved access to personal phone numbers or emails, sending several reminders by post may help increase this rate. Mass campaign promoting the survey might encourage selected households/subjects to take part in the survey. Novel recruitment strategies could include recruitment via pharmacists, primary care physicians, opticians, public events, *etc*. In order to reach populations with usually low response rates, study documents could be translated into selected foreign languages. Complementary recruitment methods, *e.g.*, using non-probability sampling, could also be necessary, such as working with people or associations from the targeted communities, or with social media (snowballing) [9, 10].

Despite reinforced recruitment, a participant rate exceeding 30 to 40% of the original sample in a national nutrition survey with a visit at a study centre is highly improbable in Switzerland. This assumption is demonstrated by the example of the 2017 Swiss Health Survey, which was only by phone and used two reminders sent by post. It reached a 51% response rate [11]. This rate has continuously declined: 54% in 2012 [12], and 62% in 2007 [13]. In 2008, a systematic review also showed that academic social studies using questionnaire (not personal visit) reached an average response rate of 52.7% (± 20.4%) [14]. To increase participation rate and reduce non-response bias due to high burden on survey participants, I suggest having a survey with two distinct protocols:

1. A ‘light’ protocol aiming at reducing burden on participants (higher representativeness of the targeted population) to the detriment of accuracy and precision in data collection, and
2. An ‘intensive’ protocol focusing on more accurate and precise measurements to the detriment of population representativeness (**Figure 2**).

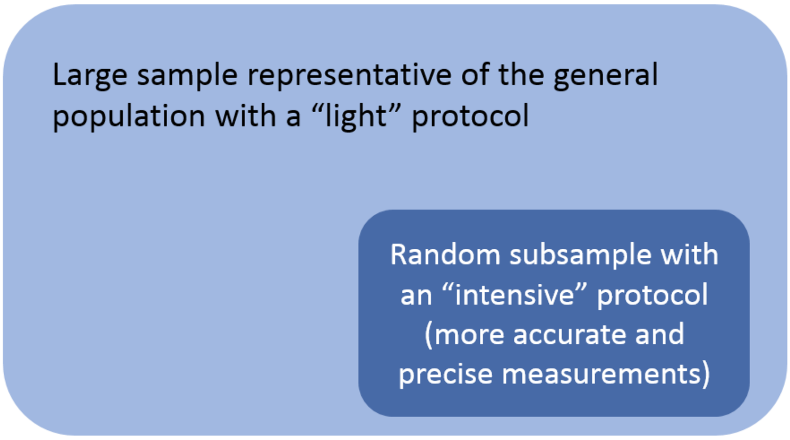


Figure 2. ‘Mixed’ survey protocol aiming at reducing non-response bias (‘light’ protocol in the large sample, light blue) and maximising accuracy and precision (‘intensive’ protocol in a subsample, dark blue).

In practice, the ‘light’ survey protocol could be implemented as follows. All survey participants could complete a short FPQ, on-line or by phone. A complementary method would be using several 24-hour food lists. The latter are intended to rapidly identify foods and beverages consumed the day before without information on portion sizes using binary questions [15, 16]: ‘Have you eaten bread yesterday? Yes / No’. Repeated 24-hour food lists allow predicting the probability of consumption [15]. Consumption probability or frequency seems to contribute more to the variation in food and nutrient intake between persons than the variation in portion sizes [17]. 24-hour food lists are also less time-consuming than traditional 24HDR. For example, Freese *et al*. reported that the median duration to complete the list of 246 items was 9 minutes in the pre-test phase of the German National Cohort [15]. For information, the main phase of this study intends to include 200 000 people aged 20-69 years all over Germany [18]. In addition, 24-hour food lists can be completed on-line, using a computer or smart-phone application, and without supervision of a dietitian [15], reducing thus costs related to data collection. Knowing that the Federal Statistical Office reported that 90% of the adult population used Internet in 2017 and that users had particularly grown among people above 65 years [19], on-line 24-hour food lists could be a useful tool to include in the next surveys. Finally, existing menuCH data could be used to develop the list of included food items based on commonly consumed foods and foods of specific interest, such as episodically consumed foods.

As for the ‘intensive’ protocol, a random subsample of survey participants aged 5 to 75 years should attend a face-to-face interview in a study centre, if possible while fasting. A nurse would take sport urine collected at home and venous blood. If refused by participants or caregivers for children, the nurse would collect capillary blood instead (Chapter 7). Biomarkers should at least include standard clinical chemistry, vitamin and mineral laboratory analyses. During the same interview, a dietitian would take anthropometric measurements (weight, height, waist and hip circumferences) and conduct a 24HDR. A second or even a third 24HDR could be conducted a few weeks later by phone. The 24HDR would be based on 24-hour food diary for children between 5 to 13 years, completed by or with their caregiver(s) (Chapter 7). **Figure 3** summarizes the suggested ‘light’ and ‘intensive’ protocols for next national nutrition surveys.

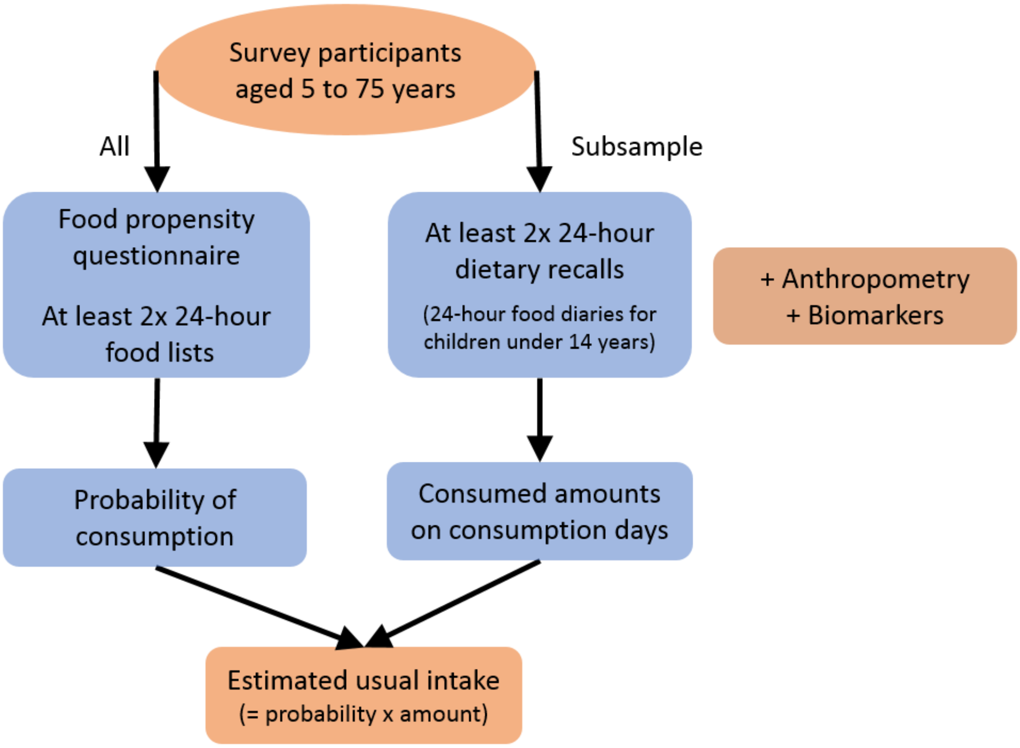


Figure 3. Suggested protocols for the next national nutrition surveys in Switzerland (adapted from [16]). A 'light' protocol for all participants and an 'intensive' protocol for a random subsample.

Cross-sectional design in surveys is often chosen to reduce burden on participants, with the aim of increasing response rate and representativeness of the targeted population. Indeed, participants need to commit only for one time point. Nevertheless, high response rates in nutrition surveys using classical recruitment methods seem more and more difficult in Switzerland, and therefore high representativeness of the general population might be an unachievable goal. Because high response rate is hard to reach despite limited burden on participants (one time point) and because a cross-sectional design limits causal inference, a longitudinal design might be desirable for future national nutrition surveys. This would mean repeated measures on the same participants at regular intervals (*e.g.*, every 5 years). This design would avoid new recruitment for each cross-sectional survey. Both menuCH (Chapter 5) and the feasibility study (Chapter 7) informed that once people accepted to take part in the survey they are likely to finish it. Only 1% of participants (28/2 085) refused to take part in the second phone interview in menuCH, and none in the feasibility study. In addition, repeated 24HDR at defined intervals, instead of only two 24HDR once in life, allow a better estimation of long-term dietary intake at the individual level. A longitudinal design would also be more appropriate to evaluate dietary changes over time (*e.g.*, reduced or increased sugar consumption) than repeated cross-sectional surveys, which may detect dietary changes resulting only from differences in sample characteristics. The risk of observing artificial differences is especially high when participation rates are low and the level representativeness varies between surveys.

If participants are interviewed repeatedly over time, it would be worth also collecting information about their health to enable analyses between long-term dietary behaviours and health outcomes. Yet, this would increase larger costs. To minimize costs, one possibility is the linkage with routinely collected health data. This would necessitates, however, improved operability across data from the different health care systems. Another solution would be to nest a nutrition survey in a larger health research projects. Collaborations with national projects, such as the population-based Swiss Health Study (also called Human Biomonitoring Project) [20], would be an optimal scenario. The pilot study of Swiss Health Study will start in 2019 in 1 000 participants. It aims to reach 100 000 people in the main phase, if the pilot phase is successful, political support obtained and public/private funding secured. As suggested earlier, the whole sample of the Swiss Health Study could complete the ‘light’ protocol, and a subsample could be randomly selected for the ‘intensive’ nutrition protocol. This would allow having access to other health behaviours, outcomes and laboratory analyses. This would also limit resources needed for recruitment, data management and protection, biobanking, and thus limit costs.

If research for nutrition surveillance (surveys with cross-sectional design) is combined research for nutritional epidemiology (cohorts with longitudinal design), integrating ‘omics’ data would be an asset. ‘Omics’ data, already used in precision nutrition, such as nutrigenomics, metabolomics, and microbiomics/metagenomics [21-26] (Chapter 8) are useful to better understand the causal biological pathways between diet and health/disease, and thus better assess the impact of dietary changes on the individual risk of diet-related diseases [24, 26-29].

Advances in wearable devices (*e.g.*, electronic food diary with digital photography, and wristband for accelerometry [23, 24]), dried blood spot testing [21], and bioinformatics and artificial intelligence [24, 27, 30, 31] offer novel opportunities for very large-scale surveillance programs with limited resources. Creating banks of pictures of meals and snacks taken by survey participants with their smart-phone camera, and analysing them with machine-learning and deep learning to extract selected features of interest (*e.g.*, meal context, eating locations) is a promising method, but remains in its infancy [32-34]. For the time being, I discourage applying these novel technologies in the ‘intensive’ protocol as main dietary assessment methods for several reasons, explained in Chapter 7.5. However, they could be implemented in the ‘light’ protocol among adolescents and adults under certain conditions, such as validity, user-friendliness, adaption to the Swiss context (*e.g.*, three main languages). Collaborations with academics specialised in ‘omics’ and digital technologies are needed in these rapidly evolving fields.

Including a few of these nine suggestions will improve future national nutrition surveys in three ways (Chapter 1.4.1, Conceptual framework). First, it will enable better surveillance and monitoring of dietary intake and nutritional status at both individual and population levels, and in sub-strata of the Swiss population, such as children and elderly people. Second, it would at the same time provide more robust evidence for nutritional epidemiology research, taking into account the Swiss socio-economic and cultural context. Third, it will enable to further fine-tune national dietary guidelines and better plan future public health interventions and evaluate their impact.

10.4. Public health perspective

So far, public health interventions implemented to improve population dietary intake have produced limited success in high-income countries [35-42]. People largely fail to follow the dietary guidelines (Chapters 4 and 5, [43-45]) and the prevalences of obesity and type 2 diabetes have not declined [46-48]. In Switzerland, the Swiss Health Survey showed that prevalence of obesity (BMI ≥ 30kg/m^2, based on self-reported weight and height) has continuously been on the rise since 1992, time of the first survey [11]. The prevalence of diabetes (self-reported information) has also increased since 2007 in both men and women [11].

Switzerland has historical precedent for structural/environmental public health interventions (*i.e.,* population approach, see Chapter 8) related to micronutrient deficiency-related diseases. In the 1920s, it was one of the first countries fortifying table salt with iodine to prevent goitre and cretinism [49, 50]. In the prevention of over-nutrition/consumption-related diseases, Switzerland focused in the past mainly on providing information about healthy eating. It used, for instance, mass campaigns to disseminate dietary guidelines and food guides. Switzerland also regulated the maximum level of trans-fat in edible oils and fats of plant origin at 2g per 100g in 2008 [51]. It was the second country changing its regulation in the world, after Denmark [52].

More recently with the 2017–2024 Swiss Nutrition Policy and its Action Plan (Chapter 9.6, [53, 54]), four action areas were defined to improve dietary behaviours of the Swiss population: 1) information and education, 2) framework conditions (i.e., food environments), 3) coordination and cooperation, and 4) monitoring and research [53, 54]. Public health measures recommended in this Action Plan mainly focus on promoting knowledge and skills to choose a balanced diet [53, 54]. While announcing the Action Plan in June 2018, the Federal Food Safety and Veterinary Office (FSVO) also launched a free smart phone application, called MySwissFoodPyramid (www.plandactionnutrition.ch). The application is an electronic three-day food diary with estimated portion size. It allows individuals to compare their dietary intake with recommendations from the Swiss Food Pyramid and learn how to compose balanced, varied and tasty menus. Together with nutrition education, the Action Plan intends to promote a favourable environment 'to autonomously maintain a healthy lifestyle' [53]. It suggests continuing the dialogue with food industry to optimize food composition and reduce marketing of foods rich in sugar, sodium and saturated fat. Actions will be on a voluntary basis and progress partly assessed by food industry itself. The Action Plan does not impose thus any compulsory measures to address the obesogenic food environment [54].

The Action Plan reflects the willingness to address the individual causes of the imbalanced diet and the lack of political will to tackle the population causes by implementing structural/environmental public health measures. As discussed in Chapter 8, individual-centred interventions have several limitations. First, they lack sustainability and efficacy at the population level. Second, dietary advice is difficult to implement without changes in the conditions in which people grow, work, live, and age. Third, individual-centred interventions may increase socio-economic inequalities in diet and health (Chapter 8). In addition, public health interventions targeting individual behaviour change are based on the principle that each individual is presumed to be capable of free lifestyle choices and accountable for choices made for disease prevention [55-57]. This emphasis on personal responsibility may have the undesirable side effect of contributing to blaming individuals who fail to adopt healthful behaviours, and considering them guilty of the subsequent adverse health outcomes, leading to their stigmatization [56, 58, 59]. Holding the individual responsibility for health-related choices is in particular problematic in the case of people with low socio-economic status [56] since they have less control over their health choices and experience more prominent obesogenic environment, as shown in Chapter 8.

In my view, individual-centred measures suggested in the Action Plan should be accompanied with structural/environmental measures and policies at global, national and community levels to transform the current food obesogenic environment and empower individuals to achieve and maintain healthy eating on the long term. Six concrete measures to improve dietary behaviours of the Swiss population are suggested in Table 1. These measures are largely taken by Hawkes *et al*. [60], Mozaffarian *et al*. [61], and the International Network for Food and Obesity / Non-communicable Diseases (NCDs) Research, Monitoring and Action Support [62].

Table 1. Structural/environmental measures to improve dietary behaviours of the Swiss population at national (cantonal) and community levels (inspired by [60-62]).

Level of intervention	Measures	Examples of implementation
National	Triggering or regulating the reformulation of nutritional composition of food products (*e.g.*, sodium and sugar reduction) [63-67]	United Kingdom: Comprehensive intervention on sodium including reformulation of 80 food categories with a clear timeframe for food industry to achieve [68, 69] France: Voluntary commitments by several companies to reduce sodium in breakfast cereals, and sodium and saturated fat in crisps [70].
National	Regulating the marketing of foods and non-alcoholic beverages high in saturated fats, free sugars, or salt to children, as proposed by the World Health Organization [71].	Ireland : Prohibition of advertising, sponsorship, teleshopping and product placement of foods high in fat, sugars and salt during children's TV and radio programmes where over 50% of the audience are under 18 years old [72, 73]. Quebec, Canada: Ban on fast food marketing aimed at children under 13 years in print and electronic media [74, 75].
National	Imposing clear and simple front-of-pack labelling for pre-packed products or in restaurants [76-78]. Despite limited evidence on impact on consumers' dietary intake [79, 80], front-of-pack labelling can drive healthier product development and reformulation by manufacturers [81].	United Kingdom: Statutory traffic light labelling system [82]. France: Recommended 5-colour logo, Nutri-score [83, 84].
National	Taxing unhealthy foods and beverages and subsidizing or providing incentives for substitution with healthier foods [85-87].	United Kingdom, Portugal, Mexico, several states in the United States, and other countries: taxes on sugar-sweetened beverages [40-42]. United States: Financial incentives for fruit and vegetable consumption in low-income households [88].
National (cantonal)	Enforcing nutritional standards for canteens in (public) institutions (*e.g.,* schools, enterprises, medical institutions) [89-91]. The Swiss Quality Standards for health promoting communal catering have already been established [92].	United States and United Kingdom: Compulsory nutritional standards for school meals [38, 39].
National or Community	Regulating food environments in schools (*e.g.,* vending machines) [93, 94] and around schools ([95] not much evidence yet)	Two French-speaking cantons of Switzerland: Cantonal guidance on food supply and price in vending machines in schools [96, 97]. Canadian and British municipalities: Creation of a fast food exclusion zones around schools [98, 99]

The six suggested measures necessitate civil and political commitments. This seems unlikely with the current federal Parliament [100]. However, history has shown that major achievements in public health occurred partly thanks to structural/environmental measures and/or law: *e.g.*, immunizations, motor vehicle safety, improved sanitation, occupational safety, safer foods, fluoridation of drinking water to prevent dental caries, and childhood lead poisoning prevention [101-103]. This means that public health actors need to advocate in favour of interventions to shape the food environments. Civil society and media are useful tools to influence public opinion and therefore politicians elected by the citizens in the governmental and parliamentary councils at cantonal and national levels. The six measures also imply changes in farming, agriculture and food systems [61, 104, 105], which imply changes also at the global level.

10.5. Conclusion

Overall, this thesis showed that diet differs across the three main linguistic regions of Switzerland, but overall is far from optimal, as already documented in many other high-income countries. Structural/environmental public health measures are needed to improve the food environments and enable the Swiss population to achieve and sustain healthier dietary behaviours. In addition, continued and improved nutritional monitoring and surveillance is needed in Switzerland. The next national nutrition surveys should thus include children and adolescents, and use objective biomarker to complement food consumption data (*e.g.*, from 24HDR and FPQ). Next surveys could have a longitudinal design instead of repeated cross-sectional studies, and could be nested in a larger population-based health study. Altogether, this would, on the one hand, improve the assessment of dietary intake and nutritional status at both individual and population levels, which is important not only for *population monitoring and surveillance*, but also for the implementation and the evaluation of public health interventions (*policy-making*). On the other hand, this would also contribute to fostering *nutritional epidemiology research* in Switzerland. A better understanding of the link between dietary behaviours and health outcomes within the Swiss context is indeed important to further fine-tune national dietary guidelines and guide future national policies.

10.6. References

1. Federal Statistical Office. Stichprobenrahmen für Personen- und Haushaltserhebungen (Swiss persons and households registry). [cited 2017 Apr 28]; Available from: https://www.bfs.admin.ch/bfs/de/home/grundlagen/volkszaehlung/volkszaehlung-teil-gesamtsystem/stichprobenrahmen.html.
2. Subar, A.F., et al., The food propensity questionnaire: concept, development, and validation for use as a covariate in a model to estimate usual food intake. J Am Diet Assoc, 2006. 106(10): p. 1556-63.
3. European Food Safety Authority (EFSA), Guidance on the EU Menu methodology. Appendix 5.3.5. Example of a protocol for application of the Food Propensity Questionnaire (FPQ) based on the PANCAKE and the PILOT-PANEU projects. EFSA Journal 2014. 12(12): p. 3944.
4. Souverein, O.W., et al., Comparing four methods to estimate usual intake distributions. Eur J Clin Nutr., 2011. 65 Suppl 1: p. S92-101.
5. Laureano, G.H., et al., Comparison of the ISU, NCI, MSM, and SPADE Methods for Estimating Usual Intake: A Simulation Study of Nutrients Consumed Daily. Nutrients, 2016. 8(3): p. 166.
6. Dekkers, A.L., et al., SPADE, a new statistical program to estimate habitual dietary intake from multiple food sources and dietary supplements. J Nutr, 2014. 144(12): p. 2083-91.
7. Harttig, U., et al., The MSM program: web-based statistics package for estimating usual dietary intake using the Multiple Source Method. Eur J Clin Nutr, 2011. 65 Suppl 1: p. S87-91.
8. Haubrock, J., et al., Estimating usual food intake distributions by using the multiple source method in the EPIC-Potsdam Calibration Study. J Nutr, 2011. 141(5): p. 914-20.
9. Shaghaghi, A., R.S. Bhopal, and A. Sheikh, Approaches to Recruiting 'Hard-To-Reach' Populations into Research: A Review of the Literature. Health Promot Perspect, 2011. 1(2): p. 86-94.
10. Bonevski, B., et al., Reaching the hard-to-reach: a systematic review of strategies for improving health and medical research with socially disadvantaged groups. BMC Med Res Methodol, 2014. 14: p. 42.
11. Federal Statistical Office (FSO), Enquête suisse sur la santé 2017. Vue d'ensemble (Swiss Health Survey 2017. Overview). 2018, FSO: Neuchatel, Switzerland.
12. Federal Statistical Office (FSO), ed. Swiss Health Survey 2012. Overview. 2013, FSO: Neuchatel, Switzerland.
13. Federal Statistical Office (FSO), Swiss Health Survey 2007. First findings. 2008, FSO: Neuchatel, Switzerland.
14. Baruch, Y. and B.C. Holtom, Survey response rate levels and trends in organizational research. Human Relations, 2008. 61(8): p. 1139-1160.

15. Freese, J., et al., Development and evaluation of a short 24-h food list as part of a blended dietary assessment strategy in large-scale cohort studies. Eur J Clin Nutr, 2014. 68(3): p. 324-9.

16. Conrad, J. and U. Nöthlings, Innovative approaches to estimate individual usual dietary intake in large-scale epidemiological studies. Proc Nutr Soc, 2017. 76(3): p. 213-219.

17. Noethlings, U., et al., Portion size adds limited information on variance in food intake of participants in the EPIC-Potsdam study. J Nutr, 2003. 133(2): p. 510-5.

18. German National Cohort Consortium, The German National Cohort: aims, study design and organization. Eur J Epidemiol, 2014. 29(5): p. 371-382.

19. Federal Statistical Office (FSO), Internet use in households 2017. 2017, FSO: Neuchatel, Switzerland.

20. Federal Office of Public Health (FOPH). Human biomonitoring projects in Switzerland. [cited 2018 Nov 15]; Available from: https://www.bag.admin.ch/bag/en/home/gesund-leben/umwelt-und-gesundheit/chemikalien/chemikalien-im-alltag/human-biomonitoring/human-biomonitoring-projekte-in-der-schweiz.html.

21. Kohlmeier, M., et al., Guide and Position of the International Society of Nutrigenetics/Nutrigenomics on Personalized Nutrition: Part 2 - Ethics, Challenges and Endeavors of Precision Nutrition. J Nutrigenet Nutrigenomics, 2016. 9(1): p. 28-46.

22. Ferguson, L.R., et al., Guide and Position of the International Society of Nutrigenetics/Nutrigenomics on Personalised Nutrition: Part 1 - Fields of Precision Nutrition. J Nutrigenet Nutrigenomics, 2016. 9(1): p. 12-27.

23. de Toro-Martin, J., et al., Precision Nutrition: A Review of Personalized Nutritional Approaches for the Prevention and Management of Metabolic Syndrome. Nutrients, 2017. 9(8).

24. Wang, D.D. and F.B. Hu, Precision nutrition for prevention and management of type 2 diabetes. Lancet Diabetes Endocrinol, 2018.

25. Heianza, Y. and L. Qi, Gene-Diet Interaction and Precision Nutrition in Obesity. Int J Mol Sci, 2017. 18(4).

26. Ferguson, J.F., et al., Nutrigenomics, the Microbiome, and Gene-Environment Interactions: New Directions in Cardiovascular Disease Research, Prevention, and Treatment: A Scientific Statement From the American Heart Association. Circ Cardiovasc Genet, 2016. 9(3): p. 291-313.

27. Zeevi, D., et al., Personalized Nutrition by Prediction of Glycemic Responses. Cell, 2015. 163(5): p. 1079-1094.

28. Vazquez-Fresno, R., et al., Metabolomic pattern analysis after Mediterranean diet intervention in a nondiabetic population: a 1- and 3-year follow-up in the PREDIMED study. J Proteome Res, 2015. 14(1): p. 531-40.

29. Esko, T., et al., Metabolomic profiles as reliable biomarkers of dietary composition. Am J Clin Nutr, 2017. 105(3): p. 547-554.

30. Rimbach, G. and A.M. Minihane, Nutrigenetics and personalised nutrition: how far have we progressed and are we likely to get there? Proc Nutr Soc, 2009. 68(2): p. 162-72.

31. Beam, A.L. and I.S. Kohane, Big Data and Machine Learning in Health Care. JAMA, 2018. 319(13): p. 1317-1318.

32. Biel, J.I., et al., Bites'n'Bits: Inferring Eating Behavior from Contextual Mobile Data. Proc. ACM Interact Mob Wearable Ubiquitous Technol, 2017. 1(4): p. Article 125.

33. Martin, C.K., et al., Measuring food intake with digital photography. J Hum Nutr Diet, 2014. 27 Suppl 1: p. 72-81.

34. Christoph, M.J., B.R. Loman, and B. Ellison, Developing a digital photography-based method for dietary analysis in self-serve dining settings. Appetite, 2017. 114: p. 217-225.

35. Food and Agriculture Organization. Food-based dietary guidelines. [cited 2018 Apr 5]; Available from: http://www.fao.org/nutrition/nutrition-education/food-dietary-guidelines/en/.

36. United States Department of Agriculture. 2015-2020 Dietary Guidelines for Americans. [cited 2018 Apr 5]; Available from: https://www.choosemyplate.gov/dietary-guidelines.

37. Public Health England. The Eatwell Guide. [cited 2018 Apr 5]; Available from: https://www.gov.uk/government/publications/the-eatwell-guide.

38. United States Department of Agriculture, Nutrition Standards in the National School Lunch and School Breakfast Programs. 2012: Federal Register, Vol. 77, No. 17.

39. United Kingdom Department of Education, The Requirements for School Food Regulations 2014: No. 1603.

40. Backholer, K., M. Blake, and S. Vandevijvere, Sugar-sweetened beverage taxation: an update on the year that was 2017. Public Health Nutr, 2017. 20(18): p. 3219-3224.

41. Silver, L.D., et al., Changes in prices, sales, consumer spending, and beverage consumption one year after a tax on sugar-sweetened beverages in Berkeley, California, US: A before-and-after study. PLoS Med, 2017. 14(4): p. e1002283.

42. Colchero, M.A., M. Molina, and C.M. Guerrero-Lopez, After Mexico Implemented a Tax, Purchases of Sugar-Sweetened Beverages Decreased and Water Increased: Difference by Place of Residence, Household Composition, and Income Level. J Nutr, 2017. 147(8): p. 1552-1557.

43. Rehm, C.D., et al., Dietary Intake Among US Adults, 1999-2012. JAMA, 2016. 315(23): p. 2542-53.

44. Bates, B., et al., National Diet and Nutrition Survey: Results from Years 1, 2, 3 and 4 (combined) of the Rolling Programme (2008/2009 – 2011/2012). 2014, Public Health England / Food Standard Agency: London, United Kingdom.

45. Diethelm, K., et al., Food intake of European adolescents in the light of different food-based dietary guidelines: results of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) Study. Public Health Nutr, 2012. 15(3): p. 386-98.

46. N. C. D. Risk Factor Collaboration, Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. Lancet, 2017. 390(10113): p. 2627-2642.

47. Hales, C.M., et al., Trends in Obesity and Severe Obesity Prevalence in US Youth and Adults by Sex and Age, 2007-2008 to 2015-2016. JAMA, 2018.

48. N. C. D. Risk Factor Collaboration, Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4.4 million participants. Lancet, 2016. 387(10027): p. 1513-30.

49. Federal Commission for Nutrition (FCN), Iodine supply in Switzerland: Current Status and Recommendations. Expert report of the FCN. 2013, Federal Office of Public Health: Zurich, Switzerland.

50. Nicod, J.-L., Le goitre endémique en Suisse et sa prophylaxie par le sel iodé (Goitre endemic in Switzerland and its prophylaxis by iodized salt). Bull World Health Organ, 1953. 9(2): p. 259-273.

51. Federal Department of Home Affairs (FDHA), Ordonnance sur les huiles et graisses comestibles et leurs dérivés (Ruling on eadible oils and fats). 2014, FDHA: Bern, Switzerland.

52. Stender, S., A. Astrup, and J. Dyerberg, Artificial trans fat in popular foods in 2012 and in 2014: a market basket investigation in six European countries. BMJ Open, 2016. 6(3): p. e010673.

53. Federal Food Safety and Veterinary Office (FSVO), Swiss Nutrition Policy 2017–2024. 2017, FSVO: Bern, Switzerland.

54. Federal Food Safety and Veterinary Office (FSVO), Plan d’action de la Stratégie suisse de nutrition 2017-2024 (Action Plan of the Swiss Nutrition Policy 2017–2024). 2018, FSVO: Bern, Switzerland.

55. Crawford, R., You are dangerous to your health: the ideology and politics of victim blaming. Int J Health Serv, 1977. 7(4): p. 663-80.

56. Minkler, M., Personal responsibility for health? A review of the arguments and the evidence at century's end. Health Educ Behav, 1999. 26(1): p. 121-40.

57. Nordstrom, K., et al., Values at stake: autonomy, responsibility, and trustworthiness in relation to genetic testing and personalized nutrition advice. Genes Nutr, 2013. 8(4): p. 365-72.

58. Nettleton, S. and R. Bunton, Sociological critiques of health promotion. In: The Sociology of Health Promotion: Critical Analyses of Consumption, Lifestyle and Risk, R. Bunton, S. Nettleton, and R. Burrows, ed. 1995, Routledge: London, United Kingdom.

59. Puhl, R.M. and C.A. Heuer, Obesity stigma: important considerations for public health. Am J Public Health, 2010. 100(6): p. 1019-28.

60. Hawkes, C., et al., Smart food policies for obesity prevention. Lancet, 2015. 385(9985): p. 2410-2421.

61. Mozaffarian, D., et al., Role of government policy in nutrition-barriers to and opportunities for healthier eating. BMJ, 2018. 361: p. k2426.

62. International Network for Food and Obesity / Non-communicable Diseases (NCDs) Research, Monitoring and Action Support. Benchmarking food environments. [cited 2018 Nov 18]; Available from: https://www.informas.org/.

63. Hyseni, L., et al., Systematic review of dietary salt reduction policies: Evidence for an effectiveness hierarchy? PLoS One, 2017. 12(5): p. e0177535.

64. Hyseni, L., et al., Systematic review of dietary trans-fat reduction interventions. Bull World Health Organ, 2017. 95(12): p. 821-830G.

65. McLaren, L., et al., Population-level interventions in government jurisdictions for dietary sodium reduction. Cochrane Database Syst Rev, 2016. 9: p. CD010166.

66. Basto-Abreu, A., et al., Expected changes in obesity after reformulation to reduce added sugars in beverages: A modeling study. PLoS Med, 2018. 15(10): p. e1002664.

67. Jaenke, R., et al., Consumer acceptance of reformulated food products: A systematic review and meta-analysis of salt-reduced foods. Crit Rev Food Sci Nutr, 2017. 57(16): p. 3357-3372.

68. He, F.J., S. Pombo-Rodrigues, and G.A. MacGregor, Salt reduction in England from 2003 to 2011: its relationship to blood pressure, stroke and ischaemic heart disease mortality. BMJ Open, 2014. 4(4).

69. He, F.J., H.C. Brinsden, and G.A. MacGregor, Salt reduction in the United Kingdom: a successful experiment in public health. J Hum Hypertens, 2014. 28(6): p. 345-52.

70. Spiteri, M. and L.-G. Soler, Food reformulation and nutritional quality of food consumption: an analysis based on households panel data in France. Eur J Clin Nutr, 2018. 72(2): p. 228-235.

71. World Health Organization (WHO), Set of recommendations on the marketing of foods and non-alcoholic beverages to children. 2010, WHO: Geneva, Switzerland.

72. Scully, P., et al., Food and beverage advertising during children’s television programming. Ir J Med Sci, 2015. 184(1): p. 207-212.

73. Tatlow-Golden, M., et al., Creating good feelings about unhealthy food: children's televised 'advertised diet' on the island of Ireland, in a climate of regulation. Ir J Psychol, 2015. 36(1-4): p. 83-100.

74. Potvin Kent, M., L. Dubois, and A. Wanless, A nutritional comparison of foods and beverages marketed to children in two advertising policy environments. Obesity (Silver Spring), 2012. 20(9): p. 1829-37.

75. Dhar, T. and K. Baylis, Fast-Food Consumption and the Ban on Advertising Targeting Children: The Quebec Experience. J Mark Res, 2011. 48(5): p. 799-813.

76. Campos, S., J. Doxey, and D. Hammond, Nutrition labels on pre-packaged foods: a systematic review. Public Health Nutr, 2011. 14(8): p. 1496-506.

77. Crockett, R.A., et al., Nutritional labelling for healthier food or non-alcoholic drink purchasing and consumption. Cochrane Database Syst Rev, 2018. 2: p. CD009315.

78. Krieger, J.W., et al., Menu labeling regulations and calories purchased at chain restaurants. Am J Prev Med, 2013. 44(6): p. 595-604.

79. Storcksdieck Genannt Bonsmann, S. and J.M. Wills, Nutrition Labeling to Prevent Obesity: Reviewing the Evidence from Europe. Curr Obes Rep, 2012. 1(3): p. 134-140.

80. Elbel, B., et al., Calorie labeling, fast food purchasing and restaurant visits. Obesity (Silver Spring), 2013. 21(11): p. 2172-9.

81. Vyth, E.L., et al., Front-of-pack nutrition label stimulates healthier product development: a quantitative analysis. Int J Behav Nutr Phys Act, 2010. 7: p. 65.

82. Food Standards Agency (FSA), Guide to creating a front of pack (FoP) nutrition label for pre-packed products sold through retail outlets. 2013, FSA: London, United Kingdom.

83. Julia, C., et al., Perception of different formats of front-of-pack nutrition labels according to sociodemographic, lifestyle and dietary factors in a French population: cross-sectional study among the NutriNet-Sante cohort participants. BMJ Open, 2017. 7(6): p. e016108.

84. Public Health France (PHF), Usage regulation for the "nutri-score" logo. 2018, PHF: Saint-Maurice, France.

85. Powell, L.M., et al., Assessing the potential effectiveness of food and beverage taxes and subsidies for improving public health: a systematic review of prices, demand and body weight outcomes. Obes Rev, 2013. 14(2): p. 110-28.

86. Thow, A.M., et al., Fiscal policy to improve diets and prevent noncommunicable diseases: from recommendations to action. Bull World Health Organ, 2018. 96(3): p. 201-210.

87. World Health Organization (WHO), Fiscal policies for diet and the prevention of noncommunicable diseases - Technical meeting report. 5-6 May 2015. 2016, WHO: Geneva, Switzerland.

88. Olsho, L.E., et al., Financial incentives increase fruit and vegetable intake among Supplemental Nutrition Assistance Program participants: a randomized controlled trial of the USDA Healthy Incentives Pilot. Am J Clin Nutr, 2016. 104(2): p. 423-35.

89. Raulio, S., E. Roos, and R. Prattala, School and workplace meals promote healthy food habits. Public Health Nutr, 2010. 13(6A): p. 987-92.

90. Wojcicki, J.M. and M.B. Heyman, Healthier choices and increased participation in a middle school lunch program: effects of nutrition policy changes in San Francisco. Am J Public Health, 2006. 96(9): p. 1542-7.

91. Lucas, P.J., et al., Preschool and School Meal Policies: An Overview of What We Know about Regulation, Implementation, and Impact on Diet in the UK, Sweden, and Australia. Nutrients, 2017. 9(7).

92. Federal Food Safety and Veterinary Office (FSVO), Standards de qualité suisses pour une restauration collective promouvant la santé (Swiss nutritional standards for communal catering). 2017, FSVO: Bern, Switzerland.

93. Grech, A. and M. Allman-Farinelli, A systematic literature review of nutrition interventions in vending machines that encourage consumers to make healthier choices. Obes Rev, 2015. 16(12): p. 1030-41.

94. Capacci, S., M. Mazzocchi, and B. Shankar, Breaking Habits: The Effect of the French Vending Machine Ban on School Snacking and Sugar Intakes. J Policy Anal Manage, 2017. 37(1): p. 88-111.

95. Ashe, M., et al., Land use planning and the control of alcohol, tobacco, firearms, and fast food restaurants. Am J Public Health, 2003. 93(9): p. 1404-8.

96. Département de la santé et de l'action sociale, Directive sur les distributeurs automatiques de boissons et d'aliments (Guidance on vending machines). 2015: Lausanne, Switzerland.

97. Maradan, N., Le parlement fribourgeois bannit le sucre des écoles (The parliament in Fribourg banishes sugar in schools), in La Liberté. Feb 7 2018.

98. Nykiforuk, C.I.J., et al., Adoption and diffusion of zoning bylaws banning fast food drive-through services across Canadian municipalities. BMC Public Health, 2018. 18(1): p. 137.

99. Dudley fast food exclusion zones around schools, in BBC News. Sep 13 2013.

100. Boschetti, P. and P. Mach, Attention, ce parlement peut nuire à votre santé (Warning, this Parliament can be dangerous for your health), in RTS (Swiss State Television). Sep 6 2018.

101. Centers for Disease Control and Prevention (CDC), Ten Great Public Health Achievements --- United States, 2001--2010. JAMA, 2011. 306(1).

102. Centers for Disease, C. and Prevention, Ten great public health achievements--United States, 1900-1999. MMWR Morb Mortal Wkly Rep, 1999. 48(12): p. 241-3.

103. Burris, S., et al., Better Health Faster: The 5 Essential Public Health Law Services. Public Health Rep, 2016. 131(6): p. 747-753.

104. Mozaffarian, D., I. Rosenberg, and R. Uauy, History of modern nutrition science-implications for current research, dietary guidelines, and food policy. BMJ, 2018. 361: p. k2392.

105. Stuckler, D. and M. Nestle, Big food, food systems, and global health. PLoS Med, 2012. 9(6): p. e1001242.

11. Appendices

11.1. List of publications

List of peer-reviewed publications included in this thesis:

Publications	Contributions	Status
Chatelan A, Marques-Vidal P, Bucher S, Siegenthaler S, Metzger N, Zuberbuehler C, Camenzind-Frey E, Renggli A, Bochud M, Beer-Borst S. Lessons learnt about conducting a multilingual nutrition survey in Switzerland: results from menuCH pilot survey. Int J Vitam Nutr Res. 2018 Apr 20:1-12.	(*field work before the thesis*) Conducted data analyses Drafted the manuscript Approved the final version	Published
Chatelan A, Beer-Borst S, Randriamiharisoa A, Pasquier J, Blanco JM, Siegenthaler S, Paccaud F, Slimani N, Nicolas G, Camenzind-Frey E, Zuberbuehler CA, Bochud M. Major Differences in Diet across Three Linguistic Regions of Switzerland: Results from the First National Nutrition Survey menuCH. Nutrients. 2017 Oct 25;9(11).	(*field work before the thesis*) Defined the food grouping Conducted part of data analyses Drafted the manuscript Approved the final version	Published
Chatelan A, Castetbon K, Pasquier J, Allemann C, Zuber A, Camenzind-Frey E, Zuberbuehler CA, Bochud, M. Breakfast dietary patterns and abdominal obesity in the Swiss adult population. Int J Behav Nutr Phys Act. 2018 (in press).	Conceived the manuscript Defined the methodology Conducted data analyses Approved the final version	Published
Chatelan A, Bochud M, Frohlich KL. Precision nutrition: Hype or hope for public health interventions to reduce obesity?	Conceived the manuscript Approved the final version	Accepted in Int J Epidemiol

List of report/webpage included in this thesis:

Publications	Contributions	Status
Chatelan A, Bochud, M. (2018). Lessons learnt about a feasibility study among children and adolescents aged 3 to 17 years to prepare the next national nutrition survey.	Conceived the study design and protocol Collected data Trained staff to collect data Cleaned data Conducted data analyses Conceived the report	Internal report for FSVO (under review)
Federal Food Safety and Veterinary Office (2017) Food consumption. Results from menuCH 2014-2015. Published online 16.03.2017. Available from: https://www.blv.admin.ch/blv/fr/home/lebensmittel-und-ernaehrung/ernaehrung/menuch/menu-ch-ergebnisse-ernaehrung.html	Defined the food grouping Conducted part of data analyses	Published webpage

List of peer-reviewed publications outside this thesis:

Publications	Contributions	Status
Chatelan A, Jewell J, Gaillard P, Kruseman M, Keller A. Total, added and free sugar consumption in Switzerland: Results from the First National Nutrition Survey menuCH.	Defined the methodology Conducted data analyses Drafted sections of the manuscript	Drafted
Chatelan A, Khalatbari-Soltani S, Frohlich KL. Public health in the era of precision medicine: from health promotion back to disease prevention. (*viewpoint*)	Conceived the manuscript	Drafted
Leyvraz M, Taffé P, **Chatelan A,** Paradis G, Tabin R, Bovet P, Bochud M, Chiolero A. Sodium intake and blood pressure in children and adolescents: protocol for a systematic review and meta-analysis. BMJ Open. 2016 Sep 21;6(9).	Critically reviewed the manuscript Approved the final version	Published
Leyvraz M, **Chatelan A**, Da Costa BR, Taffé P, Paradis G, Bovet P, Bochud M, Chiolero A. Sodium intake and blood pressure in children and adolescents: A systematic review and meta-analysis of experimental and observational studies. Int J Epidemiol. 2018 (in press).	Selected the studies, extracted the data, and assessed their quality Critically reviewed the manuscript Approved the final version	Published
Leyvraz M, Bloetzer C, **Chatelan A**, Bochud M, Burnier M, Santschi V, Paradis G, Tabin R, Bovet P, Chiolero A. Sodium intake and blood pressure in children with clinical conditions: A systematic review with meta-analysis. JCH. 2018 (in press).	Selected the studies based on abstract Critically reviewed the manuscript Approved the final version	Published
Religi A, Backes C, **Chatelan A**, Bulliard JL, Vuilleumier L, Moccozet L, Bochud M, Vernez D. Estimation of an optimal UV exposure balance between vitamin D and skin damage in Switzerland.	Calculated vitamin D intake using menuCH Drafted sections of the manuscript Critically reviewed the manuscript	Under review in J Expo Sci Environ Epidemiol.
de Mestral C*, **Chatelan A***, Stringhini S, Bochud M. The contribution of diet quality to socio-economic inequalities in obesity markers in the Swiss population.	Conducted part of data analyses Will critically review the manuscript	Drafted
Belle F, **Chatelan A**, Kasteler R, Guessous I, Beck Popovic M, Ansari M, Kuehni C, Bochud M. Dietary intake of Swiss adult survivors of childhood cancer compared to the general population.	Helped with menuCH data analyses Critically reviewed the manuscript	Drafted
Rochat C*, **Chatelan A***, Eap CB, Bochud, M. Caffeine consumption in Switzerland.	Conducted data analyses Will draft part of the manuscript	In preparation

Report outside this thesis:

Publications	Contributions	Status
Bochud M, **Chatelan A**, Blanco JM, Beer-Borst S (2017) Anthropometric characteristics and indicators of eating and physical activity behaviours in the Swiss adult population. Results from menuCH 2014-2015. Report on behalf of the Federal Office of Public Health and the Food Safety and Veterinary Office.	Cleaned data Helped with data analyses Critically reviewed the report	Published

11.2. List of awards and grants

1. Best abstracts at the Swiss Public Health Conference, Swiss School of Public Health, 2017, Basel, Switzerland (300 CHF): *Major differences in diet across three linguistic regions of Switzerland: results from the first nutrition survey menuCH*.

2. Prix de la Fondation de médecine sociale et préventive, 2018 (3 000 CHF), awarded for all the work related to the published article: *Major differences in diet across three linguistic regions of Switzerland: results from the first nutrition survey menuCH*.

3. Grant from the Fondation de l'Université de Lausanne to attend a two-month doctoral seminar on Health Promotion in the University of Montreal, and write the article: Precision nutrition: Hype or hope for public health interventions to reduce obesity?

11.3. List of courses and attended seminars/conferences

The 12 ECTS credits needed for a PhD thesis in Life Sciences in the University of Lausanne have been completed. In addition, I have passed the 25 ECTS credits required for the PhD program in Public Health from the Swiss School of Public Health ($SSPH^+$). I attend other events for personal interest.

Field	Course Name	Institution	Dates	ECTS
Courses in Epidemiology	International Summer School in nutritional epidemiology	German Institute of Human Nutrition (DIfE) - Potsdam (Germany)	August 8-19 2016	6
	Causal Inference in Observational Epidemiology	Swiss Epidemiology Winter School - Wengen	January 19-21 2017	1.5
	Systematic Reviews and Meta-Analysis: a Practical Approach	$SSPH^+$ - Bern	May 10-12 2017	1
	Assessing bias in randomized and non-randomized studies: new approaches, new tools	Swiss Epidemiology Winter School - Wengen	January 21-23 2019	1
Courses in Biostatistics	Linear multiple regression	UNIL - Lausanne	5x 3h-courses March 2016	1
	Survival analysis [in French]	UNIL - Lausanne	3x 3h-courses April 2016	1
	Multilevel Modeling: Analysis of Clustered Data	$SSPH^+$ - Basel	October 17-19 2016	1
	Logistic regression [in French]	IUMSP - Lausanne	June 27-29 2018	0
	Statistical analysis with missing data using multiple imputation and inverse probability weighting	Swiss Epidemiology Winter School - Wengen	January 24-26 2019	1
Courses in Social and Behavioural Sciences	Social science in public health	$SSPH^+$ - Bern	October 3-7 2017	2
	How (should) we research policy that saves lives? Approaching the war on smoking	University of Lucerne	March 31 2017	1
	Understanding Health Inequalities in Modern Societies: From Contemplation to Implementation	Spring School of Global Health - Geneva	April 26-28 2017	1
Courses in health systems research	Health financing policies, health system performance and obstacles to Universal Health Coverage	Summer School - Lugano	August 27-29 2018	1
Other courses (soft skills, *etc.*)	Tutorial: Genetic predispositions to obesity: is it all coded in our DNA?	UNIL - Lausanne	5x 2h-courses January 2016	1
	Tutorial: An introduction to medical genetics through the prism of endocrine and metabolic diseases	UNIL - Lausanne	6x 2h-courses February 2016	1
	Writing a Journal Article… and Getting it Published	SSPH+ - Bern	August 31-Sept. 2 2016	1.5

Conferences & Symposiums	Being a scientific writer	CHUV - Lausanne	January 14 2016	0
	1st Symposium GE-VD Nutrition and Microbiota [in French]	CHUV - Lausanne	February 11 2016	0
	Congress on clinical nutrition & metabolism: Collaboration in Nutrition	ESPEN - Copenhagen (Denmark)	Sept. 17- 20 2016	1
	2nd Symposium GE-VD Nutrition and Microbiota [in French]	HUG - Lausanne	February 9 2017	0
	Swiss Public Health Conference: Personalized Health from a Public Health Perspective	SSPH+ - Basel	November 22-23 2017	0
	Symposium: Public policy and social inequalities in smoking [in French]	University of Montreal - Montreal (Canada)	February 20 2018	0
	Food for thought: the science and politics of nutrition	The BMJ & Swiss Re - Rüschlikon/Zurich	June 14-15 2018	0
	European Congress of Epidemiology: crises, epidemiological transitions and the role of epidemiologists	International Epidemiological Association - Lyon (France)	July 4-6 2018	0
	Swiss Public Health Conference: Social Science for public Health	SSPH+ - Neuchatel	November 7-8 2018	0
	Public health and nutrition: actual and future challenges. A Belgian and Swiss perspective.	Université Libre de Bruxelles - Bruxels (Belgium)	November 21-22 2018	0
	Seminar on Nutrition	French-speaking unit of SSPH+ - Lausanne	December 5 2018	0
Seminars, workshops, & meetings	Journal Club or Progress Report in the field of public health	IUMSP - Lausanne	Yearly: every two week (1h)	-
	IUMSP seminars on public health	IUMSP - Lausanne	Yearly: every two week (1h)	-
	Doctoral seminar on health promotion [in French]	University of Montreal - Montreal (Canada)	4x 3h-courses, plus reading Jan.-Fev. 2018	-
	Workshop on reflexivity in Global Health [in French]	University of Montreal - Montreal (Canada)	January 27 2018	-
	20th meeting of the health promotion network 'Ça marche!' [in French]	Promotion Santé Vaud - Lausanne	May 3 2018	-
Others	Participation in an expert committee to develop a score to self-assess diet quality	University of Applied Sciences and Arts - Geneva	February 22 & May 29 2017	-
	Review of the level of the scientific evidence of the publications reported in Chapter 8 of the Federal Commission for Nutrition (2018). Vegan diets: review of nutritional benefits and risks.	Federal Commission for Nutrition	December 2017	-
	Evaluation of programs related to nutrition and physical activity	Promotion Santé Vaud - Lausanne	September 6 & November 19 2018	-

11.4. List of oral and poster presentations in conferences

Selected abstracts with oral presentation:

- **Swiss Public Health Conference**, 07-08.11.2018, Neuchatel, Switzerland. Chatelan A, Bochud M, Frohlich KL. Precision nutrition: Hype or hope for public health interventions to reduce obesity?
- **Swiss Public Health Conference**, 22-23.11.2017, Basel, Switzerland. Chatelan A, Beer-Borst S, Randriamiharisoa A, Pasquier J, Blanco JM, Siegenthaler S, Paccaud F, Slimani N, Nicolas G, Camenzind-Frey E, Zuberbuehler CA, Bochud M. Major differences in diet across three linguistic regions of Switzerland: results from the first nutrition survey menuCH.

Selected abstracts with poster presentation:

- **SSPH+ Summer School,** 27-29.08.2018, Lugano, Switzerland. Chatelan A, Castetbon K, Pasquier J, Allemann C, Zuber A, Esther Camenzind-Frey E, Zuberbuehler CA, Bochud M. Association between breakfast composition and abdominal obesity in the Swiss adult population eating breakfast regularly.
- **European Congress of Epidemiology**, 04-06.07.2018, Lyon, France. Chatelan A, Castetbon K, Pasquier J, Allemann C, Zuber A, Esther Camenzind-Frey E, Zuberbuehler CA, Bochud M. Are dietary patterns at breakfast associated with abdominal obesity in a population-based survey? Access to abstract: https://doi.org/10.1016/j.respe.2018.05.298.
- **Nutrition information as a tool of consumer empowerment and public health protection**, 25-26.01.2018, Lausanne Switzerland. Chatelan A, Gonseth Nusslé S, Bochud M. Compliance to the national dietary guidelines across the three linguistic regions of Switzerland.
- **Visit of Nestlé Research Center**, 23.08.2017, Vers-chez-les-Blanc, Switzerland. Chatelan A. Studying nutrition in Swiss children and adolescents.
- **38th congress of the European Society for Clinical Nutrition and Metabolism** (ESPEN), 17-20.09.2016, Copenhagen, Denmark. Chatelan A, Zuberbuehler C, Camenzind-Frey E, Bochud M. SUN-P126: Should we Adjust for Seasonality in Food Consumption Surveys? Clin Nutr. 35: S90.

11.5. List of lectures and student supervisions

Recent teaching experiences:

- 2018 (4x 3h): Lectures and workshops on '**Analyses of nutrition data'**, MSc in Health Sciences - Option Nutrition and Dietetic, University of Applied Sciences and Arts Western Switzerland, Geneva, Switzerland (02.11.2018, 09.11.2018, 16.11.2018).
- 2017 - 2018 (2h): Lecture on '**Swiss national nutrition survey menuCH'**, BSc in Nutrition and Dietetic, University of Applied Sciences and Arts Western Switzerland, Geneva, Switzerland (24.05.2017, 06.06.2018).
- 2016 (3x 2h): Lectures and workshops on '**Quality in the profession of registered dietitian'**, BSc in Nutrition and Dietetic, University of Applied Sciences and Arts Western Switzerland, Geneva, Switzerland (10.05.2016, 17.05.2016, 31.05.2016).

Students' supervisions (BSc and MSc):

- Student in **Nutrition and Dietetic** (BSc), University of Applied Sciences and Arts Western Switzerland, Geneva, Switzerland. Research topic: 'Sugar consumption in Switzerland" (2 months, 2018).
- Student in **Medicine** (MSc), University of Lausanne, Switzerland. Research topic: 'Consumption and sources of caffeine in the Swiss population' (throughout the year 2018).
- Student in **Public Management** (MSc), University of Geneva, Switzerland. Research topic: 'Analysis and recommendations for National nutrition survey menuCH in terms of public health' (6 months, 2016).
- Student in **Personalized Medicine** (MSc), Swiss Federal Institutes of Technology, Lausanne, Switzerland. Research topic: 'Dietary patterns across Switzerland' (3 months, 2016).

11.6. List of invited lectures/presentations

Date	Place	Meeting/Institution	Title
05.12.2018	Lausanne, Switzerland	French-speaking unit of the Swiss School of Public Health.	Nutritional monitoring of the Swiss population. [French]
21.11.2018	Brussels, Belgium	Public health and nutrition: actual and future challenges. A Belgian and Swiss perspective.	Food intake differences across linguistic regions of Switzerland. [French]
17.03.2018	Bienne, Switzerland	Nutridays, Swiss Dietetic Association Conference.	Research by and for dietitians: an asset for the community. [French] https://nutridays.ch/fr/nutridays-2018-2/
10.05.2017	Lausanne, Switzerland	Uthink.	What do the Swiss eat? [French] http://uthink.ch/events
31.01.2017	Bern, Switzerland	Swiss Federal Food Safety and Veterinary Office.	What do the Swiss eat? MenuCH results across the different linguistic regions. [French]
29.03.2016	Bern, Switzerland	Swiss Federal Food Safety and Veterinary Office.	Feasibility study among 50 children and adolescents aged 3 to 17 years old from the French-speaking part of CH to prepare a next survey, including objective nutritional biomarkers.

11.7. Presence in the media

Press:

- ‘What do the Swiss eat?’, in ***Illustré***, 12.09.2018. [French]
- ‘Being a research dietitian’, in ***Info - Journal of the Swiss Dietetic Association***, 08.2018. [German, French, Italian]
- ‘The Swiss know the food pyramid, but do not comply with it' in ***Newsletter of the National Research Programme*** *on Healthy Nutrition and Sustainable Food Production (NRP 69*), 30.05.2017. Access to article: http://www.nfp69.ch/en/News/Pages/170524_news_nfp69_food_pyramid.aspx

Internet:

- ‘Avoiding public confusion due to conflicting research conclusions’ in ***BMJ Rapid responses***, 23.03.2018. Access to the commentary: https://www.bmj.com/content/360/bmj.k822/rr-9