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DEVELOPMENT AND VALIDATION OF A FOOD FREQUENCY QUESTIONNAIRE FOR THE ADULT EMIRATI POPULATION FOR USE IN EPIDEMIOLOGICAL STUDIES

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Under the Supervision of Dr. Habiba I. Ali

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Declaration of Original Work

I, Najoua El Mesmoudi, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this dissertation entitled *"Development and Validation of a Food Frequency Questionnaire for the Adult Emirati National Population for Use in Epidemiological Studies"*, hereby, solemnly declare that this dissertation is my own original research work that has been done and prepared by me under the supervision of Dr. Habiba I. Ali, in the College of Medicine and Health Sciences at UAEU. This work has not previously been presented or published or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my dissertation have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this dissertation.

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Abstract

The United Arab Emirates (UAE) has been undergoing a nutritional transition in the last few decades, making diet-related Non communicable diseases (dr-NCDs) a critical health problem in the country. Food frequency questionnaire (FFQ) is the most frequently used method in epidemiological studies to investigate dietary exposures in relation to NCDs. At present, a designated FFQ for the UAE national population is lacking. To develop a culturally appropriate quantitative Web-based FFQ for the adult Emirati population (the AE-FFQ) and to assess its relative validity against three 24-hour recalls. A convenient sample of 60 (36 females and 24 males) adult Emiratis completed 3 consecutive 24HRs over a period of one month, followed by the AE-FFQ which assessed the intake over the previous month. Relative validity was evaluated by comparing nutrient and food group intakes from the AE-FFQ with the average three 24 HRs using Wilcoxon signed-rank tests, Spearman's correlation coefficients (CC), Bland-Altman analysis, and cross-classification. The AE-FFQ was composed of 139 food items and 12 food groups. Energy, most nutrient and food groups intakes were significantly higher in the AE-FFQ compared to the reference method. Bland-Altman analysis further characterized higher estimates by the AE-FFQ and the presence of significant proportional bias between the 2 methods. The de-attenuated energy-adjusted Spearman CCs were positive and statistically significant for most nutrients and food groups and ranged from 0.06 (iron) to 0.62 (fiber) for nutrients with a 0.39 median value and from 0.01(cruciferous vegetables) to 0.64 (eggs) for food groups, with a 0.41 median value. A fairly acceptable agreement was obtained, with correct classification into the same or adjacent quartile ranging from 34% (vitamin B12) to 78% (pyridoxine), median 69% for nutrients and from 55% (diet soft drinks) to 87% (soft drinks), median 67% for food groups. The AE-FFQ is an acceptable tool for ranking UAE individuals according to their dietary intake to investigate the role of Emirati dietary patterns on health and disease. Caution is needed for assessing absolute intake, however, given the bias observed in assessing group-level agreement.

Keywords: Food Frequency Questionnaire, 24-hour recall, United Arab Emirates, web-based, online, validity, diet, noncommunicable diseases.

Title and Abstract (in Arabic)

تطوير والتحقق من صحة استبيان تردد الغذاء للمواطنين الإماراتيين البالغين لاستخدامه في الدراسات الوبائية

الملخص

الخلفية: تمر دولة الإمارات العربية المتحدة بمرحلة انتقال غذائي في العقود القليلة الماضية مما يجعل الأمراض غير المعدية المتعلقة بالنظام الغذائي مشكلة صحية خطيرة في الدولة. استبيان تردد الغذاء (FFQ) هو الطريقة الأكثر استخدامًا في الدراسات الوبائية للتحقيق في التعرض الغذائي المتعلق بالأمراض غير المعدية. في الوقت الحاضر، لا يوجد FFQ مخصص للمواطنين الإماراتيين.

الهدف: تطوير استبيان تردد غذاء كمي ومناسب ثقافيًا للاماراتيين البالغين على شبكة الإنترنت (AE- FFQ) وتقييم صلاحيته النسبية ضد ثلاث مقابلات استذكار غذائي على مدار 24 ساعة.

الطريقة: أكملت عينة ملائمة من 60 إماراتيين بالغين (36 أنثى و 24 ذكرًا) 3 مقابلات استذكار غذائي على مدار شهر واحد، تلاها استبيان AE-FFQ الذي قيم تناول الطعام خلال الشهر السابق. تم تقييم الصلاحية النسبية من خلال مقارنة تناول المغذيات ومجموعات الاطعمة من AE-FFQ ومن معدل الاستذكار الغذائي باستخدام اختبارات تصنيف موقع ويلكوكسون، ومعاملات ارتباط سبيرمان، وتحليل بلاند-ألتمان، والتصنيف المتقاطع.

النتائج: يتكون AE-FFQ من 139 عنصرًا غذائيًا و 12 مجموعة غذائية. كانت الطاقة ومعظم مآخذ المغذيات ومآخذ المجموعات الغذائية أعلى بكثير في AE-FFQ مقارنة بالطريقة المرجعية. تميز تحليل بلاند-ألتمان أيضًا بتقديرات أعلى بواسطة AE-FFQ ووجود تحيز نسبي كبير بين الطريقتين. كانت معاملات ارتباط سبيرمان المعدلة للطاقة إيجابية وذات دلالة إحصائية لمعظم مآخذ المغذيات ومجموعات الطعام وتراوحت من 0.06 (حديد) إلى 0.62 (ألياف) لمآخذ المغذيات ومن 0.01 (خضروات صليبية) إلى 0.64 (بيض) للمجموعات الغذائية. التصنيف الربعي الصحيح للمشاركين في الربع نفسه والمجاور لتقديرات الطاقة المعدلة تراوحت من 34٪ (فيتامين ب 12) إلى 78٪ (بيريدوكسين) لمآخذ المغذيات ومن 55٪ (مشروبات غازية دايت) إلى 87٪ (مشروبات غازية) للمجموعات غذائية.

الخلاصة: استبيان AE-FFQ أداة مقبولة لترتيب الأفراد وفقًا لاستهلاكهم لمآخذ الطاقة ومآخذ المغذيات والمجموعات الغذائية لغاية التحقيق في دور الأنماط الغذائية الإماراتية في الأمراض غري المعدية المتصلة بالنظام الغذائي. ومع ذلك، يجب أن يتم استخدامه بحذر لتقييم المدخول المطلق نظرًا للتحيز الملحوظ عند تقييم الاتفاق بتحليل بلاند-ألتمان.

مفاهيم البحث الرئيسية: استبيان تردد الغذاء، استذكار غذائي على مدار 24 ساعة، عبر الإنترنت ، دراسة تحقق من صحة استبيان، الأمراض غير المعدية ، الإمارات العربية المتحدة.

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Above all, thank you God for giving me strength to keep going!

Dedication

To the memory of my father Mohamed El Mesmoudi, and my aunt Zoubida El Mesmoudi, who taught me to live with values of hard work and kindness

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List of Abbreviations

24HR	24-hour Recall
α-TE	Alpha-Tocopherol Equivalent
μg	Microgram
AMPM	Automated-Multiple Pass Method
BMI	Body Mass Index
BMR	Basic Metabolic Rate
CoFID	The 'Composition of Foods Integrated Dataset'
CNF	Canadian Nutrient File
Cm	Centimeter
CRN	Council of Responsible Nutrition
CVD	Cardiovascular Disease
DALY	Disability-Adjusted Life Year
DHQ	Diet History Questionnaire
DLW	Doubly Labeled Water
DM	Dry Matter
DR	Dietary Record
DSID	Dietary Supplement Ingredient Database
EI	Energy Intake
EE	Energy Expenditure
EP	Edible Portion
EPIC	European Prospective Investigation into Cancer and Nutrition
FAO/INFOODS	Food and Agriculture Organization/International Network of Food Data Systems
FCDB	Food Composition Database
FCT	Food Composition Table

FDA	Food and Drug Administration
Fl.oz	Fluid Ounce
AE-FFQ	Adult Emirati Food Frequency Questionnaire
FFQ	Food Frequency Questionnaire
FNDDS	Food and Nutrient Database for Dietary Studies
FPQ	Food Propensity Questionnaire
g	Gram
HH	Household
IDQC	Internet-based diet questionnaire for Chinese
IU	International Unit
Kg	Kilogram
L	Large
lb.	Pound
M	Medium
MPM	Multiple Pass Method
mcg	Milli centigram
mg	Milligram
mL	Milliliter
MUFA	Monounsaturated Fatty Acid
NAS	Nutrition Analysis Software
NCD	Non-Communicable Disease
NCI	National Cancer Institute
NHANES	National Health and Nutrition Examination Survey
NIH	National Institute of Heatlh
NZ	New Zealand
oz	Ounce

PAL	Physical Activity Level
PS	Portion Size
PSEA	Portion Size Estimation Aid
PUFA	Polyunsaturated Fatty Acid
QFFQ	Quantitative Food Frequency Questionnaire
RAE	Retinol Activity Equivalent
RE	Retinol Equivalent
rEI	Reported Energy Intake
RF	Retention Factor
S	Small
SFA	Saturated Fatty Acid
SFFQ	Semi-quantitative Food Frequency Questionnaire
TDEE	Total Daily Energy Expenditure
TEE	Total Energy Expenditure
TS	Tablespoon
Ts	Teaspoon
UAE	United Arab Emirates
UAEU	United Arab Emirates University
USDA SR DB	United States Department of Agriculture National Nutrient Database for Standard Reference
YF	Yield Factor

Chapter 1: Introduction

1.1 Overview

A suboptimal diet is one of the most important modifiable risk factors of non-communicable diseases (NCDs) including obesity, cardiovascular diseases (CVDs), type 2 diabetes and certain cancers (Afshin et al., 2019). It is also well-recognized that measuring dietary exposures requires the use of adequate dietary assessment tools (DATs) that can help in understanding the impact of dietary factors on disease (Willett, 2013). To investigate diet-disease relationship, the overall diet quality and food patterns rather than single nutrients need to be assessed (Afshin et al., 2019; Mozaffarian, 2016). The gold standard for dietary intake assessment is recovery biomarkers such as doubly labelled water (DLW) for energy intake (EI) or urinary nitrogen for protein intake (Freedman et al., 2014). However, biomarkers are not reflective of long-term intake, moreover, the single nutrient measurements obtained with biomarkers cannot capture the complexity of whole diets and the interactions of dietary patterns (Zuniga & McAuley, 2014). Consequently, subjective DATs that rely on self-reported dietary intake, such as dietary record (DR), 24-hour recall (24HR) and food frequency questionnaire (FFQ) are more commonly used in epidemiological studies (Willett, 2013). The use of subjective DATs requires a reliable food composition table or database (FCT/FCDB) to convert food intake data to nutrients (McNutt et al., 2008). FFQs are the only DAT that are designed to measure middle to long-term habitual food intake retrospectively (Willett, 2013). In comparison to other DATs, FFQs are also more cost and time effective and less burdensome to both the participant and the investigator (Cade et al., 2002; Willett, 2013). A basic self-administered FFQ is composed of a predefined list of foods and a frequency of consumption response section for subjects to report how often each food was eaten over a determined time period, usually the past month or year (Willett, 2013). Only a limited number of foods can be included in an FFQ, therefore, the food list needs to be specific to the population of interest and their food habits (Cade et al., 2002). Some FFQs also ask about usual portion sizes (PSs) by categorizing different PSs by weight (McNutt et al., 2008). Such FFQs are called "Quantitative", as opposed to semi-quantitative FFQ which only present a standard portion size of the foods in the list (Gurinović et al., 2017; McNutt et al., 2008). Quantitative FFQs are more accurate because they help reduce the uncertainty of the reporting of the amount of food consumed (Gurinović et al., 2017; McNutt et al., 2008). The obtention of such detailed information from an FFQ is based on complex cognitive processes depending on long-term memory and may cause systematic errors leading to inaccurate dietary estimates, which may as a consequence lead to unreliable diet-disease associations (Gurinović et al., 2017). Consequently, it is important to validate an FFQ prior to its use in dietary assessment studies, which is typically determined by comparing the FFQ to reference methods considered superior to the FFQ, such as 24HRs or DRs (Willett, 2013). The validation can be undertaken by using a range of statistical methods including comparison at the group level with group means/medians and Bland-Altman analysis, and at the individual level with correlation coefficients (CCs), cross-classification and weighted kappa statistics (Gibson, 2005; Willett, 2013). Lombard et al. (2015) and Willett (2013) recommend using a combination of statistical methods and to assess the validation based on all tests. FFQ are best suited for ranking individuals based on their intake (High, moderate, low) because the effect of diet on disease outcome is usually reported as odds ratio or relative risks rather than absolute estimates (Beaton, 1994; Sempos et al., 1999; Willett, 2013).

The emergence of web-based digital technologies has enabled the development of innovative online FFQs, thus resolving a number of issues usually encountered with print FFQs such as reducing missing data and skip questions, automated data entry, immediate generation of dietary outputs and ease of access to large populations in different locations (Falomir et al., 2012).

1.2 Statement of the problem

The nutrition transition that the United Arab Emirates (UAE) have witnessed over the last four decades has caused a significant change in the diet of its population, in terms of its quality, quantity and patterns of intake (Ng et al., 2011). People from the UAE went from a diet based mostly on fish, rice, dates and buttermilk in the middle of the last century to a more westernized diet by the end of the eighties (Musaiger, 1993). As a consequence, the country is witnessing some of the highest prevalence rates of obesity, diabetes, and heart diseases in the world, with a prevalence of obesity in adults estimated at 34.5% (WHO, 2018) , diabetes at 25% of the adult population (Meo et al., 2017) and where CVDs are responsible for 77% of all deaths (WHO, 2018). Despite the steep increase in the incidence of nutrition related-NCDs in the country, there is a paucity of data on the dietary intake of UAE nationals, which is essential for measuring the population's dietary risk factors for NCDs (Ng et al., 2011), Only one national nutrition survey has been reported, which used the USDA SR DB and complemented it with the Kuwaiti DB (Ng et al., 2011). Indeed, the country lacks a national FCT, and only 23 traditional foods were recently chemically analyzed as part of a PhD thesis (Al Dhaheri et al., 2015; Muhamad, 2016). Only one FFQ was developed 15 years ago for the assessment of usual dietary intake of both the UAE and

Kuwait, therefore not specifically for the UAE (Dehghan et al., 2005). Moreover, this FFQ was validated in Kuwait but not in the UAE (Dehghan, 2009).

Given the specificities of the dietary habits and cultural practices of the Emirati population, a DAT that can investigate the link between dietary patterns and disease outcomes specifically for the UAE and its accompanying FCT is needed because it would allow the investigation of the causes of the rising burden of nr-NCDs specifically in the country, which would allow its government to formulate country-specific, evidence-based nutritional recommendations that could ultimately help curb the spread of nr-NCDs (Naja et al., 2017; Tapsell et al., 2016).

1.3 Research question

Can a newly developed culture specific web-based FFQ for the Emirati adult population adequately assess the energy, nutrients, and food group intakes of the population?

1.4 Aims of the study

The aim of this study is to develop a culturally-appropriate FFQ for the adult Emirati population and assess its relative validity.

Following research objectives would facilitate the achievement of this aim:

<u>Research objectives</u>

Achieving the objectives of the study requires the following steps:

1. Development of a web-based quantitative FFQ specific to the dietary habits of the Emirati population

This step requires the following prerequisites:

- Construct a culture-specific food list,
- Obtaining population specific portion sizes and digital food photographs,

- Designing the web-based FFQ in Arabic language,
- Constructing the accompanying nutrient dataset to the FFQ

2. Conduct of a validation study of the FFQ against a dietary reference method that is appropriate for the study population (three 24HRs in this study).

This step requires the following prerequisites:

- Administering three non-consecutive 24HRs over a one-month period
- Administering the FFQ at the end of the one-month study period

1.5 Literature review

This literature review chapter discusses the importance of researching nr-NCDs, the DATs that are used in research to assess nutrient intake and the need for a designated FFQ that can be used as a tool for assessing dietary intake in NCDs research specifically in the Emirati population. A detailed review of FFQs including the recommendations for their development and the evolution of FFQs from print to web-based emphasizing the advantages of the latter is also covered. The chapter concludes with a review of the validation tests required for a newly developed FFQ and a survey of previously validated web-based FFQs sharing a similar objective to this study.

1.5.1 Diet as a risk factor for disease

1.5.1.1 Background

Obesity and NCDs, such as cardiovascular diseases (CVDs), type 2 diabetes and certain cancers represent a major global public health challenge because they pose substantial health issues and economic loss, premature deaths, and loss of quality of life (WHO, 2014). The latest estimates from the World Health Organization (WHO, 2018) show that NCDs account for about 71% (40 Million) of all global deaths, among these deaths, 48% occur prematurely (before the age of 70) in low and middle-income countries (WHO, 2018).

1.5.1.2 Risk factors of NCDs

Multiple factors have been associated with the rise in NCDs, such as environmental risk factors (Industrialization, globalization, urbanization, poverty), behavioral risk factors (Tobacco use, unhealthy diets, physical inactivity) and biological risk factors (High blood glucose, High blood pressure, obesity) (Dans et al., 2011).

Although the precise drivers of the rise in NCDs have not been agreed, it is believed that the economic and societal changes that have occurred since the industrial revolution have caused many of these drivers. Indeed, the increase in labor-force due to urbanization was a key determinant in the expansion of the food industry because the need for quick to prepare and convenient meals was growing (Saksena et al., 2018). To answer the rising demand in convenient foods, an urban food environment of fast food chains and supermarkets emerged to provide a ready supply of cheaper, tastier and convenient processed foods and snacks that are high in calories, added salt and processed fats, and sweets and sugary beverages that are high in energy and added sugar (Bodor et al., 2010). The rise in consumption of convenient processed foods coincided with a drop in the consumption of fruits and vegetables (Dans et al., 2011). Along with the urbanization came the technological advances inside and outside the home which progressively reduced the need for energy expenditure resulting in an increase in sedentarity (Popkin et al., 2012).

The onset of globalization coupled with the economic and epidemiologic growth of developing countries allowed the same dynamics that have initiated the change in food patterns and reduction in physical activity in the west to start playing in these countries (Schmidhuber, 2004). In fact, the shift in the food consumption patterns from traditional to Western-style diets caused by the emergence of the western model of fast food chains and supermarkets brand chains and the changes in the urban environment were termed by Popkin as the "Nutrition transition" (Popkin, 1993), and was recognized as a major contributor to the NCDs epidemic in low-income countries as well as in emerging economies (Popkin, 1993; Popkin et al., 2012).

1.5.1.3 Nutrition transition in the Gulf countries

As countries of high economic growth since the discovery of oil in the 1960's, the Gulf countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the UAE) have experienced major societal changes leading to an aggressive and rapid nutrition transition (Ng et al., 2011). Indeed, in just 4 decades, the Gulf countries observed a significant shift in their food habits (Ng et al., 2011). To illustrate the extent of the increase in food consumption since the discovery of oil, data from surveys conducted in 1975 and 1984 in Saudi Arabia revealed that within the 10 years period, the average daily Saudi caloric intake increased from about 1,800 Kcals to 3,265 Kcals, protein intake increased from 51.3 g to 88.3 g and fat intake from 32.6 g to 90.2 g. The surveys also noted that cereal consumption during this decade increased by 40%, chicken meat consumption increased by 243% and oils and fat consumption increased by 278% (Al-Musharef, 1990). There are common drivers shared by all the Gulf countries that have enabled their nutrition transition: 1) The high Gross Domestic Product (GDP) of the population driven by the important economic and industrial transformation seen since the 1970's (Musaiger, 1993); 2) The diverse landscape of food cuisines and food choices enabled by the cosmopolitan labor force (Musaiger, 1993); 3) The trade liberalization which has given easy access to food supplies from all over the world, (Al-Yousif, 2004); 4) The ease of access to processed foods due to the modernization of the food distribution system with the introduction of international fast food chains and hypermarkets and the recent trend of online takeaway applications (Ardent Advisory & Accounting, 2016); 5) The popularity of shopping malls as a lifestyle and lack of outdoor activities (Ardent Advisory & Accounting, 2016) and finally; 6) The technological advances reducing the need for physical activity inside and outside the house.

As a consequence of the obesogenic behaviors generated by these drivers, the Arabian Gulf states are witnessing some of the highest prevalence rates of obesity, diabetes, and heart diseases in the world, with UAE and Saudi Arabia exhibiting the highest prevalence rates of all Gulf countries, as reported by Ng et al. (2010) in their review of studies conducted in the region. Recent estimates indicate that the Gulf countries continue to exhibit alarming levels of NCDs, with diabetes prevalence rates attaining 31.6% in Saudi Arabia, 29% in Oman, 25.4% in Kuwait and 25% in Bahrain and the UAE (Alshaikh et al., 2017; Meo et al., 2017). These rates are much higher than the global prevalence of type 2 diabetes in urban and high-income countries (≃11%) according to 2019 estimates (Saeedi et al., 2019).

1.5.1.4 Nutrition transition in the UAE

As part of the Arabian Gulf, the UAE shares similar drivers and consequences of the nutrition transition because of the similarities in history, culture and socioeconomic development initiated by the discovery of oil (Ng et al., 2011). Indeed, the impact of the nutrition transition has caused the UAE to reach one of the highest prevalence rates of obesity, diabetes, and heart diseases in the world, with a prevalence of obesity in adults estimated at 34.5% (WHO, 2018), diabetes at 25% (Meo et al., 2017) and where NCDs are responsible for 77% of all deaths, with 40% attributable to CVDs (WHO, 2018), making CVDs the main cause of mortality in the UAE (Razzak et al., 2018). Moreover, according to the Global Burden of disease (GBD) study 2017, which examined the trends of mortality and morbidity from major diseases, injuries and risk factors to health in 195 countries from 1990 to 2017 (Afshin et al., 2019; IHME & GBD, 2017), NCDs in the UAE were found to be responsible for 76.61% (73.9–79.1%) of the burden of diseases.

Although the nutrition transition has been recognized as the primary driver of the NCDs epidemic, it was difficult to pinpoint the role of diet given the novelty of the field of nutrition science and the intricate components of diets (Kearney, 2010; Mozaffarian, 2016).

1.5.1.5 Investigating the dietary factors responsible of the NCDs epidemic

Many observational studies have associated the excess energy intake (EI) brought by the new dietary habits as part of the nutrition transition with the observed increase in obesity (Schmidhuber, 2004; Vandevijvere et al., 2015). Vandevijvere et al. (2015) found that the increases in food energy supply experienced by 56 developed and developing countries was more than sufficient to account for the observed weight gain in 80% of the countries surveyed. However, the increase in caloric intake is not the only factor responsible for the NCDs epidemic, as would prove the discoveries in nutrition science that came along with the evolution of the field. Indeed, the understanding of the nutrition-related risk factors linked to the obesity epidemic and other NCDs has only started in the last 2 to 3 decades, as before that, the field of nutrition science was more preoccupied by diseases of calories and single-nutrient deficiencies rather than diseases of excess nutrition (Mozaffarian et al., 2018).

1.5.1.6 The shift in nutrition science from the single-nutrient paradigm to foods and dietary patterns

The nutrient deficiencies caused by the food shortages experienced during the second world war led the focus of the field of nutrition research to be primarily on the identification of micronutrients and the use of single-nutrient based interventions to eradicate specific diseases of nutrient deficiency (Mozaffarian et al., 2018). This approach successfully eradicated diseases such as goiter, xerophthalmia or rickets by fortification of staple foods with Iodine, Vitamin A or Vitamin D respectively (Mozaffarian et al., 2018). The success of the single-nutrient approach based the focus of nutrition research and policy recommendations on the paradigm of single-nutrients linked to specific disease states (Mozaffarian et al., 2018). Consequently, research on chronic diseases also used the same single-nutrient paradigm to interpret the link between diet and NCDs, which led to the publication of the first Dietary Goals for the United States in 1977 recommending a reduction of the consumption of total and saturated fat in an attempt to curb the increasing chronic diseases (Reedy, 2016). These measures, based on the reductionist model of quantifying an optimum intake of a single nutrient to prevent disease, while successful for diseases of nutrient deficiencies, did not perform as well for preventing non-communicable diseases (Mozaffarian et al., 2018).

It was not until the 1990s that the use of more rigorous evidence from well-designed metabolic studies, prospective cohorts, and randomized clinical trials transformed nutrition science, bringing evidence that NCDs were mainly influenced not by single nutrients but by specific foods and overall diet patterns (the overall combination of foods usually consumed) (Micha et al., 2017; Mozaffarian, 2016; Mozaffarian et al., 2018). Diets that are low in fruits, vegetables, legumes, nuts, whole grains, yoghurt, fish, vegetable oils; and high in red meat, processed meat and sugar-sweetened beverages showed the most convincing evidence for causality with NCDs such as cardiovascular outcomes, diabetes and obesity (Micha et al., 2017; Mozaffarian, 2016). Such diets are also low in fiber and high in sodium and trans-fatty acids and glycemic load, which have been evidenced as having a causal relationship with CVDs, high blood pressure and diabetes (Micha et al., 2017). These advances in nutrition science prove that beyond the effect of excess calories, NCDs associated with the nutrition transition observed globally are caused by the widespread adoption of Western diets characterized by highly processed convenience foods high in trans-fatty acids, sodium and refined grains and low in fruits and vegetables. Such dietary patterns have been shown to be the leading risk factor for death and disability in the world (Afshin et al., 2019).

The progression towards estimating an overall diet quality raised the need for tools that can measure the differences between diets of individuals and the dietary intake recommended guidelines (Gil et al., 2015). Therefore, the development of diet quality indices that can capture the characteristics of complete diets and measure the consumption levels of food groups and nutrients concurrently became a goal in nutritional epidemiology (Gil et al., 2015). Many indices of diet quality have been reported in the literature, however, only four NCD dietary metrics; (the Mediterranean Diet Score (MDS), the Alternative Healthy Eating Index (AHEI), the Healthy Eating Index (HEI), and the Dietary Approaches to Stop Hypertension (DASH) have shown convincing evidence of protective associations with specific NCD outcomes, mainly mortality, cardiovascular disease, type 2 diabetes, and total cancer (Miller et al., 2020). These diet scores differ in diet components, scoring rates and definition of cut-off values (Gil et al., 2015). They have been adapted and modified over the years. Following is a brief description of these 4 indices.

The MDS is a tool that was constructed to evaluate adherence to the Mediterranean diet based on the observation of low rates of chronic diseases and high life expectancy in countries bordering the Mediterranean Sea (Trichopoulou et al., 2003). It is one of the few health diet indices to have been associated with reduced risk of mortality and CVD incidence in various populations (Miller et al., 2020). The traditional Mediterranean diet is described and scored by the MDS in terms of nine component characteristics: high MUFA to SFA ratio, high consumption of legumes, high consumption of wholegrains, high consumption of fruits and nuts, high consumption of vegetables, moderate consumption of fish, moderate consumption of alcohol, low consumption of meat and meat products and low consumption of milk and dairy products (Trichopoulou et al., 2003). A value of 0 or 1 is assigned for each of the nine components of the score, using the energy-adjusted group median as the cutoff value to define high/low categories. Although taking the energy- adjusted group median as a cut-off might not seem a rational choice, as it has in fact no relation with a healthy level of intake per se, the advantage of doing so follows from the definition of ‘median’: half of the subjects will score positively and half will score negatively on each index item, ensuring that each index item distinguishes well and exactly similar between subjects (Trichopoulou et al., 2003).

The HEI was developed in 1995 by the USDA Center for Nutrition Policy and Promotion (CNPP). It represents an index of overall diet quality that incorporates nutrient needs and food-based dietary guidelines for the US consumer into one measure (Kennedy et al., 1995). The HEI is revised periodically with each new edition of the GDA. Its latest revision (HEI-2015) reflects the changes introduced by the 2015 Dietary Guidelines for Americans (DGA) (Krebs-Smith et al., 2018). The HEI contains ten components that translate the food groups recommended in the DGAs: five food groups to be consumed proportionately (cereals, breads and tubers; vegetables; fruits; milk and dairy products; and meat, eggs, and leguminous plants), four nutrients that should be consumed in moderation (total fat, saturated fats, cholesterol, and sodium), and dietary variety (Krebs-Smith et al., 2018). The HEI classifies individuals into consumption categories with a scoring system that gives each component a value from zero to ten, with a maximum score of 100 indicating a good-quality diet (Krebs-Smith et al., 2018).

The AHEI was developed as an alternative to the HEI and is based on the foods and nutrients which can prevent NCDs (Onvani et al., 2017). Its latest version, the AHEI-2010 has shown more advantages than the HEI in predicting chronic diseases, it's use is therefore preferred in epidemiological studies (Chiuve et al., 2012; Onvani et al., 2017). As with the HEI, the AHEI scores components from 0 (worst) to 10 (best) based on the DGA specified recommended intake for each component (Chiuve et al., 2012).

Finally, the DASH diet index is a metric that was developed specifically to measure adherence to the DASH diet, which is a diet that was originally designed to reduce blood pressure (Fung et al., 2008). This diet emphasizes intakes of fruits, vegetables, whole grains, nuts, legumes, moderate amounts of low-fat dairy; and recommends reduced intakes of red or processed meats, sodium, and sweetened beverages (Fung et al., 2008; Miller et al., 2020). DASH score is calculated by classifying its energy-adjusted components into quantiles, where fruits, vegetables, nuts and legumes, low-fat dairy products and wholegrains are assigned 1–5 points in order of most consumption and the quintiles for red and processed meats, free sugar and sodium are assigned 1–5 points in order of least consumption (Fung et al., 2008; Miller et al., 2020).

1.5.1.7 Contribution of nr-NCD to the to global mortality and global burden of disease and the mortality and GBDs in the UAE

Findings from the Global Burden of Disease (GBD) 2017 study have shown that unhealthy dietary habits caused the death of 11 million people in 2017 in the world and caused 255 million disability adjusted life years (DALY) (DALY, a measure of

GBD), making suboptimal diet the leading cause of poor health. CVDs were the leading cause of diet-related deaths with 10 million deaths and 207 million DALYs, followed by cancers, with 913 090 deaths and 20 million DALYs, and type 2 diabetes, with 338 714 deaths and 24 million DALYs. The study also revealed that diets that were high in sodium, low in whole grains, low in fruit and vegetables, low in nuts and seeds, and low in omega-3 fatty acids accounted for more than 2% of global deaths for each of these dietary risk factors. Moreover, the non-optimal intake of three dietary factors (whole grains, fruits, and sodium) accounted for more than 50% of deaths and 66% of DALYs globally (Afshin et al., 2019), providing additional evidence that the focus on optimum intake of groups of foods might be more impactful than promoting diets that focus on single foods such as fat or sugar (Afshin et al., 2019). The authors also stated that targeting optimal intake of these specific foods could potentially prevent one in every five deaths globally.

The GBD 2017 study also revealed that in the UAE, the estimated mortality and burden of disease attributable to nutrition-related risk factors was 21.7% and 16% respectively, with CVDs responsible for about 50% of the cause of both mortality and burden of disease (Afshin et al., 2019).

Given the major impact of diet on health, it is important to research the tools that are best suited to investigating dietary exposures in a given population.

1.5.2 Dietary assessment tools used for the investigation of dietary patterns in relation to NCDs

Measuring dietary exposures requires the use of adequate DATs that can help in understanding the impact of dietary factors on disease. Adequate dietary intake assessment is important not only in the study of associations between diet and health-related outcomes but also for nutritional surveillance and the evaluation of the nutritional status of patients in clinical settings (Naska et al., 2017). The section below evaluates the different methods of measuring dietary intake, which is a necessary step for selecting the most appropriate DAT for the objective of this study.

1.5.2.1 Methods of dietary intake assessment in nutritional epidemiology

In nutritional epidemiology, the assessment of the nutritional status of individuals is required in order to investigate the relation of the dietary exposure to the disease status, therefore, DATs that can measure intake at the individual level are more relevant (Willett, 2013). The selection of the appropriate tool to assess food consumption at the individual level will depend on different parameters such as the research objectives, the need for absolute or relative intake estimations; the level of accuracy and precision required, the characteristics of the study population, the time frame of interest, the financial resources, etc. (Biró et al., 2002; Willett, 2013).

There are objective and subjective methods of dietary assessment. Each has its inherent strengths and limitations (Shim et al., 2014). Subjective methods rely on self-reported intake and encompass 24-hour recalls (24HRs), dietary records (DRs), diet histories (DHs) and food frequency questionnaires (FFQs). Objective methods rely on dietary biomarkers which are assumed to be independent of bias and errors associated with self-reporting of dietary intake and bias introduced by the use of food composition tables (Naska et al., 2017).

1.5.2.1.1 Nutritional biomarkers for objective dietary assessment

According to Potischman, a nutritional biomarker is a "Biological specimen that is an indicator of nutritional status with respect to intake or metabolism of dietary constituents" (Potischman & Freudenheim, 2003). As an objective method for the assessment of dietary exposure, any compound in food or food metabolite which is associated with exposure and that can be measured objectively can be used as a nutritional marker (Kuhnle, 2012). Depending on the relationship between intake and biomarker, nutritional biomarkers are divided into four main classes as shown in Table 1.

Table 1: Classification of nutritional biomarkers used in nutritional epidemiology

	Correlation to intake	Uses in epidemiology	Examples of biomarkers	Factors influencing the biomarker
Recovery biomarkers	Excretion levels are highly correlated with intake	Used as objective measures of true intake	DLW: Used for the measurement of TEE 24-hour urine samples: Used for protein, potassium, and sodium intake.	Not affected by metabolism or inter-individual differences in metabolism
Concentration biomarkers	Good correlation with intake but lower than for recovery biomarkers	Used to rank the intake of specific nutrients, cannot be used to estimate absolute intake nor validate other DAT	Carotenoids, lipids, vitamin C	Affected by metabolism or inter-individual characteristics (sex, age, obesity, etc.)

Table 1: Classification of nutritional biomarkers used in nutritional epidemiology (continued)

	Correlation to intake	Uses in epidemiology	Examples of biomarkers	Factors influencing the biomarker
Predictive biomarkers	Shows a dose-response relationship with intake level but does not reflect intake completely	Used to rank the intake of specific nutrients, cannot be used to estimate absolute intake nor validate other DAT	Urinary sucrose and fructose as markers of sugar intake	Affected by personal characteristics

Data adapted from Corella and Ordovás (2015).
DAT = Dietary assessment tool; DLW = Doubly labeled water; TEE = Total energy expenditure

1.5.2.1.2 Subjective methods of assessment of dietary intake used in epidemiological research

Most of the dietary assessment tools that are used in epidemiological studies are subjective dietary assessment methods that rely on self-reported dietary intake. They can be divided into prospective and retrospective methods (Shim et al., 2014).

1.5.2.1.2.1 Prospective methods of dietary assessment

- Dietary record method

A dietary record (DR) (also called food diary or food record) requires a subject to record their own dietary intake for 24 hours, at the time the foods are eaten to minimize reliance on memory. Food intake is typically recorded over a period of 3 to 7 days. Subjects are encouraged to record any food consumed with as much detail as possible (Gurinović et al., 2017). For composite dishes, the amount of each raw ingredient used in the recipe should be quantified and the final amount of the composite dish recorded, and the amount in a serving of commercial products consumed and their brand names should also be recorded (Gurinović et al., 2017; Johansson, 2006). According to the way the quantification of the foods consumed is performed, there are two types of food records: Estimated and weighted (Gurinović et al., 2017; Johansson, 2006).

The weighed food record (WFR) requires the participant to weigh all foods and beverages to be consumed before recording them (Gurinović et al., 2017). This method is considered the "Gold standard" of individual quantitative dietary assessment tools (Johansson, 2006) because it is designed to provide the most precise food amount quantification that can be provided by a participant. Conversely, DR estimate foods and beverage quantities with the use of household (HH) measuring tools such as standard measuring cups or spoons (Gurinović et al., 2017; Johansson, 2006).

The main advantage of DRs is that they do not allow for memory as a source of error since respondents are required to record foods and beverages as they are consumed throughout the reporting day (Johansson, 2006). However, these methods require training the participants to record the food items to be consumed in an adequate and timely manner (Gurinović et al., 2017). Therefore, only participants who are literate and highly motivated can be enrolled in studies using WDR or DRs as a DAT. If the participants are fatigued or if they lose their motivation, their drop-out rate may be high resulting in attrition bias, with the remaining participants probably being the more health and food conscious (Gurinović et al., 2017; Johansson, 2006). Another source of error may be introduced if participants decide to change their eating behavior while keeping the diet record, either to minimize the burden associated with recording foods or by selecting foods that are more socially acceptable to report, which may cause a change in usual eating patterns (Gurinović et al., 2017; Johansson, 2006). Other errors may occur if the respondents only fill out the record retrospectively rather than at the time of intake (Gurinović et al., 2017).

- Duplicate diet studies

A duplicate diet study requires participants to collect duplicate samples of all foods they consume separately in a container provided by the researcher. The foods can be collected over 24 hours or more according to the needs of the study. The samples collected are then homogenized and chemically analyzed (Gurinović et al., 2017).

As a prospective method, the duplicate diet study does not rely on the participant’s memory, its added advantage compared to the DR is that it does not require the participant to weigh or estimate the food consumed (Gurinović et al., 2017). Moreover, unlike all subjective DATs, the intake estimation is derived directly from duplicate portions rather than from the use of FCTs, thus reducing the errors in nutrient estimates that can be introduced due to the use of the use of the latter (Gurinović et al., 2017). This makes the method be of choice if the corresponding FCT is not available or lacking information on the nutrients of interest (e.g. if a study tries to estimate the intake of selenium but its values are lacking in the source FCT).

However, this method shares the same disadvantages as the DR, as it also incurs the risk of fatigue and demotivation of the participants and the risk that they may alter their dietary patterns or not collect all the food consumed (Gurinović et al., 2017). Additionally, the time and resources required make this method not suitable for large-scale food consumption studies. It is rather reserved for use in small surveys or in particular population subgroups where the use of chemical analysis is preferred to

FCTs, such as in the assessment of minerals or exposure to dietary contaminants (Gurinović et al., 2017).

1.5.2.1.2.2 Retrospective methods of dietary assessment

- 24-hour recalls

The 24HR method is an in-depth interview, traditionally conducted by a trained dietary interviewer either face to face or via the telephone (Willett, 2013). The participants are asked to recall and describe in detail and in an open-ended manner all foods and beverages they consumed over the preceding 24 hours, including, if possible, brand names and cooking methods. Mineral and vitamin supplement use is also noted (Naska et al., 2017). 24HRs can also provide information about dietary habits such as adding salt at the table or contextual information (location and timing of consumption, consuming food in front of the TV, etc.) that can be used for a more comprehensive interpretation in nutritional assessment (Gurinović et al., 2017).

The main advantage of the 24HR is that a relatively minimal burden is imposed on respondents as only 20 to 30 minutes are required to complete a single day recall (Shim et al., 2014). When an investigation of usual dietary intake is required, interviews covering a longer time period are necessary (Shim et al., 2014; Willett, 2013). However, as a retrospective method, one of the main issues with the use of a 24HR is its reliance on the respondent's memory and on their ability to accurately describe the type and amount of food consumed (Gurinović et al., 2017). Moreover, the method relies on the interviewer's skills for questioning that should be conducted without the use of leading or judgmental questions, as this may lead to more sources of errors such as social desirability and social approval (Gibson et al., 2017).

The ability to recall food intake has been associated with age, gender, intelligence, mood, attention, and consistency of eating patterns (Willett, 2013). To reduce the errors due to participants' recall ability and to improve the interviewer's probing skills, the USDA developed the Multiple-Pass Method (MPM) in 1999 (Moshfegh et al., 2008). It was a 5-step structured dietary interview developed according to cognitive principles and practical experience where participants receive cues to help them remember and describe foods they consumed (Moshfegh et al., 2008). This method has since been increasingly used in dietary surveys (Moshfegh et al., 2008). The 5 steps corresponding to 5 passes through the previous day consist of: The quick list, forgotten foods list, time and occasion, detail and review, and final review probe (Moshfegh et al., 2008). They are described below:

1) The quick list, an uninterrupted recall of the foods and beverages consumed the previous day by the participant;

2) The forgotten foods list includes a series of questions that probe for foods that are commonly forgotten during Step 1;

3) Time and occasion include questions about the time and occasion at which foods were consumed;

4) Detail and review, where respondents are asked specific questions about the foods consumed, such as the preparation and cooking methods, the type of fat used, if meats were consumed with or without the skin, etc. The amounts of food consumed can be estimated during this step with the help of "portion size estimation aids" (PSEA), which can be used to help reduce the error due to recalling the amounts of food consumed from memory. PSEA can be 3D food models, food images of food portions, household utensils, etc. (Faulkner et al., 2017).

5) the final probe review ensures that nothing was forgotten by reviewing food items, eating occasions, or relevant details if appropriate.

Since 2002, a computer-assisted version of the 5-step method, the Automated Multiple-Pass Method (AMPM) was developed. The AMPM navigates the interviewer through the recall, posing standardized questions, and providing response options for different foods and beverages.

When tested under controlled conditions, the USDA five-step MPM accurately assessed the intakes of energy, protein, carbohydrate, and fat in both men and women, regardless of their body mass index (BMI) (Conway et al., 2004; Conway et al., 2003; Moshfegh et al., 2008). The AMPM has been used since 2002 to collect 24HR dietary intakes in What We Eat in America (WWEIA), the dietary interview component of the National Health and Nutrition Examination Survey (NHANES) (Moshfegh et al., 2008). The MPM was also incorporated in automated self-administered tools, such as the National Cancer Institute's Automated Self-Administered 24-Hour Dietary Assessment Tool (ASA24) to conduct the dietary interview for the NHANES (Bierhoff et al., 2020; Subar et al., 2012).

Other limitations concerning all short term dietary assessment methods in general (24HR and DR) are caused by their open-ended format which requires considerable efforts for data collection, entry by matching foods with the appropriate food listed in the FCDB, and then analysis (Shim et al., 2014). This process is time-consuming and laborious. Moreover, 24HRs and DRs do not represent usual intake or inform dietary patterns unless they are performed on many days (Willett, 2013). These constraints make them costly and not appropriate to use in large epidemiological studies (Willett, 2013).

- Dietary history

Burke developed a dietary history method in 1947 to assess individual long-term dietary intake, (Johansson, 2006). This method consisted of three parts; 1) A collection of general information to estimate the respondent's usual eating pattern with a description of the foods consumed, their frequency of consumption, and the usual portion size expressed using standard household measures; 2) A questionnaire on the frequency of consumption of specific food items used to verify and clarify the information on the kinds and amounts of foods given as the usual intake in the first part; 3) A three DR using household measures (Johansson, 2006).

This assessment produces an abundance of dietary information which can be time-consuming to analyze and interpret (Gurinović et al., 2017). Furthermore, this method requires highly skilled interviewers that must be familiar with the study objective, local dietary practices etc., in order to provide good data quality (Gurinović et al., 2017). It is also expensive and time-consuming because it takes approximately 90 minutes to complete (Gurinović et al., 2017). Consequently, this method is rarely used in epidemiological studies (Johansson, 2006; Naska et al., 2017).

- Food Frequency Questionnaire

During the 1950s and 1960s, nutritionists started developing questionnaires for the assessment of habitual food intake based on a checklist of foods consumed over an extended period of time to counteract the limitations of short-term DAT (24HR and DR) (Cade et al., 2004). Years of refinement led to the adaptation of FFQ in the 1990s (Cade et al., 2004), which can be considered an advanced form of the checklist in the diet history method (Willett, 2013).

The basic form of an FFQ consists of 2 main components: A finite list of foods and beverages and a frequency of consumption response section for subjects to report how often each food was eaten over a determined time period, usually the past month or year (Willett, 2013). The food and beverage items included in the list depend on the objective of the study and the study population because dietary habits are greatly influenced by factors such as ethnicity, culture, individual preferences, and economic status (Shim et al., 2014). The foods selected should also be frequently consumed and important sources of nutrients, while at the same time contributing to the interindividual variability of intake in the population (Willett, 2013). The frequency of consumption is usually assessed by using a multiple-choice response format, most often with nine possible responses from never to six or more times per day (Bingham et al., 1997; Gurinović et al., 2017; Shim et al., 2014). Some FFQs also include questions about the frequency of intake and dosages of common supplements, such as the Block FFQ (Block et al., 1986). FFQ may or may not include questions on the usual quantity consumed. They are called “Non-quantitative” when they don’t ask about the portion size, “Semi-quantitative” when only one standard portion size is used per food line-item and “Quantitative” when they collect information on usual portion size, typically asking subjects to describe the amounts they consume on average, using the categorization of small, medium, and large portion sizes (Gurinović et al., 2017). FFQs can be self-administered or collected with the help of an interviewer, using the traditional paper-based format, or more recently, using an electronic format (Falomir et al., 2012; Shim et al., 2014). Depending on the length of the FFQ, they can usually be completed in approximately 30 to 90 minutes (Gurinović et al., 2017; Shim et al., 2014).

FFQs have major drawbacks. As other retrospective measurement tools, they introduce errors due to reliance on memory and self-reporting. Moreover, FFQs are less specific as they require cognitively complex procedures involved in the retrospective estimation of portion size and frequencies of consumption (Gurinović et al., 2017). However, FFQs have a major advantage: The ability to assess long-term 'usual' dietary intake at low cost to researchers, with less burden compared to other dietary assessment methods in a relatively simple and time-efficient manner (Shim et al., 2014). They are also convenient for large groups, making them the instrument of choice for large dietary epidemiological studies since the 1990s (Cade et al., 2004; Shim et al., 2014).

Popular FFQ include the Harvard FFQ (Willett et al., 1985), the Block FFQ (Block et al., 1986), the National Cancer Institute's (NCI's) Diet History Questionnaires (DHQ) (Subar et al., 2001) and the European Prospective Investigation into Cancer and Nutrition FFQ (EPIC)-Norfolk FFQ (Bingham et al., 1997; Bingham et al., 2001).

1.5.2.1.2.3 Dealing with errors in subjective dietary assessment tools

Subjective dietary assessment methods are prone to many measurement errors that can lead to inconsistent findings in even well-designed studies on diet-disease associations (Naska et al., 2017). Consequently, these errors must be understood and addressed in order to avoid misleading interpretations (Naska et al., 2017). Measurement errors in nutritional epidemiology can be random (non-systematic) or systematic (bias). Random errors refer to the random variations in dietary intake, they contribute to variability but don't influence the sample average (Bennett et al., 2017). Systematic errors, on the contrary, influence the sample average as the measurements consistently depart in the same direction from the true value (Bennett et al., 2017).
According to Willett (2013), random or systematic errors or a mix of both can occur at 2 different levels: Within a person and between persons, therefore, at least 4 types

of errors can exist in dietary assessments. Table 2 summarizes the different types of errors and their origins, the DATs that can generate them and some solutions for mitigating them.

Table 2: Different types of errors, their origin, and some possible solutions to reduce errors

Type of error[a]	Effect of the error on the mean[b]	Source of error[a]	Dietary instrument where error can happen[a]	Solutions for each type of error[a]
Random within-person errors	No effect, mean is an unbiased estimate of the mean usual intake	Day-to-day fluctuations in individual food choices	24HR DR	Collect more than one 24HR/DR per person
		Precision of the scale Low literacy / Lack of motivation	DR	Take the mean of 2 measurements with the scale Use another DAT e.g., 24HR if literacy and motivation are lacking
		Lack of awareness of portion sizes Difficulty with recalling foods	24HR FFQ	Use probing questions (24HR, FFQ) Use validated PSEA (e.g., food images)
		Difference in nutrient levels associated with foods in FCDB compared to actual amounts of nutrients consumed from foods	24HR FFQ DR	Use FCDB that uses chemical analysis of foods instead or borrowed data, that is updated and comprehensive (e.g., USDA SR DB)

Table 2: Different types of errors, their origin, and some possible solutions to reduce errors (continued)

Type of error[a]	Effect of the error on the mean[b]	Source of error[a]	Dietary instrument where error can happen[a]	Solutions for each type of error[a]
Random between-person errors	Mean of a large group is the true mean for the group, but the standard deviation for the group will be inflated	Overestimation of food intake for some individuals and underestimation for others (Seen in population surveys that use only 1 or 2-d 24HR/subject, and where the within-person random error is also present)	24HR DR	Account for misreporting by using rEI as a surrogate measure of the total quantity of food intake Collect more than one 24HR or DR per person if the intended purpose is to obtain the usual intakes of foods or nutrients in individuals
Systematic within-person errors	Incorrect mean, not averaged out if repeat measurements are done	Over or under-reporting of either the overall food intake or the intake of specific foods is systematic and specific to an individual e.g. misreporting linked to social desirability, such as obese subjects tend to report lower intake of sweets.	24HR DR FFQ	Account for misreporting by using rEI as a surrogate measure of the total quantity of food intake Use of structured dietary interviewing such as the MPM method in 24HRs Use validated PSEA (e.g. food images)

Table 2: Different types of errors, their origin, and some possible solutions to reduce errors (continued)

Type of error[a]	Effect of the error on the mean[b]	Source of error[a]	Dietary instrument where error can happen[a]	Solutions for each type of error[a]
Systematic between-person errors	Incorrect mean of a group, not averaged out if repeat measurements are done	Erroneous nutrient composition values for a common food that people report consuming to varying degrees. Error affects all individuals in the same direction, but not to the same degree because the use of these foods will differ among subjects	FFQ	Use FCDB that uses chemical analysis of foods instead or borrowed data, that is updated and comprehensive (e.g. USDA SR DB)
		Bias due to omission of a commonly eaten food from the list of foods of an FFQ, causing some subjects (but not all subjects) not to be able to report that particular food	FFQ	Construct FFQ based on a food list that is culturally specific and where frequently consumed foods are well researched
		Omission of different foods consumed in different seasons in FFQ and 24HR when they don't account for the difference of intake on weekdays vs weekends	FFQ 24HR	Construct FFQ based on a food list that is comprehensive of frequently consumed in all seasons For 24HRs, account for the difference of intake during the week
		The proper PS corresponding to the intake of the subject is not available (Extra-large or extra-small)	FFQ	Online FFQs that include images of a large choice of portion sizes may assist the subjects in choosing their portion size

Table compiled from Willett (2013)[a]; Bennet et al. (2017)[b].
24HR = 24h recall; DLW = Doubly Labeled Water; DR = Dietary Record; FCDB = Food Composition Database; FFQ = Food Frequency Questionnaire; PS = Portion size; PSEA = Portion size estimation aid; rEI = Reported energy intake; USDA SR DB: USDA Standard reference Database.

Given the importance of preventing measurements errors in DAT, a more detailed description of the solutions reported in the literature are outlined below.

Strategies for the reduction of measurement errors in dietary assessment tools:

Precautions to reduce measurement errors must be taken at each step, including the design, analysis, and interpretation of the study results. These precautions are essential because dietary intake data ultimately affects the interpretation of diet-health relationship as well as the assessment and monitoring of the content and quality of diets. Below are a few additional precautions to Table 2 that can be applied when conducting dietary assessment studies to reduce measurement errors (Gibson, 2005).

- Reducing random errors due to day-to-day variation in individual food choices:

To reduce error due to day-to-day variation, Willett (2013) recommends conducting three 24HRs, on 2 weekdays and 1 weekend day to capture both energy and nutrient variability of the diet. Studies that have evaluated the required number of 24HR to assess diet by comparing the rEI from 1 up to 7 days 24HR to estimates of daily energy expenditure (EE) derived from DLW also revealed that three 24HRs were sufficient to minimize the mean difference between reported and objectively measured intakes (Ma et al., 2009).

- Reducing systematic errors due to misreporting of dietary intake:

When the amounts and types of foods consumed are not reported correctly, any associations between nutrients estimates and disease outcomes will be distorted. Misreporting of dietary intakes is therefore a major concern to research on relations between diet and health (Probst & Tapsell, 2007). Researchers usually account for misreporting by using rEI as a surrogate measure of the total quantity of food intake, because all nutrients consumed are provided within the quantity of food required for the fulfillment of the energy requirements (Livingstone & Black, 2003), making any underestimation/overestimation of total EI correlated with underestimation/overestimation of the intakes of nutrients (Livingstone & Black, 2003). This correlation makes the evaluation of the validity of rEI a good surrogate for the evaluation of the general quality of the dietary data (Livingstone & Black, 2003). The validity of the rEI in dietary assessment studies is usually measured by comparing EI to total energy expenditure (TEE), assuming that during the time of the study, weight is maintained, and therefore EI equals EE (Livingstone & Black, 2003).

The gold standard for measuring TEE uses a biomarker, the DLW technique (Livingstone & Black, 2003; Mendez et al., 2011). However, this method is expensive, requires equipped laboratory settings, and only reflects a short period of time. It is therefore not often feasible in large-scale studies (Gibson et al., 2017; Rhee et al., 2015). Researchers often use other more feasible and indirect methods using established cutoffs for identifying misreporters. The use of restrictive cutoffs to identify misreporters have been reported to strengthen the associations with factors such as fat, sugar, and fiber consumption (Mendez et al., 2011). A common method used in nutrition research is based on the extent of the difference between rEIs and TEE (Mendez et al., 2011; Rhee et al., 2015). The first method uses the Goldberg cutoffs, which estimates EE based on height, weight, and self-reported physical activity levels (PALs). According to Goldberg et al. (1991), the ratio between EI and the basal metabolic rate (BMR) can be used to establish criteria for under and over-reporting of EI. The initial Goldberg equation has been restated by Black (2000), who defined new categories of dietary reporters according to their ratio between EI and EE in the following way: “true” energy reporters rEI/TEE = 0.77–1.28, Under-reporters rEI/TEE < 0.77, Over-reporters rEI/TEE > 1.28 (Rhee et al., 2015). Other EI/EE cutoff ratios have been used, e.g. ratio EI/EE between 0.68 and 1.32 (Leech et al., 2018).

A simpler method used in research excludes participants with implausible EI by using cutoffs for plausible EI. For example, Fallaize et al. (2014) excluded participants reporting EI over 4500 Kcal, and Brouwer-Brolsma et al. (2018) excluded female participants with EI < 500 kcal or >3500 kcal before running any analysis. This method is simpler and more straightforward in that it does not take energy requirements into account (Mendez et al., 2011; Rhee et al., 2015).

Studies using DLW have shown that underreporting is much more frequent than overreporting, reaching levels as high as 50% of EI underreported in all age and nutritional status groups (Schoeller, 1995). Underreporting of EI has been found to be associated with many factors, such as age, sex, BMI, or educational level (Livingstone et al., 1992; Probst & Tapsell, 2007). It is however most prevalent among obese subjects, as reported by many studies, probably for reasons linked to social desirability (Probst & Tapsell, 2007). Indeed, it has been found that obese participants tend to report relatively low intakes of foods high in fat and sugars that may be perceived as socially undesirable (Probst & Tapsell, 2007). This is problematic since obesity is an important factor in the studies exploring diet-NCDs relationships (Probst & Tapsell, 2007). Besides BMI, gender and age are also linked to misreporting, with older females underreporting to a higher degree than their younger counterparts and males of the same age (Probst & Tapsell, 2007). Moreover, misreporting of food intake is highly dependent on memory, lack of awareness of quantities of food consumed, and reluctance to disclose foods and/or amounts eaten (Probst & Tapsell, 2007). Overreporting is also encountered in dietary assessment studies, although it is less frequent, with studies indicating that less than 10% of participants over-report their intake (Johansson et al., 1998; Nielsen et al., 2009). Overreporting may also be associated with individual characteristics such as lack of awareness of portion sizes or desire to gain weight (Johansson et al., 1998; Mendez et al., 2011).

It is worth noting that the tendency of misreporting does not depend on the method of dietary assessment as it has been observed in different dietary assessment tool methods (Mendez et al., 2011). The use of structured dietary interviewing such as the MPM method described earlier and the use of validated PSEAs are two ways of decreasing misreporting. Moreover, since misreporting is linked to social desirability and the fear of judgment by the interviewer, the introduction of computerized dietary assessments such as the AMPM may encourage patients to report with less bias than in a verbal dietary assessment. Automated instruments also provide increased accuracy of food and nutrient intake information through the inclusion of food photographs to assist in portion size estimation (Probst & Tapsell, 2007).

- Reducing errors associated with the use of food composition tables/databases

Analyzing nutritional data gathered from dietary assessment surveys requires reliable and comprehensive FCTs/FCDBs for the conversion of reported food intake into nutrients. This process generates various random and systematic errors that are discussed below:

1) Converting the portion size of the foods reported to their respective weights must be done to accurately estimate the corresponding energy and nutrients content (e.g. From

measurement in cup to grams). The use of food images of portion sizes of known weights in grams can reduce the errors in this step (Gibson et al., 2017).

2) Accurate food matching happens when the exact description of the foods reported in a survey is found in an FCT/ FCDB and all the component values of interest are present in an adequate format (FAO/INFOODS., 2012d). Therefore, to avoid measurement errors, quality FCT/FCDB should be used for food matching. Some of the characteristics of low-quality FCTs/FCBDs are: (a) they contain a restricted number of foods; (b) they contain foods that are analyzed by non-accredited methods or when the analysis is performed, it is based on non-representative samples of foods; (c) they have many missing component values or many values that are borrowed from other FCDBs instead of being chemically analyzed (Gibson et al., 2017).

Often countries with low quality or inexistent FCDBs use the USDA SR DB as their core data and occasionally supplement it with country-specific data when available (Ahuja et al., 2013; De Bruyn et al., 2016). Borrowing components values from other FCDBs may engender systematic errors that may arise from the discrepancies in the expression of components, such is the case for carbohydrate, which is expressed as total carbohydrate in the USDA SR DB and as available carbohydrate in the UK DB as monosaccharide equivalents (MSE) (FAO/INFOODS., 2012c). This difference in expression is a major source of discordance between these 2 high-quality DBs (Charrondiere et al., 2004). Another example of bias is the use of the unit “International Unit” (IU) for vitamin A, (the unit used in food labels) versus the use of mg (used in most FCDBs). The use of non-country-specific FCDBs brings additional random errors that are due to the natural variability in animals or plants due to differences in feed, soil, and climate etc. (Kapsokefalou et al., 2019). It is therefore important that the FCDBs used for food matching are specific to the country of interest and to the ethnicity of the population being studied (Coulston et al., 2013). In the UAE, no formal FCT has been published to date. The only national resource is found in a recent PhD thesis where 23 traditional Emirati foods were chemically analyzed (Muhamad, 2016). In the past, nutrition surveys in the UAE used the United States Department of Agriculture Standard Reference the USDA SR DB (USDA, 2015) and the Kuwaiti FCT (Al-Amiri et al., 2009) to generate nutrient values for the foods reported (Dehghan et al., 2005; Ng et al., 2011).

3) When the foods reported originate from recipes of mixed dishes, the recipes must be representative of what is usually consumed in the population of interest and the calculation of the recipes must be performed in a way that takes into consideration the loss of water, fat and nutrients during the process of cooking (Bergström, 1994; Bognár, 2002; FAO/INFOODS., 2012d).

In summary, different DATs are used in research to obtain estimates of intake depending on their suitability to the objective of a study. Acknowledging their limitations and knowing how to mitigate the errors that they may engender are important factors that can help in the construction of DATs that can produce adequate results. Next, the DAT used in the Arab world and in the UAE are investigated.

1.5.3 DAT used in the Arab world and in the UAE

1.5.3.1 Use of DATs in nutrition research in the Arab world

According to a review of papers published between 2006 to 2015 on the research on nr-NCDs conducted in Arab countries, Naja et al. (2017) found that most of the research focused on laboratory-based studies, with only a small number of cohort and interventional studies. Only 6% of the papers assessed dietary patterns and 38.4% of the studies investigating dietary intake in relation to NCDs focused on single food items or food groups (such as fruits and vegetables, milk and milk products). FFQs were the main dietary assessment method used (51%), however, only 35% of these FFQs were validated in the population they were intended to be used in, which makes the majority of these FFQs of questionable quality as the reported estimation of dietary intake may not be accurate (Naja et al., 2017). Ng et al. (2011) also reported that only minimal research had focused on dietary and physical activity patterns in the Gulf region, despite large numbers of studies on prevalence rates of obesity and related NCDs (El Mugamer et al., 1995; Musaiger & al-Roomi, 1997).

As stated by Naja et al. (2017), the small number of studies reporting on NCDs in relation to the whole diet and food patterns compared to the larger number of studies focusing on single nutrients or single food groups proves that research in the region is still following the single-nutrient model, which, as described before, does not ascribe to the new focus of nutrition research related to NCDs that looks at the overall diet quality and food patterns to investigate the nutritional risk factors of NCDs rather than researching the effects of single nutrients or foods on NCDs (Mozaffarian, 2016).

To investigate dietary patterns, a few FFQ were developed in the last few years in some Arab countries; e.g., in Saudi Arabia, an FFQ was developed and validated in 2016 to investigate the dietary habits of the adult population (Gosadi et al., 2017). Another FFQ was developed for the investigation of the dietary patterns of obese Saudi young children (Almajwal et al., 2018). In Lebanon, a few FFQ were developed and validated to assess the dietary intake of children (Hammami et al., 2015; Moghames et al., 2016) and adults (Aoun, Bou Daher, et al., 2019; Harmouche-Karaki et al., 2020). Other Arabic countries, such as Jordan (Tayyem et al., 2014), Palestine (Hamdan et al., 2014) and Morocco (El Kinany et al., 2018) have also developed and validated FFQs to assess dietary intake of their adult populations in the last few years. Finally, in Kuwait, a web-based FFQ was recently developed and validated (Al-Awadhi et al., 2019).

1.5.3.2 Use of DATs in Nutrition research in the UAE

In the last 2 decades, many small studies based on questionnaires assessed the dietary habits of Emirati university students. The main finding of these studies showed that there was a higher consumption of a westernized diet compared to the consumption of traditional dishes (Al Dhaheri et al., 2014; Amine & Samy, 1996; Kerkadi, 2003; Musaiger & Abuirmeileh, 1998; Musaiger & Radwan, 1995). Only two studies (Dehghan et al., 2005; Ng et al., 2011) have used DATs to assess dietary intake in the UAE, one used an FFQ and the other used a 24HR as reported below.

1.5.3.2.1 FFQ developed in the UAE to assess usual dietary intake

The first study that used a DAT to assess the dietary patterns in the UAE was conducted in 2004 by Dehghan et al. (2005). They developed a semi-quantitative FFQ consisting of 153 and 152 food items for use in the UAE and Kuwait populations respectively as part of the Prospective Urban Rural Epidemiology (PURE) study (Dehghan et al., 2005). Pilot-testing the SFFQ for usual intake over the past year showed that UAE participants reported eating each day on average 3.4 servings of fruits, in the form of apples, oranges, or bananas, 3.1 servings of vegetables and 4.8 servings of cereals or rice, while meat was consumed nearly two times per day, mainly in the form of poultry

(Dehghan et al., 2005). Although the pilot testing of the semi-quantitative FFQ provided valuable insights on the food consumption patterns in the UAE, it had many limitations because the study included other Arab nationalities and was not exclusive of Emiratis and many foods specific to Kuwait were used as substitutes for foods consumed in the UAE. Moreover, the population sample was not random and was biased towards a younger group where females were more represented than males (Dehghan et al., 2005). This may have underestimated the overall consumption of foods such as dates, rice, and "laban" (buttermilk) which are reportedly preferred in older age groups (Musaiger & Abuirmeileh, 1998). The overrepresentation of women in the study underestimates the reporting of foods that are preferred by men. Although the Kuwaiti version of the FFQ was later validated in Kuwait (Dehghan, 2009), the SFFQ was not validated in the UAE population, which means that it may contain incorrect information that, if not taken into account, may lead to biased associations.

1.5.3.2.2 The UAE national nutrition survey (2009-2010)

To date, the only nationally representative survey that has studied the dietary patterns in the UAE was a study conducted in 2009 – 2010. It was conducted by the University of North Carolina (UNC) School of Public Health in collaboration with United Arab Emirates University (UAEU) School of Medicine (Ng et al., 2011). The survey was part of the larger UNC-UAE National Strategy for Environmental Health Project. It used a 24-HR to assess the habitual dietary intake of Emirati nationals (Ng et al., 2011). The dietary information collected included details on foods and beverages consumed during the previous 24 hours from three members of each of the 628 randomly-selected participating households, typically women, adolescents, and children (Ng et al., 2011).

Men did not participate in the survey. This 24HR survey confirmed the unhealthy food habits previously reported in small studies in the UAE such as increased snacking, high consumption of sugary drinks, and reduced physical activity, especially among female Emiratis and those living in urban areas (Ng et al., 2011). Some of the limitations of the survey were the non-reporting of the intake of Emirati males and the use of only one day 24h recall thus making this survey a poor reflection of the usual intake of Emirati nationals as food intake may vary substantially from day to day (Ng et al., 2011). The survey also relied heavily on the USDA SR DB (USDA, 2015) and the Kuwaiti FCT (Al-Amiri et al., 2009) to derive individual energy and nutrients intake. These sources of nutrient data however did not contain nutrient information of traditional foods consumed in the UAE. In the light of the above review, it is evident that the development of an FFQ that could allow for an accurate assessment of habitual dietary intake specifically in the adult Emirati population is warranted.

Next, a review of the structure and the recommendations for developing a tailor made FFQ for a target population is described.

1.5.4 Steps to the development of an FFQ

Developing an FFQ for use in dietary assessment studies is a highly technical task that requires attention to many details. This is performed in many steps, starting with defining the purpose of the FFQ, identifying the sources of information to construct the food list, defining the reference period of the FFQ, determining the portion sizes if needed, including additional qualitative questions according to the objectives of the study, querying about the intake of dietary supplements if needed, and finally constructing an associated FCT in order to translate the information derived from the FFQ into estimates of nutrient intake or rank individuals' energy and nutrient intake (Block et al., 1986; Cade et al., 2002).

Since developing FFQs is a laborious and time-consuming task, they are sometimes borrowed for use in studies that share a similar study group and research purpose (Thompson & Subar, 2017). Alternatively, FFQs can also be modified from an existing instrument and then adapted and validated for a new study population. Cade et al. (2002) reported that out of 227 FFQs reviewed, 54% used a modified version of an existing questionnaire. One of the most adapted FFQs for other studies is the Block FFQ (Block et al., 1986). In other cases, a new FFQ is warranted, such as when a study requires investigation of a specific study group that consumes different foods, has different food habits, a different ethnicity, culture, or economic status. The steps required for the development of a new FFQ are described below:

1.5.4.1 Defining the purpose of the FFQ

The design of an FFQ is highly dependent on the objectives of the study (Willett, 2013). The intent may be to collect data on the whole adult population, pregnant women, school-aged children, or some other specific group (Pérez Rodrigo et al., 2015).

The information needed may require the collection of data on the total daily diet or only certain food groups such as fruits and vegetables or foods that contain specific nutrients such as calcium or carotenoids (Thompson & Subar, 2017). The objective of the data collection may be to rank individuals (to discriminate according to intake) or to provide a measure of estimated intake (Willett, 2013). FFQs designed to estimate intakes such as in studies on nr-NCDs must collect comprehensive information on the diet which results in longer and more detailed questionnaires compared to FFQs that seek to evaluate food groups or specific nutrients or to rank individuals (Pérez Rodrigo et al., 2015).

1.5.4.2 Constructing the FFQ food list

An imperative quality of the food list is that it should contain the most informative foods consumed by the population of interest because the full variability of a population's diet cannot be captured fully in a finite food list (Block et al., 1986). Willett (2013) defines 3 general characteristics of the foods that should constitute an informative food list, they should be:

- Representative of the food habits and the most commonly consumed foods used by the population of interest;
- Having substantial nutrient content;
- Of variable intake across individuals in the population of interest.

Subar (2004) recommends using food intake data from national nutrition surveys when available, or collecting data by the means of 24HR or DR in the population of interest to derive the foods and portion sizes to add to the food list. Alternatively, focus groups or expert advice can be sought to help construct lists and appropriate food groupings for new culturally specific questionnaires (Cade et al., 2002; Subar, 2004). When empirical data are available, multiple regression techniques can be used to derive foods that are best predictors of dietary factors that can discriminate among individuals with varying levels of consumption of a nutrient of interest, e.g. intakes of fiber or vitamin C (Mark et al., 1996; McNutt et al., 2008). Alternatively, FCTs/FCDBs can be used to identify foods that contain the nutrients of interest (McNutt et al., 2008). Regardless of the method used to construct the food list, it should be tested in the target population to make sure the food names and descriptions are understandable, and that it provides the type of information sought by the investigators (McNutt et al., 2008; Subar, 2004).

1.5.4.3 Grouping of the food list in food groups

Once the food list is finalized, researchers may need to group certain food items together so that the food list is shorter, which may reduce the burden on the respondent while at the same time fulfilling the objectives of the study by covering the important foods (Cade et al., 2002). In their review of over 200 FFQs, Cade et al. (2002) found that the median food list of an FFQ was 79 items and varied between 5 to 350 items. Willett (2013) recommends 100 food items as the cut-off point at which the quality of answers would reduce thereafter due to boredom and fatigue.

Differences can be found between FFQs on grouping certain types of foods. Indeed, foods that can be eaten either alone or as a mixed dish (e.g. shrimps with rice or alone as a whole portion) can be reported in 2 different ways in an FFQ. They can either be presented combined in a single question in an FFQ (e.g. shrimp from all mixed dishes and consumed as a whole portion) where the respondent is asked to report the frequency of their combined consumption of the food from all the different dishes, or they can be presented separately and reported as part of the dish they are usually consumed with (e.g. one line for shrimp with rice, another line for shrimp with pasta, another line for garlic shrimp, etc.). The first approach requires an additional cognitive effort from the respondent, while the second may lead to double counting and overestimation of intake (Cade et al., 2002). The second approach may cover the identification of certain foods or nutrients that may be associated with specific diseases, for example, grouping all fats used for cooking in one line of an FFQ combines saturated fats and mono/polyunsaturated fats all in one line, without distinction, which can hinder any possible associations between specific types of fats and health outcomes (Bingham et al., 2003). Foods that share similar features of nutritional content and manner of serving are usually clustered together in subgroups as food lists must be shortened for practical reasons (Cade et al., 2002). For example, oranges and tangerines are clustered in the same line in the EPIC-FFQ (Bingham et al., 1997).

1.5.4.4 Frequency response questions

The frequency response section asks respondents to report how often each food item was consumed over a specified period of time. Most FFQs focus on the past six months to one year. Such long periods of time may cause an obvious problem of recall, especially for younger children or the elderly (Pérez Rodrigo et al., 2015). For these age groups, shorter time periods are usually preferable (Pérez Rodrigo et al., 2015). Many shorter FFQ have been developed (Sanjeevi et al., 2017; Toft et al., 2008). While the latter may not correctly estimate dietary patterns needing longer time periods to be observed, longer FFQ may be influenced by the season of the reporting rather than the entire year (Pérez Rodrigo et al., 2015). Indeed, studies have shown that memory of diet in the past can be biased by the present diet (Pérez Rodrigo et al., 2015).

Frequency questions can be either close or open-ended. In a closed-ended format, the frequency of consumption is assessed by a multiple response grid or independent questions asking respondents to estimate how often a particular food or beverage is consumed (Pérez Rodrigo et al., 2015). The advantage of close-ended questions is that they reduce coding time and increase the completion rate (Cade et al., 2002). Open-ended questions may yield more accurate estimates than close-ended questions as respondents can provide more information, for example on the consumption of ethnic foods (Cade et al., 2002; Jain & McLaughlin, 2000). However, this format presents the disadvantage of often having lower completion rates, more transcription errors, and a longer coding time (Cade et al., 2002). Many FFQ, such as the EPIC-FFQ use both types of questions (Bingham et al., 1997; Bingham et al., 2001).

The choice of the range of frequency options should be such that it allows for the discrimination between the respondents' variability of intake (Willett, 2013), from the most frequently consumed, such as staple foods through to foods that are rarely eaten but that are high in nutrients (e.g. Vitamin B12 in liver). Most FFQs with closed-ended format collect data using nine possible responses ranging from never or less than once per month up to 6 or more times per day and respondents have to choose one of these options i.e. the EPIC-FFQ (Bingham et al., 1997; Bingham et al., 2001).

1.5.4.5 Portion Size

Assessment of potion sizes is an important factor for the accuracy of food consumption surveys. The decision of adding potion sizes measurement to an FFQ depends on their purpose and on the availability of average portion size data in the population of interest (Cade et al., 2002). In the literature, there are three options with regard to portion sizes in FFQs as described in Table 3:

Table 3: Description of the different types of FFQs depending on the option of portion sizes they contain

Option of PS in the FFQ	Type of FFQ	Description
No portion information collected.	Food Propensity Questionnaire (FPQ)[a].	Used in conjunction with 24HR to add information about dietary patterns (required when only data from one or two 24HR per participant is available, which is not sufficient to describe the distribution of usual intakes[a]. Combining the FPQ estimates to the 24HR estimates allows the provision of covariate information that provides estimates of usual dietary intake[a,b].
A standard/ individual PS within a food line.	Semi-quantitative FFQ (SFFQ)[c].	Ranks individuals according to their relative level of dietary consumption. Can be used when the foods of interest are better reported in standard units such as units of fruits. May cause cognitive challenges to the participants when they try to adjust their usual PS to the standard PS provided[c].
Discrete portion size for each food line-item	Quantitative FFQs (QFFQ)[c].	Offers a clear presentation of PS questions and eliminates the uncertainty with how respondents report their average PS. Allows for the estimation of total energy and nutrient intake[c].

Table compiled from Gǿtzsche (2003)[a], Subar et al. (2006)[b], McNutt et al. (2008)[c].
24HR = 24h recalls, FFQ = Food Frequency Questionnaire, PS = Portion size.

Among the different types of FFQs described in Table 3, only quantitative FFQs can account for the variability of portion sizes in a population because they can depict a large range of expressions of PSs that varies based on age, gender, and body size (Almiron-Roig et al., 2018). Two validated and frequently used FFQ that employ this option are the Block Adult Questionnaire (Block et al., 1986) and the NCI DHQ (Subar et al., 2001). The Block FFQ depicts portion sizes in cups (e.g. 1/4 cup, 1/2 cup, and 1 cup), supported by pictures of food on a standard-sized plate within each line -item, while the

DHQ uses portion sizes that are specific to each food item, but without pictures (McNutt et al., 2008).

1.5.4.5.1 Estimation of portion sizes

Determining potion sizes accurately is one of the main challenges of all DATs (Sharma & Chadha, 2017; Timon et al., 2018). Portion size estimation aids (PSEAs) in the form of food images are often used in FFQs. Food images accompanying print FFQs are usually presented in a booklet or food atlas that represent the range of portions consumed by the target population (Nelson et al., 1996). Food photographs may be displayed in increasing sizes of three or more portions (small, medium, large) (Turconi et al., 2005), e.g. EPIC-SOFT Picture Book used up to 6 images of portion sizes to help participants in the EPIC survey estimate their portion sizes (Van K appel, 1994). This is in line with Nelson et al. (1996) recommendations which stipulate that four or more photographs per food are preferable for a more accurate reporting of portion sizes. Moreover, when possible, an even number of photographs (four, six, or eight) is preferred in order to prevent the tendency by subjects to pick the middle photograph (Nelson & Meyer, 1997). In computer and web-based FFQs, digital food images are typically used (Fallaize et al., 2014). Subar et al. (2010) found that portion sizes depicted in digital food images were estimated with a similar level of accuracy when compared to the same food pictures displayed as pictures on a poster.

1.5.4.5.2 Need for validation of food photographs

The accurate estimation of food photographs depends on how able and willing participants are to recognize the amount of food consumed (Robson & Livingstone, 2000).

It is therefore critical to validate food photographs in studies aiming at assessing diet at the individual level to ensure that the study population can assess portion sizes with an acceptable level of accuracy (Nelson & Haraldsdóttir, 1998). Nelson and Haraldsdóttir (1998) recognized that perception, conceptualization, and memory are the three main elements that affect portion-size estimation from food photographs. They define perception as the subject's ability to relate a quantity of food that is present in reality to an amount illustrated in a photograph. Conceptualization is defined as the subject's ability to develop a mental picture of a food portion not actually present and to relate to it in a photograph, while memory is the subject's ability to accurately recall the quantity of food eaten, which is influenced by conceptualization (Nelson & Haraldsdóttir, 1998).

Nelson and Haraldsdóttir (1998), reported that the accuracy of estimation of portion sizes by the perception method depends on the number of photographs used. They noticed that a single or average photograph was associated with much larger errors in the estimate of portion sizes than the use of a series of eight photographs. Moreover, it was also reported that large portion sizes were more likely to be underestimated, while small ones tended to be overestimated, creating a flat-slope phenomenon (Nelson & Haraldsdóttir, 1998; Subar et al., 2010). Factors such as age, gender, body size, study conditions and type of foods can all influence the accuracy of estimation of portion sizes, with older adults and children, men and obese individuals more likely to misestimate portion sizes (Almiron-Roig et al., 2013; Frobisher & Maxwell, 2003; Harris-Fry et al., 2016; Nelson et al., 1996; Subar et al., 2010; Timon et al., 2018). Foods that are more likely to be inaccurately estimated are amorphous foods (e.g., mashed potatoes, cereals) and foods usually eaten in smaller portions (e.g., spreads, peas or mixed vegetables)

(Howat et al., 1994; Nelson et al., 1996; Nelson & Haraldsdóttir, 1998). Depending on the instrument used for dietary assessment, some types of errors are more relevant than others. For FFQ, the accuracy of conceptualization and memory skills are critical because portion sizes need to be remembered by the participant (Nelson & Haraldsdóttir, 1998).

The sections of an FFQ described above are the most essential parts. Some FFQ may include additional sections, depending on the study objectives.

1.5.4.6 Supplementary questions in an FFQ

Supplementary questions that are qualitative in nature can be added to improve the accuracy of an FFQ. Qualitative questions, such as the ones added to the EPIC-Norfolk FFQ (Bingham (Bingham et al., 1997; Bingham et al., 2001) or the Harvard FFQ (Willett et al., 1985) cover the following subjects:

- Cooking methods;
- Treatment of fat on meat, this information can be used to adjust the fat intake and specific types of fat (Bingham et al., 1997; Bingham et al., 2001; Cade et al., 2002);
- Patterns of milk intake, as milk may be used sparingly in cereals or in larger or lesser amount in drinks);
- Patterns of salt intake, such as the addition of salt at the table;
- Brand name information, to correct nutrients values: e.g., breakfast cereals, oils, margarine, etc.

According to Cade et al. (2002), there is little evidence that proves that this type of qualitative information improves the validity of FFQs. Moreover, these questions require considerable effort to code and analyze. Some FFQs (e.g. EPIC-Norfolk FFQ, Harvard FFQ) can also include an open-ended section in which respondents may record consumption of other foods not included on the food list. This ensures that the participant's total diet is captured. This is mostly useful in populations consuming ethnic foods, or respondents whose diet is very unusual (Cade et al., 2002).

1.5.4.6.1 Cross-check section

Cross-check questions can also be included. They are used to correct for misreporting of certain food groups, mainly fruits, and vegetables as these groups tend to be overreported, particularly if each fruit or vegetable is listed in a separate line (Cade et al., 2002). Cade et al. (2002) don't recommend using cross-check questions for other food groups because they do not see a gain in validity by doing so (Cade et al., 2002). The agreement between a cross-check question and individual fruit or vegetable item questions can be assessed by creating a weighting factor that is calculated by dividing the number of servings per week from cross-check questions by the total number of servings per week from individual food items on the FFQ (Cade et al., 2002).

1.5.4.6.2 Quantifying supplement use

Traditionally, dietary assessment instruments only inquired about the intake of foods and beverages. However, the use of dietary supplements (DS) has been rising in popularity. In the United States for example, the use of DS has increased dramatically over the past 20 years, rising from 65% in 2009 to 75% in 2018, according to the 2019 Council for Responsible Nutrition (CRN) Consumer Survey on Dietary Supplements, with multivitamins, vitamin D and C being the most popular (CRN., 2019).

Since the DS marketplace is becoming increasingly international (Dwyer et al., 2018), it appears that DSs consumption in the UAE is also on the rise. Although there are no statistics on DS consumption in the UAE, they are however commonly sold at pharmacies, health stores, and supermarkets, which indicates a high demand. To back this assumption, two small studies conducted amongst university students in the UAE reported the popularity of consumption of DSs amongst the studies participants, where in one study, 48.6% of gym goers consumed whey protein and another 38.6% of gym goers consumed other supplements (Attlee et al., 2018). In the second study, one-third of the participants consumed DS, and two-thirds reported that in their opinion, the best way to obtain nutrients is through food and DS together (Alhomoud et al., 2016).

It is therefore necessary to include DSs in the design of FFQs in order to ensure a more complete nutrient assessment and to avoid misclassification of nutrient intake (Harnack et al., 2008). Popular FFQ including the Diet History Questionnaire II, the Harvard FFQ, the Block FFQ, the Women's Health Initiative FFQ all included questions on DS and validated the supplement data obtained from the FFQ (Bailey et al., 2019). However, a qualitative examination revealed that these FFQ differed in the number, dosage, frequency and duration of use of the DS, making comparison of intakes across studies using these FFQ difficult (Bailey et al., 2019). Dwyer et al. (2018) suggested that a list of common questions on DSs to add to FFQs could be helpful in improving comparability between studies. Furthermore, unlike foods, DS usage patterns can be very different from dietary patterns derived from foods because, unlike food, DS may be used sparingly, daily or seasonally (such as vitamin C in the winter, folates during pregnancy, etc.). Consequently, FFQ, which are designed to measure food intake may not be adapted to measuring DSs (Bailey et al., 2019). The measurement errors of usual nutrient intakes from DSs are not well researched and their dismissal may increase the biased estimates of population prevalence rates, which may affect the strength of nutrient-disease associations (Bailey et al., 2019).

Another challenge with DS is in quantifying the nutrient intake. While FFQ rely on available FCDB to generate estimates of nutrient content, maintaining a dietary supplement database containing analytical values in a similar manner to food databases is difficult as the number of new products on the market is very high (at least 85,000 products on the market in the US) (Bailey et al., 2019). Moreover, DS products undergo reformulation and rapid turnover (Bailey (Bailey et al., 2019). Contrary to reported foods that can be matched with generic foods if an exact match is not found on a FCDB (FAO/INFOODS., 2012d), matching a particular DS to a similar generic DS is more challenging, as the range of nutrients content between brands can be much higher than between similar foods (Bailey et al., 2019). Therefore, high-quality DS composition DBs that are frequently updated are necessary to ensure that no erroneous information is introduced due to the lack of inclusion of specific brands (Bailey et al., 2019). There are a 2 main high-quality DS composition DBs that are used to assign nutrient values to products reported in surveys and studies in the United States (Bailey et al., 2019):

1) The NHANES Dietary Supplement Database (NHANES-DSD), which provides information on the nutrient values of DS reported by NHANES respondents since 1999. It contains label information from prescribed and over-the-counter DS and default and generic formulations of products (Bailey et al., 2019).

2) The Dietary Supplement Ingredient Database (DSID): This DB, contrary to the previous one, derives the nutrient composition data of DS products analytically (not from the label), in a manner analogous to food databases. It has been developed by the USDA Nutrient Data Laboratory, in collaboration with the Office of Dietary Supplements (Bailey et al., 2019). To date, the DSID provides chemically estimated levels of 18 vitamin and mineral ingredients from 115 adult multivitamin/multimineral supplements (MVMs) (NIH., 2019). While the DSID DB provides an improved accuracy to nutrients estimates from some MVMs compared to label based DBs, its content is still minimal given the expanding and highly changeable market in these products, and the high cost of maintaining such a DB (Cade et al., 2002; Dwyer et al., 2003). Consequently, relying on a label-based DB (e.g. NHANES-DSD) is still required if DATs are to assess nutrient intake deriving from the use of DS.

1.5.4.7 Constructing an associated food composition table

When dietary data from an FFQ are obtained, a corresponding nutrient composition table must be developed simultaneously to convert the food intake data to nutrient intake data. Different methodologies have been used to generate the nutrient component values corresponding to single and composite food line-items of an FFQ (Subar et al., 2000). For single food line-items, the foods may be linked to a generic food code from an FCDB that matches the corresponding food line-item. This method may lack specificity when the FCDB is not specific to the study population where it is used (e.g. the generic food for “Nuts, Mixed, with Peanuts, Oil Roasted, with Salt Added”, from the USDA SR DB may encompass nuts not typically consumed in other countries).

Alternatively, the nutrient values of single food line-items may be obtained from nationally representative dietary intake data to improve the chances of an FFQ to reflect the reality of consumption in the population of interest, as described by Block et al. (Block et al., 1986). This methodology ensures that the most unbiased nutrient estimates for each food line-item are obtained. The Block method used NHANES data to derive for each food line-item the weighted median densities x sex-age-portion size median gram weights (Block et al., 1986; Subar et al., 2000). There is no consensus for assigning nutrient values to composite food line-items of an FFQ. Some FFQs simply apply the nutrient values of the one food that is most frequently reported in a line of aggregated foods to represent the nutrient composition of the whole line, thus not taking into account the other foods in the line (Willett et al., 1985). Other methods use both a combination of expert opinion and empirical data (Kristal et al., 1992). More accurate estimates may be obtained by using national food consumption surveys (if available) and assigning a nutritional value to each aggregated food item on the basis of the weighted means of the intake of the items included in the composite food line. This approach has been used for the development of the nutrients content of different FFQs (Shahar et al., 2003; Tucker et al., 2005). Consequently, according to the methodology of assigning nutrient values used, different FFQ nutrient databases can be obtained, which may yield different nutrient estimates by the same FFQ and different associations of diet-diseases relationships (Shahar et al., 2003; Subar et al., 2000).

Once an FFQ is constructed, its mode of administration can vary from print format to mobile application. The evolution of the mode of administration of FFQs has increased the scope of their advantages and reduced some of their inherent as described in the next chapter.

1.5.5 Evolution of food frequency questionnaires

1.5.5.1 Print FFQ

Traditionally, FFQs were print questionnaires and were either conducted by an interviewer or were self-administered. Interviewer-administered FFQs were preferred when literacy of the participants was low (Cade et al., 2002). Self-administered FFQs required more careful preparation and pre-testing because they were prone to many errors such as incomplete answers, errors due to skipped questions and missed responses and/or missed pages (Cade et al., 2002). These FFQs were also relatively costly when they were used in large epidemiological studies because of the costs associated with mailing to and from participants and issuing reminders by mail or by phone. Moreover, the subsequent work of data entry and the extensive work of data processing were burdensome (Lo Siou et al., 2017). Administering FFQs by telephone produced higher response rates than postal surveys and had the potential to reach larger numbers of people in widely scattered geographic areas (Cade et al., 2002).

1.5.5.2 Computer-based FFQ

By the 1990s, advances in computer science allowed the development of software applications that automated self-administered FFQs, allowing respondents to enter their own food choices in a computer program (Engle et al., 1990; Falomir et al., 2012; Heath et al., 2000). Computerized FFQs helped reduce measurement errors that were inherent to paper-based formats by eliminating researcher coding and entry errors and minimizing missing data, and allowed for an immediate and automatic control for incomplete and implausible data (Falomir et al., 2012). Moreover, they were efficient in saving time and resources because the answers could be stored automatically on databases easily accessible by the study centers, thus avoiding the costs of printing, mailing and data typing (Falomir et al., 2012). These computerized questionnaires had however the inconvenience of being operational only on a specific computer system, which impeded their use on a wider scale that was compatible with the requirement of large epidemiological studies (Lo Siou et al., 2017).

1.5.5.2.1 Web-based FFQ

The inconvenience seen with computer-based FFQs was greatly improved with the spread of the World Wide Web, which allowed the emergence of innovative tools that provided a larger accessibility and improved functionality to dietary instruments through the use of the internet (Falomir et al., 2012). Indeed, in the last 15 to 20 years, innovative dietary assessment technologies have been increasing (Falomir et al., 2012; Illner et al., 2012), creating a diverse range of innovative dietary assessment instruments, such as online tools (web-based); mobile systems (applications), camera-based tools and wearable sensors (Eldridge et al., 2018).

Automated (computer-based and web-based) FFQs can be found in the literature in the form of computer-administered FFQs (Engle et al., 1990; Heath et al., 2000; Wong et al., 2008), web-based FFQs (Fallaize et al., 2014; Kato et al., 2017; Labonté et al., 2012) or as mobile applications, such as E-epidemiology (Bejar et al., 2016) or E-Nutri (Zenun Franco et al., 2018).

The added advantages of web-based FFQs include their ability to communicate with geographically dispersed populations (provided they have a good connectivity to the internet), less missing data, enhanced reporting of portion sizes by the use of digital food images, better guidance with interactive visual aids and reminders, automated data entry that omits data entry errors, and higher flexibility of completion at any time and location (Falomir et al., 2012; Illner et al., 2012). Because of these advantages, online versions of some popular print FFQs were developed, e.g. the DASH FFQ (Apovian et al., 2010), the online DHQ in successive versions (DHQI, II, III) (NCI., 2016), and the online version of the block questionnaire "NutritionQuest" (NutritionQuest, 2016). The comparison of the print and the online versions of many FFQs (Beasley et al., 2009; Kato et al., 2017; Lo Siou et al., 2017) have shown that the results of both versions of the FFQs were comparable.

1.5.5.2.2 Challenges of computer-based FFQ

Although technology-based dietary assessment methods have drastically reduced many of the measurement errors of more traditional instruments, they do not appear to reduce the social desirability response bias, as shown by a recent report that demonstrated that subjects still underreported their diet in response to being surveyed, despite the non-interaction with an interviewer and the convenience of reporting provided (Naska et al., 2017). Moreover, the use of automated FFQs may generate other types of errors such as altered response behavior due to design issues and technical prerequisites or other methodology-associated measurement errors (Illner et al., 2012).

Although usability studies have shown that web-based FFQ are generally preferred to print FFQ (Eldridge et al., 2018) because of the popularity of technology tools among younger people (Eldridge et al., 2018), older adults may struggle if they are not familiar with computer technology (Cade, 2017). This proves that paper-based questionnaires still have their place in research, especially when studies are conducted on populations that are not technology savvy, such as older adults, or that have low literacy skills (Cade, 2017). In the UAE, 99% of the population are active internet users (GMI., 2017), and the country has a predominantly young population of Emiratis (Statistics-Centre., 2019). Consequently, a web-based FFQ could be more appropriate to use in this population than a print FFQ.

The quality of a newly developed FFQ must be assessed in order to determine the degree to which it can measure true dietary intake, because incorrect information may lead to false associations between dietary factors and diseases or disease-related markers (Cade et al., 2004). The quality of an FFQ can be measured by assessing its validity and reproducibility.

1.5.6 Validity and reproducibility of a Food Frequency Questionnaire

1.5.6.1 Reproducibility of an FFQ

Reproducibility of an FFQ is its ability to produce the same results when used repeatedly in the same circumstances (Nelson & Meyer, 1997; Willett, 2013). Since diets normally vary on a daily, weekly or seasonal basis, the measure of reproducibility will reflect both the true "biological" change in diet (within-subject variation) as well as the measurement error in the method. The interpretation of the reproducibility measures should account for these variations (Nelson & Meyer, 1997; Willett, 2013). Measuring the repeatability of an FFQ is usually done by administering the same FFQ twice to the same group of subjects and analyzing the association between the two responses (Cade et al., 2004).

1.5.6.2 Validation of an FFQ

The validity of an FFQ is the degree to which it can provide a true and accurate measure of what it was designed to measure; foods and nutrients (Johansson, 2006; Willett, 2013). Valid dietary data can be obtained when: 1) A person has eaten as usual and; 2) A person reports their true intake (Johansson, 2006).

1.5.6.2.1 Reference instruments used to validate FFQs

Measuring the validity of an FFQ implies that a comparison is made with a superior, more accurate method that is considered to be the gold standard (Willett, 2013). Since there is no method in nutrition science that is able to provide the absolute measure of true intake, the measure of validity can only be relative and assessed by another method that is judged to be superior (Willett, 2013).

1.5.6.2.1.1 Use of objective methods as reference instruments

The measurement of biochemical markers is often used in validation studies because they provide objective measures of intake, thus circumventing the errors due to recall and social desirability induced by FFQs (Slater, 2010; Weir et al., 2016). Most of the biomarkers used in large epidemiological studies are recovery biomarkers because they are the least invasive, while concentration biomarkers require serum samples or biopsies which limits the sample size (Willett, 2013), moreover, they are not reflective of absolute intake (unlike recovery biomarkers) and are influenced by metabolism, personal characteristics (e.g. age, sex), and lifestyle factors (e.g. smoking, physical activity) (Corella & Ordovás, 2015). Since these characteristics may also induce errors in subjective dietary assessment methods, concentration biomarkers are usually not used alone in validation studies but combined with the use of repeat 24HRs or DRs (Fayet et al., 2011; Harding et al., 2008). Other disadvantages of biomarkers measurements are that they are costly and cannot capture which foods and beverages were consumed (Cade et al., 2017), consequently, the traditional model of validation using two subjective dietary methods (a reference instrument versus an FFQ) are still the most used in validation studies (Willett, 2013).

1.5.6.2.1.2 Use of subjective methods as reference instruments

A subjective reference instrument must have the least correlated errors with FFQ. As such, the WDRs are considered the "Gold standard" of reference instruments for the validation of FFQs because they do not rely on memory, are open-ended and allow for accurate measurement of portion sizes (Carlsen et al., 2010; Willett, 2013). It is worth noting that the FCDB applied to convert the reported foods to energy and nutrients is still a common source of error since the interpretation of nutrient data of both the methods depends on the quality of the FCDB used (Willett, 2013). Cade et al. (2002) found that DR were used as reference instruments in 51% of the FFQ they reviewed, but only half of these records were WDRs. The drawback with WDR is that they require participants to be literate and highly motivated (Willett, 2013). When these requirements are not met in the participants of a study, the collection of multiple 24HR is generally the alternative used for evaluating FFQs, even though they have a higher probability of correlated errors with FFQ, as both the methods rely on memory and perception of portion sizes (Willett, 2013).

Whichever the choice of the reference instrument, the factors that need to be considered in the design of validation studies are the sample size, the number of recording days of the reference instrument, the sequence of administration, and the statistical tests.

1.5.6.2.1.3 Sample size

The recommended sample size varies according to different criteria and authors: Willett (2013) noted that the sample size will depend on the level of precision required and the type of nutrient studied, recommending a sample size for a validation study of 100 to 200 people. Cade et al. (2004) advised in their review of FFQs that the required sample size will differ with the statistical test employed, for the Bland – Altman method, the sample size should be large enough to allow the limits of agreement (LOA) to be estimated precisely, in which case, a sample size of at least 50 is acceptable, while for the correlation analysis, the sample size would depend on the expected association between the two measures or methods. They advise that based on the CC desired and assuming that the amount of recorded days is sufficient to describe the participant's usual diet accurately, a sample size of no more than 100 to 200 should be sufficient. CCs in validation studies usually fall within the range of 0.4 to 0.7 according to a review of validation studies done by Thompson and Buyers (1994).

1.5.6.2.1.4 Sequence of Administration:

Willett (2013) advises that administering an FFQ can be done before, after, or both prior and post completion of the reference instrument. He notes that administering the FFQ before the reference instrument results in an artificially low correlation, as the questionnaire relates to diet before the period of detailed assessment, while administering the FFQ after the end of the study may influence awareness of the foods consumed. To reduce the disadvantages from both these approaches, the average of the result of both the FFQs (before and after) can be used, or alternatively, a random selection of either the first or second FFQ could be used for each participant.

1.5.6.2.2 Statistical methods used in validation studies

The validity of an FFQ can be assessed using a variety of statistical methods. There is no consensus on the most appropriate technique to use (Gibson, 2005; Lombard et al., 2015). In general, there are four main methods of analysis that are used to establish the validity of an FFQ: Comparison of mean values and Bland Altman at the group level, and correlations and cross classification and weighted Kappa statistic at the individual level (Lombard et al., 2015). Willett et al. (1997) recommend adjusting for EI when validating FFQs designed for use in epidemiological studies because total EI intake is a potential confounder for disease outcome. They recommend 2 main methods for adjusting for EI: The nutrient density method, where the nutrient intake is divided by total EI and expressed as percentage of energy or as intake per 1000 kcal, and the residual method, where the energy-adjusted intake estimate is the residual from a regression model in which total EI is the independent variable and absolute nutrient intake is the dependent variable (Willett et al., 1997). In the latter method, the estimated nutrient intake is uncorrelated with total EI and is directly associated with the overall variation in the composition of food intake, making it the preferred method in studies exploring the association of dietary exposures with NCDs (Willett et al., 1997).

1.5.6.2.2.1 Comparison of mean values

To assess the relative validity at the group level, the means or medians of the nutrients obtained from the FFQ and the reference method can be compared (Gibson, 2005). This test will indicate if there is bias in the FFQ when significant differences are found between the means or medians of the FFQ and the reference instrument, and when these differences are all in the same direction (Gibson, 2005). The comparisons between test and reference methods of energy, nutrient and food intake can be examined by Student´s t-test if the distribution is normal, or by Wilcoxon's signed rank test for paired data to compare the median for non-parametric distributions (Johansson, 2006). Thompson and Byers (1994) reported that, food frequency instruments with very long lists of foods tend to yield higher estimates of food and nutrient intake compared to reference methods, which may result in unrealistic caloric intakes. They advise to adjust for total EI when analyzing nutrient intake estimates derived from FFQs.

1.5.6.2.2.2 Correlation coefficients

Correlation analysis is the most commonly used method to measure the strength and direction of the association at the individual level between the intakes of a test and the reference method (Gibson, 2005). The data distribution (normal or skewed) will determine whether Pearson's or Spearman rank correlations respectively should be used

(Gibson, 2005). When the chosen reference method uses multiple days, such as multiple 24HR, the effect of large within-subject variations in nutrient intakes will lower and make less significant any existing correlations. To adjust for the effects of day-to-day variation, de-attenuated CCs are recommended (Gibson, 2005). Bland and Altman (1986) argue that CCs are not appropriate to use as the sole determinant of validity (Gibson, 2005) because a positive correlation is to be anticipated when two dietary assessment methods are used to measure the same variable, therefore producing inflated measures of agreements. They argue further that CCs do not provide any insight into the extent of agreement between two measurements since a poor agreement can still exist between a test and reference method even when CC are very high (Bland, 1986; Gibson, 2005). This is because a high correlation will still occur if the test method generates results which are exactly a fixed proportion greater or less than the reference method. Such bias is not detected by correlation analysis (Gibson, 2005). Despite these limitations, Cade et al. (2004) indicated that 83 % (168) of the studies reviewed used CCs to compare between methods. They recommended in their review using CCs in conjunction with the Bland–Altman method which assesses agreement (Cade et al., 2004).

1.5.6.2.2.3 Bland-Altman analysis

Bland-Altman analysis involves plotting the difference between the measurements (test - reference measure) (y-axis) against the mean of the two measures (x-axis) for each subject and drawing the line of equality (Bland, 1986). Visualization of the plots obtained identifies outliers outside of the LOA (defined as the mean difference ± 1.96 SD of differences) and indicates the presence of bias in the test method if the data for the component of interest falls preferentially either above or below the line of equality, rather than being scattered homogeneously along the line of equality (Gibson, 2005; Lombard et al., 2015).

1.5.6.2.2.4 Cross-classification and weighted Kappa statistic

Cross-classification enables the classification of the participants in both methods into categories, usually according to terciles, quartiles, or quintiles depending on the sample size (Gibson, 2005). The calculation of the percentage of participants correctly classified in the same category and the percentage misclassified in the opposite category indicates to what extent the test method is able to rank participants into classes of intake, which reflects agreement at the individual level (Lombard et al., 2015). This ranking of dietary intake data is especially important in the investigation of diet-disease associations (Beaton, 1994; Lombard et al., 2015).

Because some of the agreement in cross-classification of data may be due to chance, the Cohen's weighted Kappa coefficient is sometimes used to bypass this limitation (Gibson, 2005). The weighting applied and the number of categories included in the scale determines the magnitude of weighted Kappa coefficient values (Lombard et al., 2015). They range from −1 to 1 with values usually between 0 and 1 (Lombard et al., 2015). Values closer to zero are considered due to chance, while negative values indicate agreement "worse" than can be expected by chance alone (Lombard et al., 2015). The Kappa coefficient does not take into account the degree of disagreement between methods and all disagreement is treated equally as total disagreement (Lombard et al., 2015).

The next chapter reviews published validation studies performed on web-based FFQs because it is the format intended for use in this study.

1.5.7 Review of studies of automated FFQs in the literature

1.5.7.1 Automated FFQs in the literature

Although many automated FFQs have been developed in the last few years, only a few have been validated. The automated FFQs found in the literature have been developed and validated in different countries and for different research objectives. Only one study has reported the validation of a web-based FFQ in an Arabic country, the EatWellQ8 FFQ, in Kuwait (Alawadhi et al., 2019).

Some FFQs assessed specific nutrients intake such as iron, calcium, omega-3 and omega-6 polyunsaturated fatty acids (PUFA) (Heath et al., 2000; Swierk et al., 2011; Wong et al., 2008). Other automated FFQs assessed a specific food group intake, e.g. Vandelanotte et al. (2004) validated a computerized questionnaire to measure fat intake in Belgian adults. Automated FFQs were also developed and validated to assess dietary intake in different age groups, e.g. children below 6 years old (Nyström et al., 2017), adolescents and university students (Du et al., 2015; Matthys et al., 2007; Segovia-Siapco et al., 2016). Some studies have validated automated FFQs that assess intake of populations with specific conditions such as diabetes, cardiometabolic diseases or prostate cancer (Allaire et al., 2015; Bentzen et al., 2016; Verger et al., 2017) or specific life stages such as pregnancy (Knudsen et al., 2016) or preconception (Salvesen et al., 2019). The literature shows however that, the majority of web-based FFQs have been developed and validated for populations of healthy adults (Fallaize et al., 2014; Feng et al., 2016; Kato et al., 2017; Labonté et al., 2012).

1.5.7.2 Review of automated FFQs having assessed usual dietary intake among adult populations

In line with the objective of this study, a review of selected web-based FFQs that assessed usual dietary intake among adult populations is presented below (Table 4).

Table 4: Studies on validation of web-based Food frequency questionnaires for assessment of usual dietary intake in healthy adults

#	Reference and country of study	Time period covered by FFQ	Name of the FFQ	Study population; Reference method	Results (Pearson or Spearman Correlations coefficient (r) for energy and selected nutrients)	Illustration of Portion size
1	(Labonté et al., 2012); Canada	Past one month	Web-FFQ	Adults (n = 69; Mean age: 37.1±14.2 y); compared Web-FFQ with a 3-d DRs	Energy r = 0.58 (p < 0.0001) Macronutrients (Energy adjusted) Fat: r = 0.15, CHO: r = 0.55, Protein: r = 0.52 Micronutrients range (Energy adjusted) Iron: r = 0.25 – Sodium: r = 0.80	Digital food portion photographs
2	(Kato et al., 2017); Japan	Past one year	Web-FFQ	Adults (n = 237; Mean age: 57.4 ±8.6 y); compared Web-FFQ with a 12-day WDRs	Energy r = 0.18 (p < 0.01) for women, r = 0.42 (p <0.01 for men) Macronutrients (de-attenuated, sex and energy adjusted) Fat: r = 0.39, CHO: r = 0.51, Protein: r = 0.40 (for women) Fat: r = 0.47, CHO: r = 0.74. Protein: r = 0.46 (for men) Range micronutrients (Energy adjusted) Beta-tocopherol: r = 0.16 - Vitamin B12: r = 0.61 (for women) Iodine: r = 0.10 - Cryptoxanthin: r = 0.67 (for men)	No visual artifices or photographic images of food items

Table 4: Studies on validation of web-based Food frequency questionnaires for assessment of usual dietary intake in healthy adults (continued)

#	Reference and country of study	Time period covered by FFQ	Name of the FFQ	Study population; Reference method	Results (Pearson or Spearman Correlations coefficient (r) for energy and selected nutrients)	Illustration of Portion size
3	(Fallaize et al., 2014); United Kingdom	Past one month	Food4Me FFQ	Adults ($n = 49$; Mean age 26.9 y); compared Web-FFQ with a 4-day WDRs	Energy $r = 0.53$ ($p < 0.01$) Macronutrients (Unadjusted) Fat: $r = 0.56$, CHO: $r = 0.43$, Protein: $r = 0.59$ Micronutrients (Unadjusted) 0.23 (vitamin D) to 0.61 (Total sugar)	3 Food portion photographs
4	(Christensen et al., 2013); Sweden	Past 3 months	Meal-Q	Adults, ($n = 163$; 20-63 y), Meal-Q compared to 7-d WDRs and DLW (for energy)	Energy $r = 0.18$ ($p < 0.01$) (with 7dWDR) $r = 0.42$ ($p < 0.001$) (with DLW) Macronutrients vs. 7dWFR (Deattenuated and Energy adjusted) Fat: $r = 0.55$, CHO: $r = 0.62$, Protein: $r = 0.3$ Micronutrients (Energy adjusted) $r = 0.33$-0.74 for macronutrients 0.16 (riboflavin) to 0.66 (fiber)	5 standard photos of portion sizes Standard PS

Table 4: Studies on validation of web-based Food frequency questionnaires for assessment of usual dietary intake in healthy adults (continued)

#	Reference and country of study	Time period covered by FFQ	Name of the FFQ	Study population; Reference method	Results (Pearson or Spearman Correlations coefficient (r) for energy and selected nutrients)	Illustration of Portion size
5	(Du et al., 2015); China	Past 4 months	Internet-based diet and lifestyle questionnaire for Chinese (IDQC)	Male College students: (n = 644, mean age:21.2 ± 1.9y) IDQC vs 3-d Rs	Energy r = 0.69 (p < 0.05) Macronutrients (Energy adjusted) CHO: r = 0.57, Protein: r = 0.65, Micronutrients range (Energy adjusted) Vitamin C: r = 0.28 - Iodine: r = 0.98 (for men)	Images of each food item's weight/volume
6	(Feng et al., 2016); China	Past 4 months	Internet-based diet and lifestyle questionnaire for Chinese (IDQC)	City residents (n = 292, range: 18 - 65 y) IDQC compared to 3 24HRs	Energy r = 0.51 (p < 0.05) Macronutrients (Energy adjusted) Fat: r = 0.59, CHO: r = 0.46, protein: r = 0.53 Micronutrients range (Energy adjusted) Folic acid: r = 0.37 - Iodine: r = 0.98	Standard food photographs

Table 4: Studies on validation of web-based Food frequency questionnaires for assessment of usual dietary intake in healthy adults (continued)

#	Reference and country of study	Time period covered by FFQ	Name of the FFQ	Study population; Reference method	Results (Pearson or Spearman Correlations coefficient (r) for energy and selected nutrients)	Illustration of Portion size
7	(Kristal et al., 2014); USA	Past 3 months	Graphical Food Frequency System GraFFS	Adults (n = 74, age 18-69 y) Compare web-FFQ with 6 phone 24HRs	Energy $r = 0.39$ ($p < 0.001$) Macronutrients (De-attenuated and Energy adjusted) Fat: $r = 0.82$, CHO: $r = 0.79$ Micronutrients range (De-attenuated and Energy adjusted) β-carotene: $r = 0.43$ - Zinc: $r = 0.43$	Food portion photographs

Table 4: Studies on validation of web-based Food frequency questionnaires for assessment of usual dietary intake in healthy adults (continued)

#	Reference and country of study	Time period covered by FFQ	Name of the FFQ	Study population; Reference method	Results (Pearson or Spearman Correlations coefficient (r) for energy and selected nutrients)	Illustration of Portion size
8	(Beasley et al., 2009); USA	Past 1 year	Web – Pictorial Diet History Questionnaire (Web-PDHQ)	Adults (n = 218, mean age: 54.9±14.4 y); compared Web-PDHQ with 2-d DRs and 2 24HRs	Energy (with DRs) r = 0.39 (p < 0.001) Energy (with 24HRs) r = 0.18 (p < 0.001) Macronutrients (Energy adjusted) (with DR) Fat: r = 0.39, CHO: r = 0.30, Protein: r = 0.40 Macronutrients (Energy adjusted) (with 24HRs) Fat: r = 0.30, CHO: r = 0.38, Protein: r = 0.45 Micronutrients range (De-attenuated and Energy adjusted) (with DRs) Energy-adjusted correlations Vitamin E: r = 0.25 to Vitamin C: r = 0.57 Micronutrients range (De-attenuated and Energy adjusted) (with 24HRs) Energy-adjusted correlations Vitamin E: r = 0.19 to: Calcium: r = 0.55	Food portion photographs

Table 4: Studies on validation of web-based Food frequency questionnaires for assessment of usual dietary intake in healthy adults (continued)

#	Reference and country of study	Time period covered by FFQ	Name of the FFQ	Study population; Reference method	Results (Pearson or Spearman Correlations coefficient (r) for energy and selected nutrients)	Illustration of Portion size
9	(Alawadhi et al., 2019); Kuwait	Past 1 week	EatWellQ8	Adults (n = 46, age 35, ± 8.4); compare FFQ with 4-d WDR	Energy Not available Crude unadjusted correlations r: (0.40-0.88)	Digital food photographs
10	(Affret et al., 2018); France	Past 1 year	French food frequency e-questionnaire (FFeQ)	Adults (n = 58, age 47.7, ± 14.9); compare FFeQ with 3 to 6 24HRs	Energy r = 0.50 (p < 0.05) Macronutrients (Energy adjusted) Fat: r = 0.55, CHO: r = 0.49, Protein: r = 0.47 Micronutrients range (Energy adjusted) Energy-adjusted correlations Sodium: r = 0.05 to Potassium: r = 0.59	Digital food images in a series of 3 most of the time

24HR = 24-hour recall; CHO = Carbohydrate; d =Day; DR = Dietary record; DLW = Doubly Labeled water; 24HR = 24 Hour recall; FFQ = Food frequency questionnaire; p = p value; PS = Portion size; r = Correlation coefficient; WDR = Weighted dietary record; y = Year.

This review includes 10 self-administered web-based FFQs that measured the intake of both macronutrients and micronutrients in healthy free-living adults. Computer-administered FFQs were not reviewed because they are outdated.

- Number of food items and inclusion of dietary supplements

The number of food items included in the web-based FFQs reviewed ranged from 44 food items in the FFeQ (Affret et al., 2018) to 156 food items in the GraFFS FFQ (Kristal et al., 2014). Only Labonté et al. (2012) and the Christensen et al. (2013) included supplements in their validation studies.

- Time period covered by the validation study

The consumption period covered by the 10 web-based validation studies reviewed ranged from 1 week (Alawadhi et al., 2019) to 1 year (Beasley et al., 2009; Kato et al., 2017).

- Reporting of portion sizes

Digital food images were the most frequently used PSEA reported in the studies reviewed. Kristal et al. (2014) used 3 to 6 pictures for each food, Christensen et al. (2013) used 5 food images for some of the food groups while Labonté et al. (2012) used 2 to 4 images and Beasley et al. (2009) used 2 food images per food. Two FFQs reported using 3 food images (Al-Awadhi et al., 2019; Fallaize et al., 2014) while the IDQC FFQ had 1 food image for certain foods and six levels of amounts of food items (Du et al., 2015; Feng et al., 2016) and Kato et al. (2017) did not use any visual aids.

- Participants characteristics and sample size

All the studies were conducted on adults of both genders. Du et al. (2015) performed the validation study of the IDQC on male university students. The same FFQ was validated on city residents by Feng et al. (2016). The sample size ranged from 46 in the EatwellQ8 FFQ (Alawadhi et al., 2019) to 644 participants in the IDQC FFQ (Du et al., 2015).

- Reference instrument

The most used reference method in the validation studies reviewed was the DRs, for 7 out of the 10 studies (All but Kristal et al. (2014), Feng et al. (2016) and Affret et al. (2018), who used 24HRs). Two studies used a combination of two reference methods, Beasley et al. (2009) used both 24HR and food records, and Christensen et al. (2013) used both DR and DLW.

- Results of validation studies
    - Energy and Nutrients correlations

The measurement of EE in the validation of the Meal-Q FFQ was compared to a biomarker, the DLW. It showed that EI was underestimated compared to total energy expenditure by DWL (Christensen et al., 2013).

CCs obtained were used to compare the results of the studies reviewed because CCs are the statistical analysis that are commonly used in FFQ validation studies.

Based on measures of Pearson or Spearman correlation coefficient (r) obtained between the web-based FFQ and the reference method reviewed, the correlation of energy between the 2 methods ranged from 0.16 for Meal-Q (Christensen et al., 2013) to 0.58 for the web-FFQ of Labonté et al. (2012). When classifying the studies reviewed according to Lombard et al. criteria (Lombard et al., 2015), the CC of EI between the methods was judged to be good ($r > 0.5$) in 4 studies (Du et al., 2015; Fallaize et al., 2014; Feng et al., 2016; Labonté et al., 2012), acceptable (r between 0.20 - 0.49) in 3 studies (Kristal et al., 2014; Beasley et al., 2009; Kato et al., 2017 (men's results)) with DR as reference method. This association was found to be poor (r < 0.19) in 3 other studies (Beasley et al., 2009 (with 24HR); Christensen et al., 2013; Kato et al., 2017 (women’s results)).

Most CCs for the 3 main macronutrients (Carbohydrate, protein, and fat) in the 10 studies were between 0.3 to 0.6. The energy-adjusted CCs between the methods for macronutrients ranged from 0.04 for PUFA to 0.89 for vegetable proteins (Labonté et al., 2012). The correlations of energy-adjusted values for micronutrients varied from 0.10 for iodine for men (Kato et al., 2017) to 0.98 for iodine (Feng et al., 2016).

- Range of correlation of food groups

Only 3 of the reviewed studies addressed the correlation of food groups (Du et al., 2015; Fallaize et al., 2014; Feng et al., 2016). Correlations ranged from 0.73 for yogurt (Fallaize et al., 2014) to 0.19 for sweets (Feng et al., 2016).

- Conclusion

In conclusion, it appears that most of the web-based FFQs reviewed generated acceptable to good estimates for EI, macro, and micronutrients. Most reported using energy-adjusted deattenuated values in their analysis for both Marco and Micronutrients. Since only 3 studies have validated food groups, it is difficult to draw conclusions. As per the reference method, DR was the preferred tool in most of the studies reviewed. The preference of the Web-based format reported by the usability evaluation of the web-based FFQ reported in 3 studies (Beasley et al., 2009; Christensen et al., 2013; Fallaize et al., 2014) confirms the increasing popularity of technology based questionnaires. Although the benefits of web-based FFQs compared to print FFQs are undeniable, more studies are warranted to improve their effectiveness and their validity in different population groups.

- ❖ Potential Contributions of the Study

In the light of the above review that shows the lack of a country specific DAT in the UAE, and in the context of the dramatic increase of nr-NCDs, it is evident that the development of such a web-based FFQ is warranted. Developing a culture-specific online FFQ for the UAE would allow for an accurate assessment of country level dietary intake, which would enable the investigation of the Emirati population's dietary risk factors for NCD and the development of dietary policies or guidelines on the basis of sound research. Future research could potentially focus on developing sophisticated DAT on mobile applications as a way to improve the usability and acceptability of web-based FFQs in different population groups such as children, pregnant women, etc.

- ❖ Potential limitations of the study

Some of the potential limitations of the study include: 1) The development of a web-based FFQ that is not culturally specific to the Emirati population because there is no empirical data on the food consumption of the entire adult population of the UAE; 2) A low usability of the tool, more specifically by older adults and people with low literacy, and 3) The lack of accuracy of the nutrients estimates because of the lack of a country specific FCT to date.

Chapter 2: Materials and Methods

2.1 Introduction

This chapter describes the steps undertaken to develop and validate a culturally specific web-based FFQ that can be used to determine the dietary habits of the adult Emirati population with reference to the high prevalence of NCDs. The task of developing and validating the FFQ for the adult Emirati population, the AE-FFQ was conducted in accordance with the guidelines laid down in the Declaration of Helsinki and all procedures involving human participants were approved by the University's Human Medical Research Ethics Committee after the submission of the research proposal. There were 5 phases required to conduct this study:

The first phase involved the development of the draft of the online AE-FFQ. This phase required sourcing data for the construction of the food list and the weight and range of portion sizes, pretesting the draft FFQ and the portion sizes food images, developing the food images for use in the web-based AE-FFQ, and designing the online format of the AE-FFQ.

The second phase involved the transfer of the draft AE-FFQ to an automated online format and installing the technical features required to promote a better usability, clarity, and data completeness of the AE-FFQ.

The third phase involved conducting the validation of the web-based AE-FFQ. This phase was based on a cross-sectional study design where the AE-FFQ was validated against three 24HRs on a convenience sample of 60 participants from the city of Al Ain in the UAE. After providing their informed consent, an initial sample of 83 participants were invited to take part in 3 consecutive 24HRs over a period of a month, followed by the AE-FFQ at the end of the one-month period. The response rate was 72% as described in the recruitment process provided in the section discussing the validation study in more details.

The fourth phase of the study involved obtaining nutrient data for the foods reported from the three 24HRs and building a FCT for the web-based FFQ.

The fifth phase of the study involved conducting data analysis of the validation study on both nutrients and food groups.

A detailed description of each of the phases of the study are described in the sections below.

2.2 Creation of the Food Frequency Questionnaire

As the first ever FFQ to be created specifically for the adult Emirati population, all components of the instrument needed to be newly developed. This section describes the methodology used to construct the initial draft of the FFQ based on its stated objective, including the food list, the rationale for food grouping, the format of the FFQ and finally the development of the portion sizes.

2.2.1 Purpose of the FFQ

As described by many authors (Block et al., 1986; Cade et al., 2002; Willett, 2013), the first step in the development of an FFQ is to define its objective. Since the objective of the AE-FFQ is to estimate the usual dietary intake for the investigation of diet-related NCDs in the Emirati adult population, the dietary information gathered should be comprehensive and the nutrients and food groups investigated should be in line with the evidence of their association with NCDs and all-cause mortality.

2.2.1.1 Rationale of the choice of the nutrients of interest

The study targeted in its analysis nutrients that were shown to have etiological hypotheses of correlations with nr-NCDs. These nutrients were also selected for use in other FFQs that examined possible etiological relationships between nutrition and the development of NCDs such as the EPIC prospective study on nutrition and cancer (Riboli, 2001) and the Food4me study (Celis-Morales et al., 2015)

In total, Energy and 21 macro and micronutrients were analyzed (presented here with their corresponding units): Total energy (kcal), total carbohydrates (g), protein (g), fat (g), saturated fatty acids (SFA) (g), monounsaturated fatty acids (MUFA) (g), polyunsaturated fatty acids (PUFA) (g), cholesterol (mg), calcium (mg), sodium (mg), vitamin A (mcg RAE), Vitamin E (mg AT), Vitamin D (mcg), Vitamin B1 (mg), Vitamin B2 (mg), Vitamin B6 (mg), Total folates (mcg), Vitamin B12 (mcg), vitamin C (mg), Total dietary fiber (g) and Total sugar (g).

It is well known that, for a given EI, an imbalance in the relative proportions of macronutrients resulting in an excess of one or more macronutrients, and a high overall EI can both increase the risk of NCDs (NRV., 2014). Beyond macronutrients' effect on total energy, total carbohydrate intake and total fat intake have been found to be linearly associated with incident CVDs (Ho et al., 2020). Macronutrients’ constituents were also included as components of interest due to their direct association with CVDs. For example, higher sugar consumption (in sugar-sweetened beverages) has been associated with a greater risk of obesity, CVD, including dyslipidemia, elevated blood pressure, diabetes, and cancer (Ho et al., 2020; Rippe & Angelopoulos, 2016).

In this study, total sugar was tracked instead of added sugar because data on added sugar are usually not available in FCDBs. Moreover, it is impossible to analytically distinguish between added and naturally occurring sugar in a food product, therefore, accounting for total sugar intake is a better option than trying to account purely for added sugars (Mela & Woolner, 2018). Fiber was included based on its strong implication in the prevention of CVDs (McRae, 2017). Regarding the constituents of total fat assessed in the study, the intake of SFA, MUFA, and PUFA were added as they have all been found to be linearly associated with all-cause mortality (Ho et al., 2020). There is less evidence on the association of protein intake with NCDs (Ho et al., 2020), however, the source of protein (e.g., animal versus plant protein) has been shown to influence CVD and mortality risks, as described in prospective cohort studies that have shown that plant proteins were associated with a lower mortality risk compared to animal protein sources (Song et al., 2016; Virtanen et al., 2019). Consequently, the sources of proteins were differentiated in the food list in the AE-FFQ. The rationale for investigating some specific micronutrients is summarized in the table below (Table 5).

Table 5: Some micronutrients of interest and their association to NCDs

Micronutrient	Rationale	Reference
Excess sodium intake	Associated with effects on raised blood pressure and related CVDs. Responsible for more than 3 million deaths and 70 million DALYs.	(He & MacGregor, 2010) (Afshin et al., 2019)
Vitamin D and Calcium insufficiencies	Correlated with cardiovascular risk factors (Obesity, hypertension), with incident cardiovascular symptoms (myocardial infarction, stroke) and with greater mortality from chronic CVDs.	(Peterlik & Cross, 2009)
Excess calcium intake	Supplemental doses of calcium exceeding 1,000 mg/day linked to an increased risk of cancer death.	(Chen et al., 2019)
Vitamin D deficiency	Linked to the onset and progression of many chronic diseases such as CVDs, diabetes, and cancer.	(Wang et al., 2017)
Deficiency in antioxidant vitamins (A, C and E)	Associated with an increased risk of CVDs, cancer, and mortality.	(Aune et al., 2018)
Deficiency in Methyl Donors (folate, riboflavin, vitamin B12, vitamin B6)	These vitamins are necessary to the effect on DNA methylation process which is implicated as an underlying molecular mechanism in the development of CVDs.	(Glier et al., 2014)

CVD = Cardiovascular diseases; DALY = Disability-Adjusted Life Year; DNA = Deoxyribonucleic acid.

2.2.1.2 Rationale of the choice of the food groups of interest

Nutrient analysis is not enough when investigating the relationship between food and chronic diseases (Afshin et al., 2019; Micha et al., 2017; Mozaffarian, 2016). This is because there is an association between dietary habits, foods, and the nutrients they hold

(Mozaffarian, 2016). It becomes therefore important to identify the correlation between food groups and disease independently. For example, Ursin et al. (1993) found that low dietary fat was associated with higher intakes of vegetables, fruits, and whole grains. The dietary pattern of consuming less fruits and vegetables may be an independent risk factor for developing CVDs, therefore they become potential confounders in the study of the relationship between dietary fat and coronary disease (Hu, 2002). Moreover, long-term prospective observational studies have provided supporting evidence for potential causal relationships between specific foods (e.g. fruits, vegetables, processed meat, etc.) and NCDs (ischemic heart disease, diabetes, and colorectal cancer) (Afshin et al., 2019; Micha et al., 2017).

The choice of the foods to include in AE-FFQ was therefore based on the requirement of including a food list that is comprehensive and representative of habitual intake, and that includes foods that were evidenced to have potential protective or adverse effect in relation to NCDs. To that end, the following dietary factors that had either a potentially protective or adverse effect on NCDs based on findings from the recent GBDs study (Afshin et al., 2019) and the supporting evidence of causality with NCDs reported by Micha et al. (2017) and Mozaffarian et al. (2016) were included in the food list:

Food groups with potential protective effects: fruits, vegetables, legumes, whole grains, dairy (milk and high calcium foods), nuts and seeds, fish rich in omega-3 fatty acids (Afshin et al., 2019).

Food groups with potential adverse effects: meat, processed meat, sugar-sweetened beverages, and foods with high content in sodium or trans fatty acids, such as processed foods e.g. chips and fast foods (Afshin et al., 2019).

2.2.2 Format of the AE-FFQ

The horizontal layout or grid format of the AE-FFQ was chosen because of its simplicity, ease of administration and ease of transfer to a digital format for display on a computer screen without the need for complex algorithms. A similar format was adopted by some popular and extensively validated FFQs, such as the Harvard FFQ (Willett et al., 1985), the Block FFQ (Block et al., 1986) and the EPIC-Norfolk FFQ (Bingham et al., 1997). Moreover, these FFQ were automated into web-based FFQs e.g. the Block FFQ web-version is found under nutritionquest.com, while the EPIC-Norfolk FFQ was the building block for the development of the online Food4me FFQ (Forster et al., 2014) and the Metacardis FFQ (Verger et al., 2017).

FFQs designed in a vertical layout have also been automated, e.g. the online DHQ, the automated format of the NCI Diet History Questionnaire (NCI., 2016; Subar et al., 2001) or the “VioScreen” Graphical Food Frequency System (GraFFS) (Kristal et al., 2014). These web-based FFQs used complex skip patterns and branching logic that required high technical expertise. Therefore, because of limitations of both time and technical resources in the development of the AE-FFQ, it was not feasible to develop an online FFQ with a complex format such as that of “VioScreen” or the online DHQ. A simpler layout adopted from EPIC-Norfolk FFQ (Version 6, CAMB/PQ/6/1205) (Bingham et al., 1997) and its modified online version, the Food4me online FFQ (Forster et al., 2014) was used. The grid format of the AE-FFQ was therefore designed on Microsoft Excel^{TM} because Excel^{TM} cells could be easily transformed into response options using radio buttons once the file is transferred to the automated format.

2.2.3 Creation of the food list

Based on Willett's recommendations (2013), the food list should include foods that are specific to the culture and food habits of the population of interest, therefore, the food list mirrored the modern Emirati diet, which includes traditional Emirati foods, Middle-Eastern cuisine, International cuisine and various Arabic and Western fast foods and snacks (Dehghan et al., 2005; Musaiger & Abuirmeileh, 1998; Ng et al., 2011). The food list should also be comprehensive so that it could capture total EI. Indeed, according to Willett, Howe and Kushi (1997), total EI must be controlled for because the intake of many nutrients is strongly correlated with total EI. Another requirement of the food list is that it should be composed of foods that are good sources of the nutrients and food groups of interest to the objective of the study, as discussed in Section 2.2.1. Moreover, these foods should be varied to ensure that their variability in consumption across adults Emiratis allows for the discrimination of their intake (Willett, 2013). The different data sources used to obtain the initial food list are described below:

2.2.3.1 Sources of information on food consumption in the UAE

As recommended by Subar (2004) and Block et al. (1986), population specific data when available should be the first resource to use to determine the foods to include in the food list. In this study, the first source of information consulted was the national nutrition survey which was conducted in 2009-2010 (Ng et al., 2011). The data from that study was based on a single 24-hour dietary recall collected from 628 randomly selected Emirati national households from all seven Emirates of the UAE. The survey included dietary intake information on 477 women, from the age of 19 to 50 years old and 529 children and adolescents aged 6-18 years.

Food consumption data of women participants in the 2009-2010 national nutrition survey was used to obtain a comprehensive scope of the most consumed foods by Emirati women in the UAE. The foods and beverages reported in this survey were classified into food groups (e.g., dairy food group, fruits group, rice dishes group etc.,) and the foods and beverages that were reported by 90% of the respondents were considered for inclusion in the food list. For example, avocado or peanut butter were reported by less than 10% of the participants, thus, these foods were not included in the AE-FFQ's food list.

The second source of information on the foods consumed in the UAE was the food list of the FFQ developed by Dehghan et al. (2005), which was designated for use in both the Kuwaiti and Emirati populations as part of the PURE study.

The third source of information was the photographic food atlas developed by Abu Dhabi Food Control Authority, which contained food photographs of 115 commonly consumed foods in the UAE (Al Marzooqi et al., 2015).

Other sources of information included different cookbooks that portray traditional Emirati cuisine.

2.2.3.2 Building the initial food list

Compiling foods from the sources mentioned above resulted in an initial food list of 182 food items, which encompassed foods consumed during ordinary days and other times of the year such as during Ramadan or on special occasions. The resulting list was very comprehensive and with minimal possibility of missing important foods.

As recommended by Cade et al. (2002) and Subar (2004), expert advice was sought to evaluate the completeness and cultural specificity of the food list. To that end, two Emirati nutritionists and four Emirati dietetics students from the United Arab Emirates University (UAEU) were consulted. Based on the feedback received, the following 8 foods were removed because they were not commonly consumed: 3 traditional desserts (Biteeth, Khabisa, Asida), 3 dairy products (Chami cheese, camel milk, sour cream), salad dressing and the vegetable mushroom.

2.2.3.3 Grouping of the list of foods in food groups

The list of foods collected was organized into food categories to ease cognitive burden on participants. This involved clustering foods into groups, such as dairy foods group, vegetable group, etc. Moreover, within each group, foods that shared similar features of nutritional content and manner of serving were grouped together into subgroups, thus, resulting in further reduction of the number of food items in each food group. For example, apples and pears were grouped together, Arabic savory pies (Fatayer) were grouped together, despite their different fillings, and cheeses were clustered together according to their salt content (Halloumi and Feta cheese together in one group since they contain more sodium than the popular sliced Cheddar cheese commonly added to sandwiches). The sweet snacks group included chocolates, chocolate bars, and hard candies since the main nutrient of interest is these foods is their sugar content.

The grouping of foods was inspired by the clustering used in the EPIC-Norfolk FFQ (Bingham et al., 1997) and Dehghan's FFQ (Dehghan et al., 2005). While most of the food group categories were similar in both these FFQs, there was no category for mixed dishes in the EPIC-Norfolk FFQ. Also, the EPIC-Norfolk FFQ's vegetables' group included fresh, frozen, or tinned vegetables only, leaving out cooked vegetables, which does not represent the way vegetables are usually consumed. On the other hand, Dehghan's FFQ took into consideration the mixed nature of some staple dishes consumed in the UAE and presented the vegetables as "cooked or raw".

Since among Emirati nationals, consuming foods prepared outside the home is common (Barda, 2011) and foods at home are often prepared by housemaids and cooks, estimating PSs of single ingredients from mixed dishes could be a challenging task for some people. Consequently, food groups of mixed dishes were introduced to provide a simpler depiction of foods as consumed. Groups such as "Composite dishes" group, where staple mixed dishes, such as cooked rice and meat (Biryani, Machbous, etc.) or vegetables and meat dishes (e.g. Salona (meat and vegetables stew), Thareed (Bread in meat and vegetables broth), etc.) were therefore included. Similarly sandwiches and baked snacks (Pakoras, Fatayer, Shawarma) were grouped together since these foods consist of a mixture of different ingredients often prepared in different ways.

The initial food list consisted of 146 food-line items and 12 food groups. The food groups were (1) Dairy foods, (2) Composite dishes, (3) Proteins (including vegetarian and animal sources of proteins), (4) Vegetables (fresh and cooked vegetables including potatoes), (5) Cereals (pasta and other cereals), rice and starches, (6) Sandwiches and baked snacks, (7) Breads and savory biscuits, (8) Spreads on breads, vegetables or salads (excluding use in cooking), (9) Soups, (10) Fruits and dried fruits, (11) Beverages, and (12) Sweets and other snacks.

2.2.3.4 Time frame covered

In this study, the time frame chosen for the AE-FFQ was the preceding month, because FFQs with shorter time frames have been found to have higher correlations with the reference method than those recalling over the previous year (Cade et al., 2004) and because longer time frames, such over the preceding year, tend to challenge their cognitive process (Willett, 2013). Another reason for choosing a timeframe of one month over a longer recall period is that there is no habit of seasonal eating in the UAE (Dehghan et al., 2005) because the country relies mostly on food products that are imported from different regions of the world, thus providing the population with fruits and vegetables all year round, regardless of the season . Foods that were consumed more frequently during the fasting month of Ramadan (e.g., Harees, Thareed, Bakora, Qurs bread) were also included in the food list, making it comprehensive and inclusive of foods consumed all year round.

2.2.3.5 Range of frequency options

There are usually nine options of frequencies of intake in most FFQs that range from never or less than once per month to 6 or more times per day (Pérez Rodrigo et al., 2015). Therefore, the initial draft of the FF- AE FFQ was designed with the same nine frequencies of intake: (1) Never or less than once per month, (2) one to three times per month, (3) once per week, (4) two to four times per week, (5) five to six times per week, (6) once a day, (7) two to three times per day, (8) four to five times per day and (9) six-plus times per day.

2.2.3.6 Obtention of food images of portion sizes

To improve portion size estimation when reporting dietary intake using the AE-FFQ, the obtention of culturally specific food images depicting the range of distribution of intake among adult Emiratis was required. The development of the food images for use in the AE-FFQ was done according to the 2 following steps:

- Obtaining UAE specific portion sizes that encompass the range of consumption of the adult Emirati population.
- Depicting the estimated portion sizes in a series of three digital food photographs of increasing sizes in a way that is easily identifiable to the population of interest.

According to Cade et al. (2002) and Nelson and Haraldsdóttir (1998), the best way to determine the range of portion sizes in a population is by using data-driven methods in the form of previously collected dietary intake survey data on the same group of interest. In the absence of nationally representative data, alternative methods can be used (Hotz & Abdelrahman, 2019). Hotz and Abdelrahman (2019) recommend consulting with households to derive new portion sizes or using an average portion size from existing survey data and applying fixed ratios to derive small and large portion sizes (Hotz & Abdelrahman, 2019; Lombard et al., 2013). Consequently, in the context of the lack of nationally representative data for the adult Emirati population, a methodology for deriving the medium portion size for the foods in the AE-FFQ was developed based on following available sources of data.

1. The 2009/2010 UAE Nutrition survey
2. Expert advice
3. Units of foods that can be served in individual serving sizes (e.g. branded food).

Once a medium portion size was decided based on the above data sources, the range of estimates of the three portion sizes were decided by assigning a coefficient equal to 1 to the medium portion size, while the small portion size was half the medium portion size, and the large portion size was generally calculated by multiplying the medium portion size by a factor of 1.5. Exceptions to this rule were required for certain foods, such as the ones presented in their original packaging, as explained in Table 6 below.

2.2.3.6.1 Description of the different sources of data used to derive a range of portion sizes for the adult Emirati population

- The 2009/2010 UAE Nutrition survey

Since it has long been recognized that gender is a major contributing factor in the variance of nutrient intake (Beaton et al., 1979), data from the 2009/2010 UAE Nutrition survey was not a sufficient source of data for deriving population-based portion sizes because it was missing data on Emirati men. Also, because the 2009/2010 survey used only a one-day 24HR, some common dishes such as the pudding “Um Ali”, or the popular grilled meat dishes “Shish Taouk” or “Meat Tikka” were not reported in the survey. Other popular foods were reported by only a small number of women, for example, the eggplant dip “Mutabal” was reported by only 3 women in the survey. For such foods and for foods known to be consumed in larger quantities by Middle-Eastern men e.g. meat dishes, pasta and rice dishes are typically consumed in larger quantities by Middle-Eastern (Moradi-Lakeh et al., 2017), the medium portion sizes were obtained after consultation with a team of experts (two Emirati nutritionists, four Emirati dietetics students and one chef familiar with cooking Emirati dishes).

- Expert advice

The medium portion size of meats, pasta and rice dishes was determined after consultation with the team of experts. Similarly, foods that were rarely reported or not reported in the survey were also estimated by the team of experts (e.g., Um Ali, Qurs Bread). Once the medium portion size was decided, the small portion size was assigned a factor of 0.5 of the medium portion size and the large portion size was assigned a factor of 1.5 as appropriate.

- Units of foods that can be served in individual serving sizes

Since foods of regular shapes presented in units are easier to recognize, compared to foods presented in plates or bowls (Nelson & Haraldsdóttir, 1998), individual units were used to depict the foods in the AE-FFQ whenever possible (e.g. cucumber presented in parts of one unit instead of just sliced (See photos a, b and c in Appendix 1.). Table 6 depicts some of the foods in the AE-FFQ that were presented in units and the criteria used for assigning them to a small (S), medium (M) or a large (L) portion size. For example, some branded foods are available in the market in “regular” and “small” serving sizes, such as juices, chips, or sugary drinks. Accordingly, the small portion size was assigned the “small” serving size and not half of the “regular” serving size because people are more likely to consume one or the other serving sizes rather than half of the regular size. In case this latter option was not available, such as for buttermilk, half the medium portion size was used to depict the small portion size, while the large portion size was depicted as two single-serving units. Foods like mayonnaise, ketchup or butter were presented simultaneously in the photographs in spoons and individual packets, with one spoon containing the same amount as in the individual packet (See photos d, e and f in Appendix

1.). The simultaneous presentation in 2 different measurement units was used to improve their identification by the participants. The serving sizes of fruits and vegetables were obtained from the 2009/2010 national survey and finalized after consultation with the team of experts. Accordingly, the medium potion size for carrots, cucumbers, oranges, and apples were half a piece. For yoghurt, although the portion sizes were based on the individual cup size sold in the market in the 2009/2010 survey, the serving size of two tablespoons was frequently reported in the survey and was therefore used as the small portion size. A similar decision was taken for french fries with a small portion size expressed as 30 grams because it was the portion most reported in the 2009/2010 national survey, while the medium portion size was determined as the serving size of 1 medium order of french fries from McDonald’s™, which was 114 g (McDonald's, 2017). For burgers, chicken burger ‘McChicken™’ was one of the most common burgers consumed in the population, as confirmed by the team of experts and McDonalds™ restaurant staff. It was therefore used to represent the medium portion size while the small and the large portion size were illustrated by a smaller and a larger burger that were considered popular by McDonald’s™ staff. There were 101 foods (73%) depicted in units in the food images in the AE-FFQ.

In addition to the precautions taken for improving the recognition of foods in the images, the presentation of the dishes took into consideration the customs of the country. Traditional dishes were presented as served according to Emirati eating habits. For example, rice dishes such as Malleh fish (rice and preserved fish) or chicken in a mixed rice dish were presented with meat on the same plate (See photos g, h and i in Appendix 1.). Grilled meat dishes were presented as served in a restaurant setting. Moreover, the fish used to represent the image of grilled fish was grilled Kingfish, presented in multiples of a steak, as it was one of the most popular types of fish used for grilling, as confirmed by Emirati restaurants and the Chef. For fried fish, qualitative consultations with the team of experts revealed that the most popular fish used for frying in the UAE were Sea Bream and Red Mullet. Fried Sea Bream was the main fried fish on the menu of a leading seafood restaurant in the country, therefore, it was used to depict the different portion sizes of fried fish in the food pictures.

Table 6: Deriving the Small, Medium and Large portion sizes of foods depicted in individual portion sizes, according to their type

Type of food	Branded foods sold in single serving units	Branded foods sold in large units	Foods (Spreadables) that can be presented in single serving units and spoons (s)	Fruits Raw vegetables	Cooked foods presented in units
Example of foods	Carbonated drinks Juices	Arabic bread Manaqeesh** Pizza	Mayonnaise Ketchup Butter Honey	Apples Bananas Dates Tomatoes Strawberries	Stuffed vegetables Sambosa Sweets (baklawa) Paratha Chapati Croissants
Small PS	"Small size"	⅓ of a unit	1 s/packet	0.5 - 3 piece*	0.5- 2 piece*
Medium PS	Regular size	Half a unit	2 s/Packets	1-4 pieces*	1-4 pieces*
Large PS	2 x Regular size	1 unit	4 s/packets	2-8 pieces*	2-6 pieces*

*The number of pieces depends on the size of the fruit or the food, e.g. for strawberries, a small sized fruit, the M PS was 4 pieces, the M PS and the L PS were 2 and 8 respectively. For stuffed grape leaves, 2, 4 and 6 units represented the S, M and L PS respectively.
**Manaqeesh: (flatbread topped with thyme or cheese).

Once the portion sizes and their desired presentation were finalized, the next step was to purchase the food items composing the food list of the AE-FFQ and to take the digital food photographs.

2.2.3.6.2 Development of digital food images for the AE-FFQ

Preparing and developing the food photographs was carried out in a classroom at UAEU where a space was allocated to set up a small photography studio in close vicinity to the food preparation facility. The involvement of a chef in the project ensured that the food used for the pictures was always fresh and well presented, which is a factor that may help in the accurate estimation of portion sizes from food images.

2.2.3.6.2.1 Food purchasing and preparing

Foods were purchased from supermarkets, bakeries, and restaurants which were close to the food preparation facility. Foods bought from the supermarkets were either presented in the photographs as purchased, such as branded foods (e.g. chocolate candies, juices, etc.), or they required a prior step of preparation. For example, raw vegetables (e.g. carrots, potatoes) were first cleaned and peeled into their edible form before being sliced in the desired final form for presentation (slices or cubes). The choice of the supermarkets to buy the foods from was not random but corresponded to the places where Emirati Nationals shop the most from. As such, Carrefour™ and Al Ain Coop™ were the supermarkets that were visited for the project of food photography. The brands of foods that were represented the most in these supermarkets were assumed to be the most consumed amongst Emirati nationals. This assumption was further confirmed by the team of experts helping with this project. Upon this confirmation, popular brands of milk and other dairy products, juices, carbonated drinks, chocolate candies, etc. were bought from these supermarkets to be presented in the food photographs. As described earlier, the different serving sizes available in the market were used to depict the different choices available to the participants.

Fruits and vegetables were bought from Carrefour™ supermarket because of its wider choice of products. Many of the fruits were uniform in size and shape (apples, oranges, kiwis, etc.), which simplified the choice of these fruits. Larger fruits such as watermelon were sold in ready to consume slices and were therefore presented in the food photographs in increasing numbers of slices as bought from the market.

Traditional Emirati foods such as Maleh fish, Harees (porridge like cracked wheat with meat), Thareed, Chebab bread, etc., were purchased from restaurants specializing in Emirati cuisine. Fried and grilled fish were bought from restaurants specializing in fish. Fast food restaurants (Pizza Hut™, McDonald's™, and KFC™) were approached for pizzas, burgers, and fried chicken, respectively. Cafeterias were used to buy other types of bakeries such as parathas, chapatis, and popular sandwiches such as shawarma.

The chef was informed about the desired presentation and decoration of the plates, and care was taken to present the foods in a way that conformed to the customs of the country and in a way that made the food more recognizable and pleasant to the eye. Besides the efforts done to improve the presentation of the food, other factors that could influence the estimation of food portions in food photographs were accounted for, namely the type of dinnerware, the lighting, the camera angle, and the quality of the photographs (Nelson & Haraldsdóttir, 1998).

2.2.3.6.2.2 Food weighing

Each of the three portion sizes was weighed by the researcher on an electronic kitchen scale (Salter™, Model SKU# 1047 HBBKDR14, Germany) which had a maximum weighing precision of 1 g/1/8 oz/1 mL/1/8 fl.oz. increments and a load capacity of 5 kg/11 lb/5000 mL/176 fl.oz.

Certain foods were not presented in their edible form. For example, meat in mixed rice dishes such as Biryani was usually prepared and cooked on the bone. Since foods were illustrated in a culture-specific way, foods that were not presented in their edible form were weighed in both the illustrated and the edible form (e.g. meat, chicken, and fish were weighed before and after deboning, fruits were weighed before and after being peeled and pitted). All measured weights and volumes were converted to grams and were recorded with the corresponding photo numbers and later entered in an Excel™ sheet.

2.2.3.6.2.3 Food presentation

- The standard dinner set

White porcelain dinnerware was chosen to present the weighed portions of food. White dinnerware was preferred as it highlighted the appearance of the food items in the series of food images. Dinnerware was standardized and commonly used in the UAE. A standard 27 cm dinner plate was used to present most of the weighed portions of food. Small size sweets were presented on a 14 cm white ceramic saucer. Standard 10 cm diameter white ceramic bowls were used to present soups, Stews (Salona) and puddings such as Um Ali. Beverages were depicted in their industrial packaging as it was the presentation deemed most recognizable. Milk and water were presented in a standard clear drinking glass measuring 11 cm in height and 7 cm diameter for a total capacity of 250 mL.

Standardization was further accomplished by placing reference cutlery, such as a spoon, fork, and knife at a fixed distance of the plates in all photographs as appropriate (e.g. a soup spoon was placed next to a bowl of soup) to help improve the respondent's perception of the size of the plate/bowl on which the food was portrayed, as recommended by Nelson and Haraldsdóttir (1998). The standard cutlery used was in stainless steel and had a minimum design to avoid distraction.

- Photographing

A professional photographer took the pictures of all the food items in a series of 3 photographs of increasing portion size to represent the small, medium, and large portion sizes. The standard dining set of plates and cutlery, positioned uniformly with the same lighting, was used in each of the 12 sessions that were required to take the pictures of all 146 foods listed in the FFQ.

- Camera

The serial photographs were taken using a camera mounted on a tripod. The distance between the tripod and the food item was kept constant. The angle of the camera was set at 45° above the horizontal, which is considered to represent the view of a person of average height, sitting at a table, looking at a plate of food on the table in front of him (See photo of camera setting in Appendix 2). The camera used was a Nikon™ D300 (Japan), with 18 - 140 mm lenses, 24.5 megapixel digital SLR that used 1/25 speed, aperture f18 to f11 depending on the color of the food item, ISO speed of 200, and a white balancing feature color checker to optimize the color result.

Pictures were reviewed using the software program Photoshop™ to make any additional adjustments to the colors in the photographs and to ensure the settings were consistent in each picture.

- Lighting

All foods were photographed on a small photography shooting table made of white matte board. The placement and retrieval of the plate/bowl was marked with tape in order not to disturb the set-up. Lighting was supplied by two electronic flash heads. The main light came from an 18 inch times 18 inch soft box suspended at a 90° angle above the place setting and slightly behind the camera. The light emanating from the lamp came from an umbrella reflector that softened the light through a layer of diffusion material that forms the top of the booth. The other electronic flashlight was positioned at the back of the table to provide a daylight effect.

2.2.3.6.3 Pre-testing and finalizing of the food photographs

Pre-testing of the food photographs was required to assess the following 2 assumptions:

- That the food images accurately estimated the portion size they depict

Before uploading the food pictures taken into the AE-FFQ, it was important to assess if the PSs depicted on the food images accurately estimated the portion size of the same foods on the plate. Indeed, while all precautions were taken to obtain food photographs that could help identify the food portion sizes, it was not clear if the foods that were irregular in shape or size or not presented in identifiable units could be correctly evaluated, because such foods are known to be more difficult to estimate (Nelson &

Haraldsdóttir, 1998; Subar et al., 2010). Consequently, a pre-testing study was conducted to assess this assumption, where 20 foods were chosen based on inherent characteristics that are susceptible to induce misjudgment as described by Nelson and Haraldsdóttir (1998). For example, foods like Mutabal, Hummus or Harees are all amorphous foods usually served in semi-solid mounds. This characteristic may cause people to estimate the amount of food differently according to their perception of the area and the depth of the mound formed by the food (Nelson & Haraldsdóttir, 1998). Other foods pre-tested based on such characteristics are foods in cups and foods in irregular shapes.

- That the range of portion sizes can be used to represent the entire adult Emirati population

The methodology used for finalizing the portion sizes described above (Subsection. 2.2.3.6.2.) was based on numerous assumptions because the portion sizes were not derived from population-based data. While the 2009/2010 National survey and the serving size of standardized packaged foods from the market were used to obtain the medium portion sizes for more than 90% of the foods listed in the AE-FFQ, about 10 popular foods were not reported or only reported by a small number of women in this survey (e.g. Mutabal, Um Ali, Grilled meat, green pepper, etc.). Portion sizes of the latter foods and portion sizes specific to Emirati men were therefore obtained based on the judgment of the researcher and the team of experts. Consequently, a pre-testing study was conducted to assess if some of the portion sizes that were derived on speculative decisions were within the range that could be considered usual or ideal for men. The choice of the foods to be tested was based on their popularity, their caloric density, and their higher intake among men (e.g., meat and rice), as reported by the team of experts and the findings from the Saudi Health Interview Survey (SHIS), 2013 (Moradi-Lakeh et al., 2017) which used a DHQ to assess dietary intake of the Saudi population, a country that shares similar dietary habits with the UAE (Table 8).

2.2.3.6.3.1 Objective of the pre-testing study

This pre-testing study was conducted to:

- Assess if foods of different sizes and shapes depicted in the food images can be accurately estimated by the participants
- Assess if the portion sizes chosen for a select number of foods were within the range of an ideal portion size for men
- Collect feedback from the participants to modify the portion sizes tested when necessary and make new food pictures accordingly.

2.2.3.6.3.2 Study design and participants

The study was conducted in April 2017, near the university's restaurant area. Participants were selected randomly from the flow of people going to the restaurant for lunch. They were approached by the researcher and were asked if they were willing to participate in a study that investigated the perception of food portion sizes, also informing them that the study would not take more than 15 minutes to complete. Upon verbal agreement, the researcher provided the participants with 4 forms: An information sheet, a consent form, a demographic questionnaire including questions about age category, gender, and educational level and an answer sheet (See Appendix 4: Ethical Approval, Appendix 5: Information sheet, Appendix 6: Consent form, Appendix 7: Demographic questionnaire and Appendix 8: Answer sheet).

2.2.3.6.3.3 Participants characteristics

In total, 21 volunteers were recruited. The majority were men with graduate level education between the ages of 26 to 40 years. Emiratis and non-Emiratis volunteers were equally represented (Table 7).

Table 7: Sociodemographic profile of the participants of the pre-testing of the portion sizes study participants (n = 21)

Characteristics	Male n (%)	Female n (%)	Total n (%)
Age groups (Years)			
18-25	4 (100)	0 (0)	4 (19.0)
26-40	4 (36.36)	7 (63.63)	11 (52.4)
41-55	2 (50)	2 (50)	4 (19.0)
$\geq$56	2 (100)	0 (0)	2 (9.5)
Education			
High School	5 (100)	0 (0)	5 (23.8)
Undergraduate degree	2 (66.7)	1 (33.3)	3 (14.3)
Graduate degree	5 (38.5)	8 (61.5)	13 (61.9)
Nationality			
Emirati	6 (60.0)	4 (40.0)	10 (47.6)
Non-Emirati	5 (45.5)	6 (54.5)	11 (52.4)
Total (%)	12 (57.1)	9 (42.9)	21 (100.0)

2.2.3.6.3.4 Methodology

Twenty different foods in different portion sizes were displayed on dinner plates or bowls (according to their consistency) on a long table. The portion sizes of the foods displayed on the table were of the same weight as either the small, medium and large portion sizes of the foods depicted in the food photographs displayed on a laptop in front of the different foods. Similar white plates and bowls were used for the foods displayed on the table as for the foods depicted on the food images on the laptop. The list of the 20 foods and the chosen portion sizes to be tested for both the experiments are depicted in Table 8. Participants received written instructions and were asked verbally to complete the following two experiments and mark their answers on the answer sheet.

- Experiment 1: Testing the suitability of the food pictures by the visual perception method

Based on the visual perception method, volunteers were asked to identify which of the three portion sizes in the digital pictures corresponded to the amount of real food presented on the table. Only one portion size was served on the table for each of the twenty foods. Participants were not allowed to select in-between sizes and were asked to report their choice of either small, medium or large for each of the 20 foods displayed on the table and mark their choice on the answer sheet. The choice of the 20 foods to include in this experiment was made based on the characteristics described by Nelson and Haraldsdóttir (1998) that may lead to a misestimation of the portion sizes. The foods assessed based on their characteristics were: 9 foods usually served in amorphous mounds (Coleslaw, Mutabal, Tabouleh, Hummus, Green salad, Biryani rice, white rice, chips, french fries), 1 food served in strips (green peppers), 5 foods composed of discrete pieces of different sizes (fried fish, Chicken in mixed dish, lamb in mixed dish, fish filet and fried chicken), 2 slippery foods (Harees, boiled pasta) and 3 foods served in bowls (Balaleet, Um Ali, Salona).

The decision to keep or change a portion size was set at the cut-off percentage of 50% of participants correctly estimating the portion size depicted in the food images. If a portion size was correctly estimated by less than 50% of the volunteers, feedback from the volunteers was obtained and the portion sizes were changed accordingly. The cut-off percentage of 50% was based on several studies having assigned 50% of correct estimations as an acceptable accuracy of the food images (Lucas et al., 1995; Turconi et al., 2005).

- Experiment 2: Estimating the ideal portion size of men volunteers

In the next step, the twelve male volunteers in the study were asked to estimate if the portions of real food on the table were: Less than their ideal portion size, corresponds to their ideal portion size or more than their ideal portion size. The same 20 foods were tested in both experiment 1 and experiment 2.

The decision to change a range of PSs to include a larger portion size was done if more than 50% of the men volunteers reported that a large portion of real food tested was less than their ideal portion size (Table 8). The decision to change the portion sizes at the cut-off percentage of 50 was arbitrary.

In this experiment, only the testing of the large portion size of foods was considered for the decision of changing the range of portion sizes. Indeed, if the large portion size of a food was tested and reported as ideal or more than ideal by more than 50% of men, it was assumed that the initial range was acceptable. However, if the large portion size of a food was tested but reported as less than ideal by more than 50% of the male volunteers, then a new range of portion sizes containing a larger portion size was required.

Nine foods were tested in their large portion sizes, these foods were chosen specifically for their popularity (Hummus, Harees), their high energy density and a reported higher intake by men (rice, meat, fish, and chicken). Moreover, the large portion size of salads and green pepper were tested because they were derived from the 2009/2010 survey and it was not clear if these PSs were considered ideal for men's usual consumption.

2.2.3.6.3.5 Results and discussion

- Results of Experiment 1: The portion size assessment by the visual perception method

Table 8 depicts the percentage of participants who have correctly estimated the portion size tested by the visual perception method (e.g. for coleslaw, 90% of the 21 participants correctly estimated the portion size depicted in the food image as a large portion size.). Out of the 20 foods tested, 6 foods were incorrectly estimated by more than 50% of the participants (Harees, white rice, Biryani rice, fried fish, fried chicken, Um Ali). Consequently, changes were made to improve the recognition of the portion sizes of these foods by mitigating the characteristics that may have caused misjudgment in their perception. Table 9 summarizes these findings and the solutions that were implemented accordingly.

- Results of Experiment 2: The Estimation of the ideal portion size of men volunteers

As depicted in Table 8, all foods for which the large portion size was assessed, and which were estimated as less than ideal by the 12 men volunteers were modified to include a larger portion size. Out of the 9 foods that were tested in their large portion size, 5 were reported as less than an ideal portion size by more than 50% of the men volunteers: Mutabal, rice dishes, hummus, Harees and bell pepper, thus requiring the inclusion of a larger portion size to account for usual men portion sizes. Table 10 summarizes these findings, the change in the range in portion sizes performed and its rationale for each of the foods.

Table 8: Foods tested in experiment 1 and 2, with the initial portion size and the distribution of responses in percentages for each of the experiments (n = 21)

		Experiment 1: Perception method (n = 21, 12 male and 9 female)								Experiment 2: Identifying ideal food PS for men (n = 12 men)		
Food #	Food Name	Reason for testing by perception method	Tentative PSs (before Pre-test) In grams			PS tested	Distribution of the participants' responses for estimating the PS by the visual Perception Method (Food on plate compared to digital images) (%)			Distribution of the participants' estimation of each PS as an ideal PS (%)		
			S	M	L		S	M	L	Less than ideal	Ideal	More than ideal
1	Coleslaw	Amorphous mound	56	112	168	L	0	10	90	8	75	17
2	Mutabal §	Amorphous mound	30	60	90	L	9	29	62	84	8	8
3	Tabouleh	Amorphous mound	65	130	195	M	14	71	14	42	58	0
4	Biryani*§	Amorphous mound	150	225	300	L	5	57	38	58	33	8

Table 8: Foods tested in experiment 1 and 2, with the initial portion size and the distribution of responses in percentages for each of the experiments (n = 21) (continued)

		Experiment 1: Perception method (n = 21, 12 male and 9 female)								Experiment 2: Identifying ideal food PS for men (n = 12 men)		
Food #	Food Name	Reason for testing by perception method	Tentative PSs (before Pre-test) In grams			PS tested	Distribution of the participants' responses for estimating the PS by the visual Perception Method (Food on plate compared to digital images) (%)			Distribution of the participants' estimation of each PS as an ideal PS (%)		
			S	M	L		S	M	L	Less than ideal	Ideal	More than ideal
5	Bell Pepper§	Served in strips	15	30	60	L	5	38	57	66	33	0
6	Green Salad	Amorphous mound	65	130	260	L	0	28	72	8	42	50
7	Hummus§	Amorphous mound	30	60	120	L	10	14	76	58	34	8
8	Fried fish*	Discrete piece of different size	130	160	180	M	5	33	62	8	58	34

Table 8: Foods tested in experiment 1 and 2, with the initial portion size and the distribution of responses in percentages for each of the experiments (n = 21) (continued)

		Experiment 1: Perception method (n = 21, 12 male and 9 female)								Experiment 2: Identifying ideal food PS for men (n = 12 men)		
Food #	Food Name	Reason for testing by perception method	Tentative PSs (before Pre-test) In grams			PS tested	Distribution of the participants' responses for estimating the PS by the visual Perception Method (Food on plate compared to digital images) (%)			Distribution of the participants' estimation of each PS as an ideal PS (%)		
			S	M	L		S	M	L	Less than ideal	Ideal	More than ideal
9	Balaleet	Dry food in bowl	60	130	190	S	71	24	5	66	33	0
10	White rice*§	Amorphous mound	150	225	300	M	52	43	5	67	25	8
11	Um Ali*	Wet food in bowl	60	120	180	M	86	14	0	42	58	0
12	Salona	Wet food in bowl	90	150	240	M	0	76	24	50	42	8

Table 8: Foods tested in experiment 1 and 2, with the initial portion size and the distribution of responses in percentages for each of the experiments (n = 21) (continued)

		Experiment 1: Perception method (n = 21, 12 male and 9 female)								Experiment 2: Identifying ideal food PS for men (n = 12 men)		
Food #	Food Name	Reason for testing by perception method	Tentative PSs (before Pre-test) In grams			PS tested	Distribution of the participants' responses for estimating the PS by the visual Perception Method (Food on plate compared to digital images) (%)			Distribution of the participants' estimation of each PS as an ideal PS (%)		
			S	M	L		S	M	L	Less than ideal	Ideal	More than ideal
13	Chicken in mixed dish	Discrete piece of different size	70	120	190	M	0	100	0	8	67	25
14	Chips	Served in mound	15	25	50	L	0	5	95	0	25	75
15	Lamb in mixed dish	Discrete piece of different size	60	120	180	S	86	14	0	50	42	8
16	French fries	Served in mound	30	120	180	M	0	57	43	8	75	17

Table 8: Foods tested in experiment 1 and 2, with the initial portion size and the distribution of responses in percentages for each of the experiments (n = 21) (continued)

		Experiment 1: Perception method (n = 21, 12 male and 9 female)								Experiment 2: Identifying ideal food PS for men (n = 12 men)		
Food #	Food Name	Reason for testing by perception method	Tentative PSs (before Pre-test) In grams			PS tested	Distribution of the participants' responses for estimating the PS by the visual Perception Method (Food on plate compared to digital images) (%)			Distribution of the participants' estimation of each PS as an ideal PS (%)		
			S	M	L		S	M	L	Less than ideal	Ideal	More than ideal
17	Fish in a mixed dish	Discrete piece of different size	90	150	240	S	100	0	0	75	25	0
18	Harees*§	Slippery food	75	150	225	L	5	62	33	58	34	8
19	Pasta, boiled	Slippery food	90	180	270	S	57	38	5	50	50	0
20	Fried* chicken	Discrete piece of different size	90	150	240	L	0	75	25	0	58	42

*Foods that were misestimated by the perception method
§ Foods depicted in a large portion size that were deemed less than ideal by male volunteers
S = Small; M = Medium; L = Large; PS = Portion Size

Table 9: Foods not accurately estimated by the visual perception method, possible reason, changes made and rationale of the change

Characteristics of the food*	Food name	Possible reason for the misjudgment of the food PSs in the photographs based on the characteristics of the food.	Changes in the weight/presentation of the food to mitigate the misjudgment by visual perception	Rationale of the changes made
Food served in mound	Harees (Porridge like ground wheat with meat)	The porridge-like slippery consistency of Harees may have caused it to spread over on the plate and therefore lose depth, leading some participants to perceive it as a smaller quantity than it actually is.	Adding foods to the different PSs in a way that shows an increase in the height of the mound formed by the food. Increase the increments between PS from 50 g between the different PSs to 125 g between the S and M PS and 250 g between the M and the L PSs, making the final PSs for Harees 125 g, 250 g, and 500 g.	A higher mound could emphasize the difference in weight between PSs because it gives the visual impression of more food on the plate With larger weight increments between the different PSs, the difference between the PSs is more detectable.

Table 9: Foods not accurately estimated by the visual perception method, possible reason, changes made and rationale of the change (continued)

Characteristics of the food*	Food name	Possible reason for the misjudgment of the food PSs in the photographs based on the characteristics of the food.	Changes in the weight/presentation of the food to mitigate the misjudgment by visual perception	Rationale of the changes made
Food served in mound	White rice	Increments in weight between the different PSs were not large enough to reveal the actual difference in weight.	Change the increments in weight between the different PSs from 75 g to 150 g, making the new PSs 150 g, 300 g, and 450 g for the S, M and L PS.	With larger weight increments between the different PSs, the difference between PSs is more detectable.
	Biryani rice	Biryani rice in the food images was presented as habitually consumed (with a piece of chicken on the plate) while the plate on the table did not contain any meat. The area covered by the meat on the plates in the food images may have misled the participants by masking some of the rice thus making the quantity look smaller than it actually is. Non discernment of the increments in weight may have also been a reason, as was revealed with the assessment of plain white rice.	Make new pictures without meat in the dish. Change the increments in weight between the different PSs from 75 g to 150 g, making the new PSs 150 g, 300 g, and 450 g for the S, M and L PS.	With larger weight increments between the different PSs, the difference between PSs is more detectable.

Table 9: Foods not accurately estimated by the visual perception method, possible reason, changes made and rationale of the change (continued)

Characteristics of the food*	Food name	Possible reason for the misjudgment of the food PSs in the photographs based on the characteristics of the food.	Changes in the weight/presentation of the food to mitigate the misjudgment by visual perception	Rationale of the changes made
Irregularly shaped foods	Fried fish	The difference in the area covered by the fish on the plate between the M and the L PS were not detectable by the participants	New PSs of fried fish purchased from a popular fish restaurant, where all fried Sea Bream fish served were of the same size. New PSs for the S, M and L PSs presented as half of a standard fish, 1 whole fish and 2 standard fish, respectively.	Presenting fried fish in multiples of a standardized size makes it easier to identify.
	Fried chicken	The irregularity of the shape of fried chicken breast may have induced a misjudgment in the difference in weight between the M and L PSs.	New PSs of fried chicken in the form of chicken strips (not chicken parts). Knowing that a usual serving of fried chicken strips was composed of 3 strips, the M PS was presented as 2 strips, the S PS as 1 and the large PS as 4 strips	Fried chicken in the form of strips is a popular dish and easily identifiable

Table 9: Foods not accurately estimated by the visual perception method, possible reason, changes made and rationale of the change (continued)

Characteristics of the food*	Food name	Possible reason for the misjudgment of the food PSs in the photographs based on the characteristics of the food.	Changes in the weight/presentation of the food to mitigate the misjudgment by visual perception	Rationale of the changes made
Foods served in bowls	Um Ali (pudding made of milk and puff pastry)	The consistency of the pudding may have caused the change in weight not to be noticeable enough between different PSs because the puff pastry soaks the milk thus making the mixture become denser with larger portion sizes but without a noticeable increase in volume that could be captured in photographs	New increments of weight between PSs increased from 60 g to 120 g, making the new PSs 120 g, 240 g and 360 g	Change in the increments of weight between PSs to a level that could be discernable in the food images

* Characteristics of the foods are based on Nelson and Haraldsdóttir (1998) classification.
S = Small; M = Medium; L = Large, PS = Portion size.

Table 10: Foods reported as less than ideal by male participants, new portion sizes and rationale of the choice of the new portion siz1es

Food pre-tested	Reason for inclusion	Tentative range of PS (in grams)			% of men reporting that the tentative Large PS was less than ideal	New range of PS to include an ideal men's PS (in grams)			Rationale for the new range of PS that includes an ideal men's PS
Mutabal	Highly popular side dish Median PS reported in 2009/2010 survey was 30 g, may not be ideal PS of an average man	30	60	90	84%	60	90	180	New range of PS where the tentative large PS becomes the medium, and the new small and large PSs were obtained by multiplying the medium PS by a factor of 0.5 and 2 respectively. Larger increments applied to better distinguish between the PSs in the pictures (as reported in experiment 1)
Rice dishes (white rice and Biryani rice)	Staple food, highly popular and high in energy Median PS reported in 2009/2010 survey was 200 g, may not be ideal for an average man	150	225	300	58%	150	300	450	New range of PS where the tentative large PS becomes the medium, and the new small and large PSs were obtained by multiplying the medium PS by a factor of 0.5 and 1.5 respectively. Larger increments applied to better distinguish between the PSs in the pictures (as reported in experiment 1)

Table 10: Foods reported as less than ideal by male participants, new portion sizes and rationale of the choice of the new portion sizes (continued)

Food pre-tested	Reason for inclusion	Tentative range of PS (in grams)			% of men reporting that the tentative Large PS was less than ideal	New range of PS to include an ideal men's PS (in grams)			Rationale for the new range of PS that includes an ideal men's PS
Hummus	Highly popular dish Median PS reported in 2009/2010 survey was 150 g, may not be ideal for an average man	30	60	120	66%	60	120	180	New range of PS where the tentative large PS becomes the medium, and the new small and large PSs were obtained by multiplying the medium PS by a factor of 0.5 and 1.5 respectively. Larger increments applied to better distinguish between the PSs in the pictures (as reported in experiment 1)

Table 10: Foods reported as less than ideal by male participants, new portion sizes and rationale of the choice of the new portion sizes (continued)

Food pre-tested	Reason for inclusion	Tentative range of PS (in grams)			% of men reporting that the tentative Large PS was less than ideal	New range of PS to include an ideal men's PS (in grams)			Rationale for the new range of PS that includes an ideal men's PS
Harees	Highly popular dish Median PS reported in 2009/2010 survey was 125 g, may not be ideal for average man	75	150	225	58%	125	250	500	New range of PS where the tentative L PS becomes the medium, and the new small and large PSs are obtained by multiplying the medium PS by a factor of 0.5 and 2 respectively. Larger increments applied to better distinguish between the PSs in the pictures (as reported in experiment 1)
Bell pepper	Only 7 women reported consuming bell pepper in the 2009/2010 survey and Median PS reported was only 9 g	15	30	60	66%	Quarter	Half	whole	Partition of the vegetable in parts that are recognizable, as was done for presenting other fruits and vegetables.

S = Small; M = Medium; L = Large, PS = Portion size.

2.2.3.7 Supplementary questions added to the draft AE-FFQ before testing

Similar to both EPIC-Norfolk FFQ (Bingham et al., 1997) and Dehghan's FFQ (Dehghan et al., 2005), the initial draft of AE-FFQ was composed of two parts. The first part contained the main food list and the second part contained supplementary questions that were adapted from the EPIC-Norfolk FFQ to fit the dietary habits of the Emirati population .The supplementary questions added to the AE-FFQ were: 1) Open-ended questions to capture any other foods that were not included in the main food list, 2) Qualitative cross-check questions asking about the frequency of consumption of fruits, vegetables, green leafy vegetables, different meats and fruit juices, 3) Qualitative questions about the habits of consuming salt at the table, fast foods, fat around the meat, use of stock cubes during cooking and types of oils used for cooking, 4) Frequency and dose of consumption of the main dietary supplements.

Conversely to the EPIC-Norfolk FFQ, the AE-FFQ did not include questions about the type of milk consumed with tea, coffee, or breakfast cereals because Emirati nationals usually use evaporated milk rather than plain milk in their hot beverages, and the consumption of breakfast cereals is not very popular among adults, as reported by the expert team of nutritionists. Moreover, the cross-check questions in the AE-FFQ did not ask about the weekly consumption of a standard serving of fruits and vegetables as was the case in the EPIC-FFQ because a large choice of portion sizes was offered in the AE-FFQ while only one standard serving was suggested in the EPIC-FFQ. Instead, the cross-check questions were included to ascertain the accurate reporting of the frequencies of consumption of foods groups that are of interest to the study.

Questions on the additional foods consumed used the same frequencies of intake as in part 1 of the AE-FFQ, while the qualitative questions all used the frequency options “Per month”, “Per week” and “Per day”, which are a similar but more comprehensible way to assess the likert frequencies of Never, rarely, sometimes, usually and always. The questions on the consumption of DSs used the frequency options: Never or less than once per month, 1-3 times per month, once per week, 2 to 4 times per week, 5 to 6 times per week, once per day, 2 to 3 times per day and 4 to 5 times per day. These latter frequencies were obtained from the EPIC-Norfolk FFQ (Bingham et al., 1997). All the supplementary questions described above were presented in 4 tables forming 4 groups of questions: 1) Food preferences (Cross-check questions on consumption of fruits, vegetables, different meats, and juices), 2) Food habits (Habits of eating out, habits of eating fried foods, habits of consuming fat around the meat and adding stock during cooking) and 3) Fats used in cooking and 4) Dietary Supplements.

- Rationale for the choice of the dietary supplements included in the AE-FFQ

The intake of 8 supplements was queried in the AE-FFQ: Multivitamins and minerals, vitamin D, vitamin B complex, vitamin C, folic Acid, calcium, iron, and Omega 3 and fish oil. The selection of these supplements was done based on their popularity in the United States (US) market, as reported by the 2019 CRN Consumer Survey on Dietary Supplements (CRN., 2019) because there are no statistics on the use of DSs in the UAE. Another reason for their inclusion is their relevance as nutrients of interest to the study, regardless of their claimed health benefits (e.g. Omega 3 supplementation for the prevention of CVDs is controversial (Mohebi-Nejad & Bikdeli, 2014), and calcium supplementation for the prevention of osteoporosis has not proven to be useful (Chiodini

& Bolland, 2018). Nevertheless, their use can significantly increase the reported intake of vitamins and minerals of interest by the participants and should therefore be accounted for (Bailey et al., 2019).

The list of DSs did not include protein supplements because they are not popular in the public and mostly used by dieters and gym-goers. However, the design of the DSs table for the AE-FFQ included two free cells where participants could add any DS they used other than what was listed.

In summary, the initial draft of the AE-FFQ developed to assess usual intake in the adult Emirati national population contained 146 food lines, comprising both simple and composite dishes. The general format of AE-FFQ was inspired mainly by the EPIC-Norfolk FFQ, including the range of frequency options used, the type of supplementary questions and the questions on supplements use.

2.2.4 Pre-testing of the initial FFQ

Subar (2004) recommends pre-testing and cognitive testing newly developed FFQs to ensure that they are well adapted to the target population. After developing the initial version of the AE-FFQ, it was pre-tested to assess the following:

- The time required for the completion of the questionnaire
- The comprehensiveness of the food list
- The general feedback for improving the questionnaire and making it be more culture specific.

The initial draft of the AE-FFQ was pre-tested by a total of 31 Emirati volunteers (5 males, 26 females), between the ages of 25 and 50 years old. Volunteers were recruited from visitors of a nearby clinic and from UAE university employees. The sample of volunteers included 16 housewives, while the rest of the volunteers were employed. Recruitment of participants took place from April 27th to May 7th, 2017. The inclusion criteria were: Holding an Emirati nationality and not being on any special diet. Upon verbal agreement, the investigator set a meeting with every participant according to their availability. On one occasion, a focus group made of 4 women met with the investigator to discuss the questionnaire. During the meetings, the volunteers were provided with the AE-FFQ in print and were requested to provide feedback. The investigator took note of the comments of each of the volunteers as they were filling the questionnaire and used the information to modify AE-FFQ as required.

- Results of the pre-testing experiment

The feedback obtained touched different aspects of the AE-FFQ and provided valuable insight on the specific meal patterns and preferences of the Emirati population. In general, the volunteers were familiar with all the foods in the food list but found the AE-FFQ to be rather lengthy because it took on average 45 minutes to complete. The challenges encountered by the volunteers, the modifications applied, and their rationales are described in Table 11 below.

Table 11: Results of the pre-testing of the draft Food frequency questionnaire (n = 31)

Challenge encountered based on the volunteers' feedback	Gender and number of participants facing the challenge n (%)	Description of the challenge	Modifications on the AE-FFQ following feedback	Rationale and/or benefits of the modifications
Length of the questionnaire	Female 21(81) Male 2 (40)	Questionnaire took more than 45 min to complete	4 food line-items (Meat-Kibbeh, rusks, Sushi, and dried figs) removed.	Reducing the number of food items shortens the FFQ Volunteers reported consuming these foods rarely
Misinterpretation of specific food items	Female 12 (46) Male 0 (0)	Volunteers checked both the food lines for “full-fat” and “low-fat” milk and/or yogurt (not one or the other), for the same frequency of intake	Both full-fat and low-fat types of dairy products included in the same line. A supplementary question on the frequency of consumption of low-fat dairy products added in part 2 of the questionnaire under the “Food preferences” category.	Including both types of dairy in the same line may reduce the misreporting and the double counting of these food items Adding a question on type of dairy consumed to account for the consumption of low-fat dairy exclusively.

Table 11: Results of the pre-testing of the draft Food frequency questionnaire (n = 31) (Continued)

Challenge encountered based on the volunteers' feedback	Gender and number of participants facing the challenge n (%)	Description of the challenge	Modifications on the AE-FFQ following feedback	Rationale and/or benefits of the modifications
Variability of intake of vegetables in mixed dishes	Female 7 (27) Male 5 (100)	Low intake of the vegetables in mixed dishes such as "Salona" (Emirati stew). Sauce in stew was used to season the rice but vegetables are discarded or only few potato pieces are consumed.	A note was added to the "Composite dishes" group, requesting respondents to report their intake of vegetables from any mixed dish separately and exclusively in the corresponding vegetable line-item in the "Vegetables" group.	Adding a note to the food group of "Composite dishes" may help account for the variability of intake of vegetables in the population. Obtaining more accurate estimates of vegetables intake§
Variability of intake of meat in mixed dishes	Female 22 (85) Male 3 (60)	Reported intake of meat from rice mixed dishes such as "Biryani or Machboos" varied between individuals and varied more between genders	A note was added to the "Composite dishes" group, requesting respondents to report their intake of meat from any mixed dish separately and exclusively in the corresponding meat food line-item in the "Proteins" group.	Adding a note to the food group of "Composite dishes" may help account for the variability of intake of meat in the population. Obtaining more accurate estimates of meat§§

Table 11: Results of the pre-testing of the draft Food frequency questionnaire (n = 31) (Continued)

Challenge encountered based on the volunteers' feedback	Gender and number of participants facing the challenge n (%)	Description of the challenge	Modifications on the AE-FFQ following feedback	Rationale and/or benefits of the modifications
Classification of meat-based dishes according to whether meat is part of a mixed dish or a main dish*	Female 17 (65) Male 4 (80)	Volunteers did not relate to this classification of meat-based dishes, as they were more familiar with describing the type of meat based on its method of cooking	Group the different meat-based dishes based on their method of cooking as follows: Replace the food line "Lamb or mutton, in a mixed dish" with "Lamb or mutton cooked with rice, Salona or Margooga" where, the meat is cooked by braising. Replace the food line "Lamb or mutton as a main dish" with "Lamb, mutton, grilled or barbecued (with bread or rice), as in Kebab, meat Tikka or Shish Tawook" where the meat is cooked exclusively by grilling. Group the different chicken/fish-based dishes based on their method of cooking (braised, fried, or grilled).	Participants can relate to the meat consumed more intuitively based on its method of cooking Specifying the method of cooking (e.g. by braising) allows for a more specific matching of the food with a food match on an FCDB, because FCDBs identify foods by their method of cooking.

Table 11: Results of the pre-testing of the draft Food frequency questionnaire (n = 31) (Continued)

Challenge encountered based on the volunteers' feedback	Gender and number of participants facing the challenge n (%)	Description of the challenge	Modifications on the AE-FFQ following feedback	Rationale and/or benefits of the modifications
Most reported frequencies of intake	Female 19 (73) Male 0 (0)	Volunteers used frequency "1 to 2 times per month", or "2 times per week" more often than any other frequencies to report their monthly or weekly food intake	Modify the frequency options from the typical 9 frequencies to 10 frequencies: Never or less than once per month, 1-2 times per month, 3 times per month, once per week, 2 times per week, 3 to 4 times per week, 5 to 6 times per week, once per day, 2 times per day, 3 times per day	Modifying the frequencies of intake better reflects the volunteers' preferences
Overall clarity of the AE-FFQ	Female 13 (50) Male 1 (20)	Confusion in the interpretation of the higher daily frequencies (6+ per day)	Create a separate section for items typically consumed on a daily basis (water, table sugar, evaporated milk in beverages, salt added at the table) in part 2 of the questionnaire.	Shortening the main list of the AE-FFQ makes it quicker to complete and may reduce boredom. Creating a separate list of foods consumed daily may improve the accuracy of reporting of added sugar and salt intake§§§

§ Importance of vegetables intake in the prevention of nr-NCDs (Mozaffarian, 2016; Zhan et al., 2017).
§§ Importance of meat intake as a risk factor in NCDs (Mozaffarian, 2016; Qian et al., 2020).
§§§ Added salt and sugar are two of the main risk factors of CVDs (Gupta et al., 2018; Mozaffarian, 2016).
*As described in Dehghan's FFQ (Dehghan et al., 2005).
FCDB: Food Composition Database; AE-FFQ = food frequency–adult Emirati food frequency questionnaire.

2.2.5 Characteristics of the final draft of the AE-FFQ

After the modifications were introduced to the draft AE-FFQ based on the feedback of the 31 volunteers, the final draft used for the online version of the AE-FFQ was composed of 2 parts (See the final print version of the AE-FFQ in Appendix 3.):

- Part 1 contained the main FFQ with a list of 135 food-line items, clustered in 12 food groups. The food groups were: (1) Dairy foods, (2) Composite dishes, (3) Proteins (including vegetarian and animal sources of proteins), (4) Vegetables (fresh and cooked vegetables including potatoes), (5) Cereals (pasta and other cereals), rice and starches, (6) Sandwiches and baked snacks, (7) Breads and savory biscuits, (8) Spreads on breads, vegetables or salads (excluding use in cooking), (9) Soups, (10) Fruits and dried fruits, (11) Beverages, and (12) Sweets and other snacks. The frequency response options were: Never or less than once per month, 1-2 times per month, 3 times per month, once per week, 2 times per week, 3 to 4 times per week, 5 to 6 times per week, Once per day, 2 times per day and 3 times per day.
- Part 2 of the AE-FFQ was composed of 1) An open-ended questions section on "Additional foods", 2) 3 groups of qualitative questions, and 3) A group of quantitative questions on the "Foods consumed daily" and that are part of the main FFQ where 4 foods were quantified (Water, evaporated milk, added sugar, salt added to the table) based on a range of seven frequency options: Never or less than once per day, 1 time per day, 2 times per day, 3 times per day, 4 times /day, 5 times /day, and 6 times /day, making 139 the total number of food-line items queried in

the AE-FFQ (135 food line-items in part 1 of the FFQ and 4 food line-items in part 2 of the FFQ) and 4) Quantitative questions on the use of DSs containing the same list of supplements as described in Subsection 2.2.3.7.

The 3 groups of qualitative questions in part 2 of the AE-FFQ are described below:

- Food preferences: Qualitative and cross-check questions querying about the consumption of low-fat dairy, fruits, vegetables, red meat, chicken, fish, and juices)
- Food habits: Habits of eating out, habits of eating fried foods, habits of consuming fat around the meat and adding stock during cooking
- Fats used in cooking (Type of fats used in cooking: Ghee, butter, vegetable oils, olive oil)

The frequencies queried for the qualitative questions and the DSs were described earlier in Subsection 2.2.3.7.

After pre-testing and finalizing the draft of the AE-FFQ, the next phase of the methodology was to build the online FFQ and upload the food images to the corresponding food lines.

2.3 Development of the online AE-FFQ

The online FFQ was developed by an experienced web developer who was hired for this task. The technical features that were communicated to the web developer included the requirements for data completeness, the need for user-friendliness and clarity of the administration process and the need for easy data collection and transfer, while at the same time ensuring the security and confidentiality of the data. To fulfill these requirements, the following technical features and design were implemented in the web-based AE-FFQ.

2.3.1 Technical features

2.3.1.1 To collect complete data

Obtaining complete data was ensured by not allowing participants to skip a field in the AE-FFQ. Respondents could not proceed to the next line until both options; the portion size option, and the food frequency option were selected within a line item. Moreover, respondents were not allowed to move on to the next food group until food lines within the current group were completed. Moving from one webpage representing one section of the AE-FFQ to the next was also only possible if all lines of the current section were completed in the order presented.

Participants were given the possibility to go back to check or modify their previous responses in any food line if desired. Once a section was completed, it was automatically saved, and no more changes were made possible.

2.3.1.2 To improve confidentiality of the AE-FFQ responses

To address data confidentiality and security, Secure Sockets Layer (SSL) encryption was used during all internet data transmission (i.e., from participant to server and from server to the investigator). Both client side-and server-side user authentication was done on the website and the admin portal to ensure that passwords were secure. A unique participant identification number (PIN) was generated for each participant to access the online AE-FFQ. To fill the questionnaire, participants were asked to enter their unique username and password.

Based on the features described above, the print AE-FFQ created was converted to HTML format. The front-end could be accessed at the Uniform Resource Locator (URL): https://foodfrequencymiddleeast.com and the admin panel was accessible at the URL: https://foodfrequencymiddleeast.com/admin.

The complete client and server architecture were developed in ASP .NET 4.7 language. The system used a database supported by a SQL Server 2016 that provided high storage capacity and quick access to multiple users at the same time. All these technologies were installed on Windows™ 10 and used Internet Information Server™ 7 to publish the portal over the Internet.

2.3.2 Description of the structure of the online AE-FFQ

The AE-FFQ was built entirely in Arabic, as a self-administered desktop-only FFQ. It was composed of three main parts: The homepage, the Login page, and the FFQ itself (Figure 1). The flowchart below describes the different parts and sections of the AE-FFQ, and the steps required for completing the questionnaire.

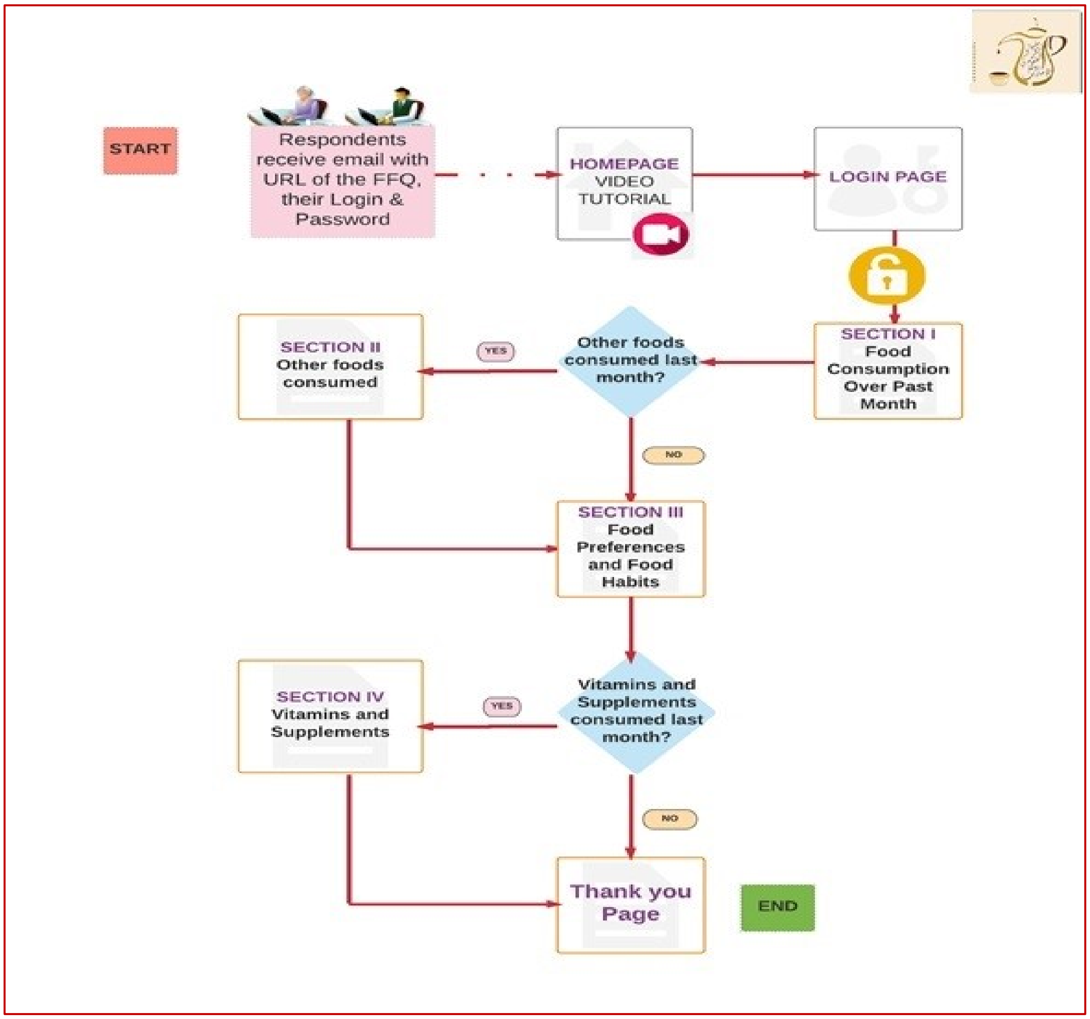


Figure 1: Flowchart of the AE-FFQ

2.3.2.1 The home page screen

The homepage of the AE-FFQ provides a brief explanation of the aim of the study, information about data confidentiality, contact of the researcher in case the participants require additional information, a simplified definition of FFQs and step-by-step instructions on taking the online AE-FFQ. To help the respondents better estimate their portion sizes, a slideshow made of 5 photographs displaying the same dinnerware used for the food photographs with their measurements was included in order to provide users with an idea of scale of the tableware size.

Finally, a video tutorial in Arabic was included at the bottom of the homepage. This video takes the respondents through the different sections of the FFQ and provides examples on how to take the FFQ at every step. Participants were encouraged to complete the FFQ in one sitting/session but were also informed that their responses were saved after the completion of each section, and that they could return to the AE-FFQ at another convenient time. At the end of the page, participants could click on a button with the mention “Start the Questionnaire now” in Arabic. After which they were taken to the login page.

2.3.2.2 The login page

The login page displayed a screen containing a username and password fields, the current date, and the “Enter” button (Figure 2). Entering a participant identification number (PIN) and its unique, automatically generated password gave access to “Section 1” of the AE-FFQ.

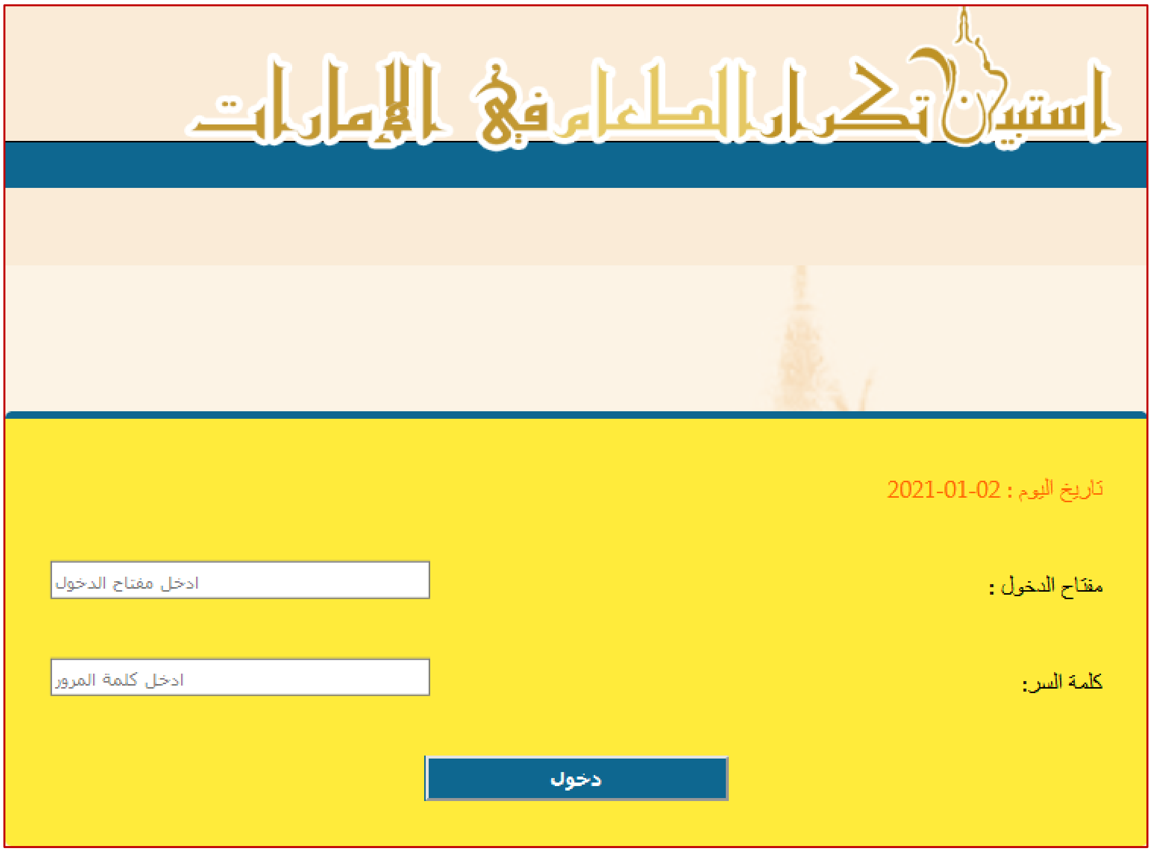


Figure 2: Login page of the AE-FFQ

2.3.2.3 The AE-FFQ itself

The pre-tested and finalized print AE-FFQ was uploaded to form the basis of the online AE-FFQ. It was composed of 4 sections, each displayed on a new webpage (figure 2). Section 1: “Food consumption over the past month” corresponded to the main FFQ or Part 1 of the print AE-FFQ. Part 2 of the print AE-FFQ was divided into 3 sections as follows: Section 2: “Other foods frequently consumed”; Section 3: “Food Preferences and Eating habits” and Section 4: “Supplements and Vitamins”.

A description of each of the sections of the AE-FFQ is presented below:

2.3.2.3.1 Section 1: Food consumption over the past month

The webpage displaying the main FFQ was the first screen that appeared to the user after clicking the “Enter” button in the login page. This page contained the 135 food items clustered in the 12 food groups described before. The 12 food group names were displayed each in the form of a horizontal clickable header. Initiating the questionnaire required clicking on the first top header labeled “Dairy products” (Figure 3), which resulted in the unrolling and displaying of all food line-items within the first group. It was mandatory to answer all food line-items within the group because skipping a line did not allow the next line to display the response options. After all food line-items within the first food groups were completed, clicking on the next header was mandatory to continue with the questionnaire because skipping a header did not allow any content display.

Figure 3: Section 1: AE-FFQ itself with the 12 food groups

Within each food group, next to the name of each food line-item was the frequency option "Never or less than once a month". The radio button was set as the default choice on this option. This allowed participants to simply skip the line if they did not consume that specific food item, thus helping in a faster completion time of the questionnaire (Figure 4).

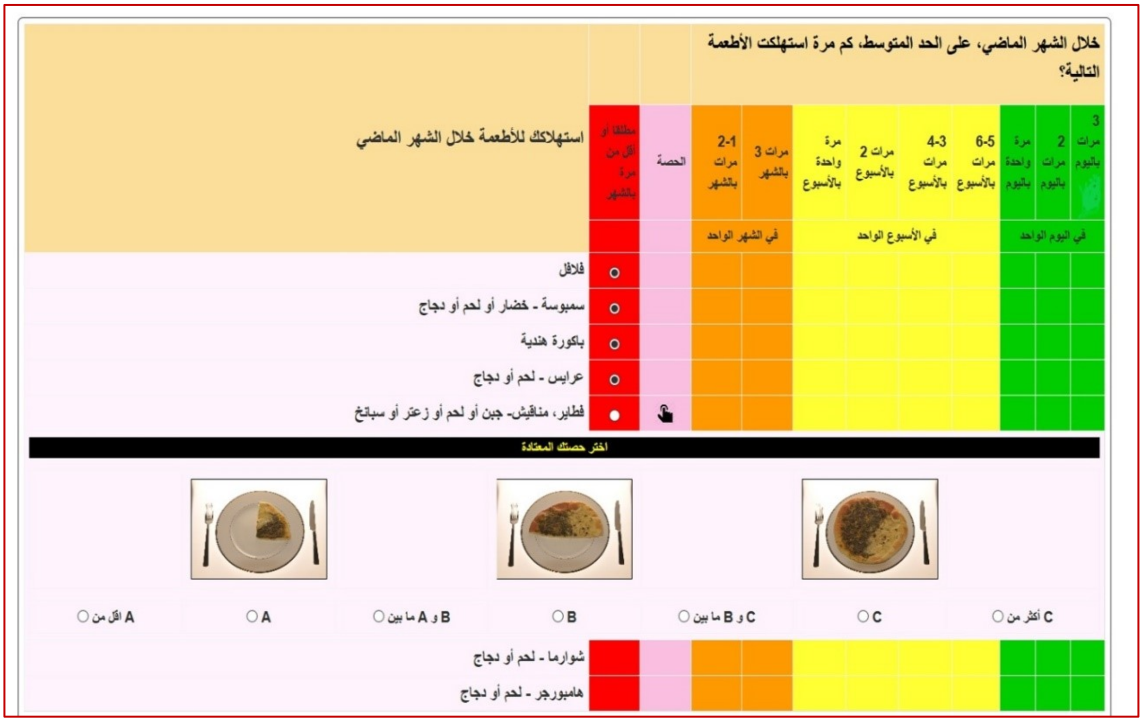


Figure 4: Choosing a portion size within a food line-item on AE-FFQ

Alternatively, reporting a food line-item required selecting the desired portion sizes from a range of 7 options offered, which are a combination of the 3 food images and 4 additional radio buttons in between the food images indicating portion sizes that were bigger or smaller than those shown in the photos. The portion size photographs were labeled A, B, and C without the mention of small, medium and large portion sizes in order to avoid potentially biasing the users in their choices with descriptive labels. After a user selected their desired portion size image, the users' selection was presented as "Size A," "Size B," "Size C" etc. (Figure 5). In order to allow for a better comparison between the three food portion sizes in the photographs, images could be enlarged when the computer cursor is positioned over the food image, thanks to a mouseover effect. The food depicted in the pictures in each food line-item was intended to represent all the foods from that line. Following the selection of the portion size, choosing the desired frequency of intake option was required to allow the user to access the following food line.

Figure 5: Range of portion sizes provided on each food line-item on the AE-FFQ

To help reduce the users' error when selecting the proper food consumption frequency, the monthly, weekly, and daily frequencies were made distinctively different from each other by using 4 different colors. The column covering the option "Never or less than once a month" was in red, the monthly frequency options were in orange, the weekly frequency options were in yellow, while the more frequently consumed daily options were in green color (Figure 5).

Once the responses of all food lines in all food groups were specified, they were automatically saved when the user clicked the "Next' button at the end of the page. This action led the user to a new screen that asked the following: "Were there any other foods that you ate at least once in the previous month?" Users had the choice of clicking on one of 2 buttons, a "Yes" button and a "No" button. Selecting the "Yes" button took the user to section 2 of the questionnaire while selecting the "No" button allowed the user to skip Section 2 and be directed to Section 3 of the questionnaire.

2.3.2.3.2 Section 2: Additional foods

This section was created to provide the participants with the possibility to add foods that they consumed at least once during the previous month but that was not covered in the foods listed in section 1 of the AE-FFQ (Figure 6).

Figure 6: Section 2 of the AE-FFQ

The format of the questionnaire used in this section was similar to the one used in section 1. However, since it is a section inviting users to enter their own foods, a few changes were required. The food name entry in section 1 was replaced by a free text field where users could enter the name of the food they consumed in Arabic or English language. The next column, corresponding to the frequency option "Never or less than once a month" in section 1 was removed because any food entered in section 2 was necessarily already consumed at least once in the previous month.

The next field replaced the food images of portion sizes in section 1 with PSEA in the form of 5 hand images representing different food portion sizes and the image of one glass of 240 mL capacity. Although not a validated method, using images of hands as PS estimators has been used by health professionals as a guide to portion size estimation when more accurate PSEA were not available (Gibson et al., 2016; McGaffey et al., 2010). Each hand picture highlighted a different part of the hand(s) to portray a different portion estimator, as described in the literature (Ameh et al., 2016). Table 12 provides a description of the PSEA used in section 2 of the AE-FFQ.

Table 12: PSEA used in section 2 of the AE-FFQ with the corresponding quantification of foods

PSEA used in section 2 of the AE-FFQ	Foods more suitable for the PSEA	Quantification of the serving in household measurements and/or grams (g)
One thumb (from tip to base)	Peanut butter, butter	28 g
Two fingers	Cheese or cake	28 g
One handful	vegetables, nuts, raisins, or beans	25 g
Two cupped hands	Cup of rice, beans, or vegetables	225 g (for rice)
One full palm of a hand	Average portions of meat, chicken, or fish	85 g
One full hand, without the thumb	Larger portions of white fish or chicken fillet	150 g
One glass of 240 mL capacity	Beverages	240 g

Table adapted from Ameh et al. (2016).

A person could consume multiples of a serving using one of the PSEA described above. Consequently, it was necessary to include a serving size multiplier in order to allow users to report the number of servings that corresponded to their usual intake of the food reported. To that end, the next field asked participants to select from a drop-down list the numbers 0.5, 1, 2, and 3 to indicate the multiplier factor of the portion estimated by the PSEA image selected. e.g., if a person ate 3 handfuls of walnuts in one serving, they needed to select the image where the palm of a hand is highlighted then choose 3 from the drop-down list to provide the usual portion size consumed. The next fields pertained to questions about the frequency of intake and were identical to the frequency of intake fields used in section 1 of the AE-FFQ.

After answering all fields for the food entered, users could go to the next line and add another food if they wished to. A total of 5 lines were provided in section 2 of the AE-FFQ thus allowing users to enter up to 5 new foods.

After completing section 2, the respondent had to click on the "next" button, which automatically saved the responses, and directed the user to section 3 of the questionnaire.

2.3.2.3.3 Section 3: Food preferences and food habits

This section contained the 4 categories described in part 2 of the print AE-FFQ: Food preferences, Monthly food habits, Fats used for cooking, and Foods consumed daily (Figure 7).

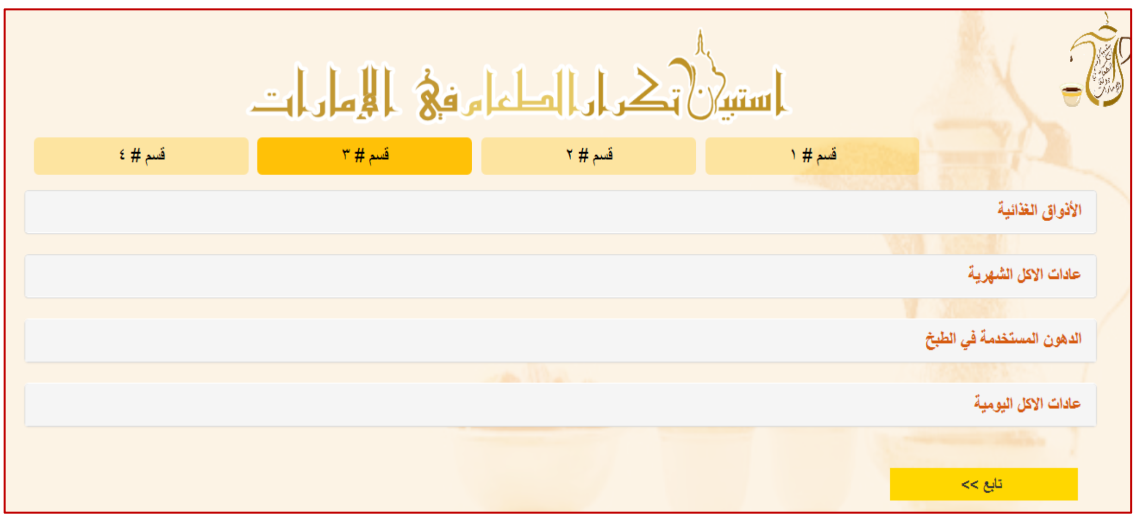


Figure 7: Section 3 of the AE-FFQ

After clicking on the "Food preferences" header, a list of 8 lines, each representing a food group (Dairy, vegetables, green leafy vegetables, fruits, fish, red meat, chicken, juices) was unrolled. Users were requested to indicate the frequency of consumption of each of the 8 food groups by selecting one of the 4 frequency options: “Never or less than once per month”, “1-3 times per month”, ‘1-5 times per week” and “Daily”.

The next group of questions “Monthly food habits” could be accessed after completing questions under the previous header. Responding to all questions in this category allowed access to the following group of questions: the “Fats used in cooking” group. All the groups of questions had the same layout and range of frequencies of intake. The content of all the categories was described in detail in Section 2.2.5.

The last group of questions in this section, the “Foods consumed daily” group presented a similar layout as the section 1 of the AE-FFQ. Users were presented with images of three portion sizes and seven categories of intake ranging from Never or less than once per day, 1 time /day, 2 times /day, 3 times/ day, 4 times /day, 5 times /day and 6 times /day. This group contained 4 foods that are typically consumed on a daily basis in the Emirati culture, water, sugar added to beverages, salt added at the table, as described in Section 2.2.5.

Once users responded to all the questions in the 4 categories of this section, in the order prescribed, they were directed to a page that showed a screen with the following question: “Did you have any supplements or vitamins during last month?”

Two options of responses were available, a “Yes” button and a “No” button. If the respondent clicked on the “Yes” button, they were directed to section 4 of the questionnaire, while if they clicked on the “No” button, they were taken directly to the “Thank you page” of the questionnaire.

2.3.2.3.4 Section 4: Supplements use

Users were presented with a list of eight of the most common vitamins and supplements susceptible to be consumed in the UAE, each presented in one line: Multivitamin/Mineral Supplements, Vitamin D, Folic Acid, Vitamin B-Complex, Vitamin C, Calcium, Iron, Omega 3 and Fish oil Supplements. Additionally, two free text fields were made available for users to add their own vitamins or supplements if they were different from the ones already listed (Figure 8).

Figure 8: Section 4 of AE-FFQ

For each line of a vitamin or supplement, participants were requested to choose the relevant pharmaceutical dosage or measurement unit from a drop list menu. Six options were provided: Tablet/capsule, mg, µg, IU, teaspoon, mL. Next, users could enter in a free text field the dosage quantity in numbers. Following, the commercial brand could be informed. The fields were not mandatory because the respondents might not remember every piece of information. However, the more information they provided, the more a supplement and its dosage could be accurately identified. The last step in filling a line of vitamin/supplement was to indicate the frequency of intake from seven categories that were: Never or less than once /month, 1-3 times/month, Once /week, 2-4 times/ week, 5-6 times/ week, 1 time /day, 2-3 times /day and 6-4 times /day.

At the end of this section, the respondent had to click on the "Send the questionnaire" button at the bottom of the page, after which a "Thank you page" was displayed (Figure 9). The logo displayed on the "Thank you page" represents the coffee pot "Dallah", a symbol of the Emirati hospitality, which was inscribed with the sentence "Food Frequency questionnaire for the UAE" in Arabic calligraphy.

Figure 9: Thank you page

The questionnaire responses were collected from the administrator panel, accessible at the URL: https://foodfrequencymiddleeast.com/admin after entering a login and password.

2.3.3 Description of the administrator website

The dashboard of the administrator website shows the total number of participants, the total number of active participants, and the total number of deactivated users. A menu on the dashboard displays a “Participants management” and a “Questionnaire management” tab (Figure 10).

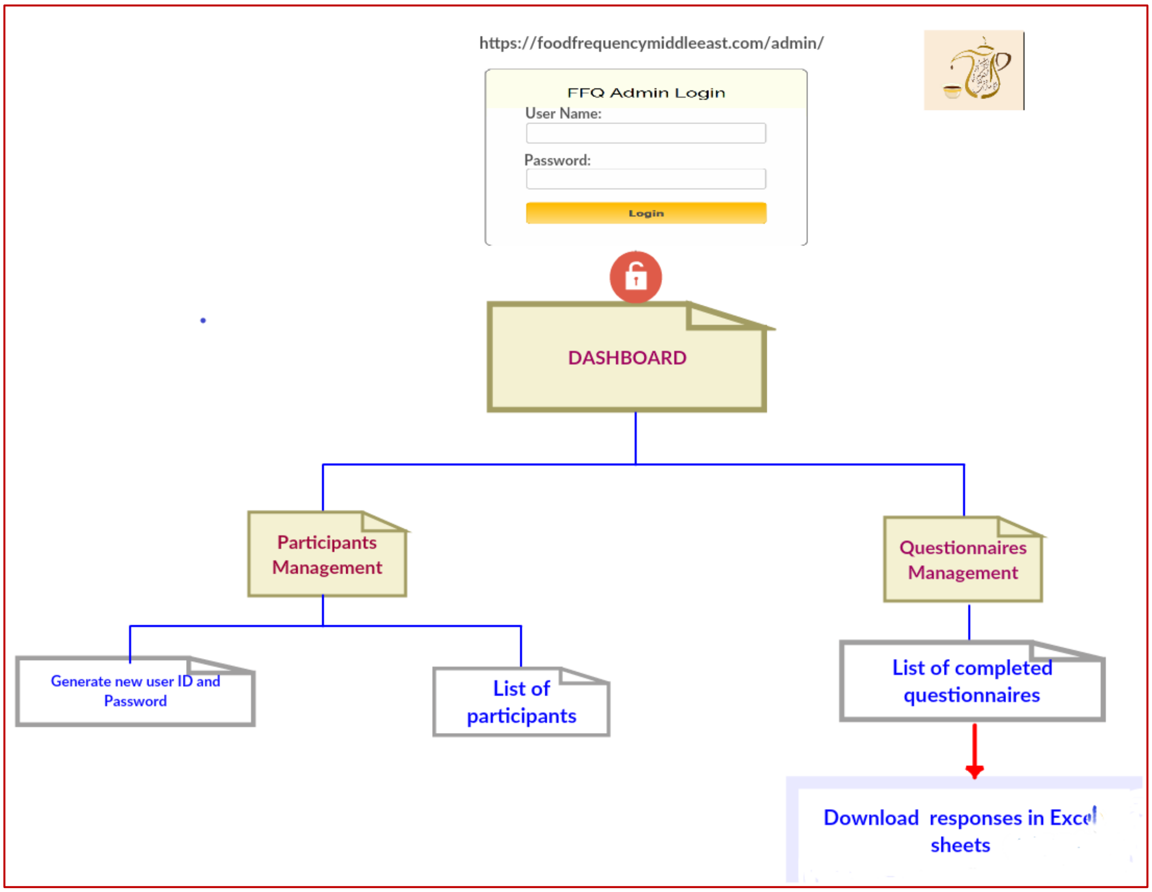


Figure 10: Administrator panel

The participants’ management page gives access to two additional tabs: The “List of participants” tab and the “Add a new participant” tab. “The list of participants” page displays the user Login and password, their status (active is shown as a green icon), and a delete button, which gives the possibility of deleting a particular user. The "Add a new participant" page allows the administrator to generate new users' login and passwords.

The questionnaire management page is where all the questionnaires data are collected and stored. The information is presented as a table that contains the line number, the participant ID, the timestamp corresponding to the FFQ entry in the database, and a clickable "View" button. The view button gives access to a page with 4 tabs. The tabs are labeled "Section 1", "Section 2", "Section 3" and "Section 4", each corresponding to the collected responses of the respective section of the AE-FFQ. A download button allows the data from each screen tab to be downloaded in Excel™ format.

In summary, this chapter described the technical features applied to the online AE-FFQ and provided a detailed overview of the different components of both the user and the administrator websites. After the online AE-FFQ was developed, it was pre-tested by the researcher and her assistant to ensure that the technical features were well implemented and that the responses to the questionnaire were properly saved in the administrator website. After this pre-testing step, the validation study of the AE-FFQ was conducted as follows.

2.4 Validation study

2.4.1 Ethical approval

Prior to data collection, the study procedures were approved by the University's Human Medical Research Ethics Committee (See Appendix 4.) after submitting the research proposal.

2.4.2 Sample size

Based on Thompson and Byers review (1994) review that indicated that correlation coefficients between FFQ and reference instrument for most foods and nutrients were within the range of 0.4 to 0.7, a minimum sample size of 59 participants for a desired minimum correlation coefficient of 0.4 between the AE-FFQ and the three 24HRs (at α = .05 and 95% power) was obtained by power analysis for correlation studies, using G*Power software (version 3.1.9.7.). Cade et al. (2002) recommends a sample size of at least 50 subjects in a validation studies. Since the study at hand required the commitment of the participants for a full month to respond to 4 questionnaires (three 24HRs and one FFQ), the researcher aimed at recruiting 50% more participants than what was required as a minimum sample size to account for any drop-out that may occur during the time of the study.

2.4.3 Eligibility criteria

Inclusion in the study was based on the following criteria:

- Emirati Nationals living in the city of Al Ain and not intending to travel for the next month.
- Being older than 18 years of age.
- Physically and mentally capable of providing informed written consent to participate in the study.
- Not following any type of diet for weight loss or for any medical reason.
- Having maintained a constant weight during the last 3 months.
- Not being pregnant or breastfeeding for female participants.

2.4.4 Recruitment of the study population

Recruitment efforts were done by soliciting adult Emirati volunteers working at different UAE University's departments and offices, UAEU students living in the city of Al Ain, staff working at the nearby hospital, and other governmental offices in the city of Al Ain. It was important that the students recruited for the study live outside of the campuses of the university because food intake inside is limited to the menus offered by the restaurants of the campuses, which is not reflective of the habitual intake and eating choices of the general adult Emirati population.

Initial recruitment was conducted during the month of May 2017. It was important to recruit participants from their place of work rather than from their homes because this allowed the researcher to visit them during their break time without prior notice. This was done in line with the recommended protocol of conducting 24HRs which requires that participants do not know when the interviewer is coming for the interview to ensure that they don't modify their usual diet or their food reporting (Willett, 2013). In total, 83 people were met face to face and screened for eligibility. The recruitment process that was followed and the sample overview are presented in Figure 11 below.

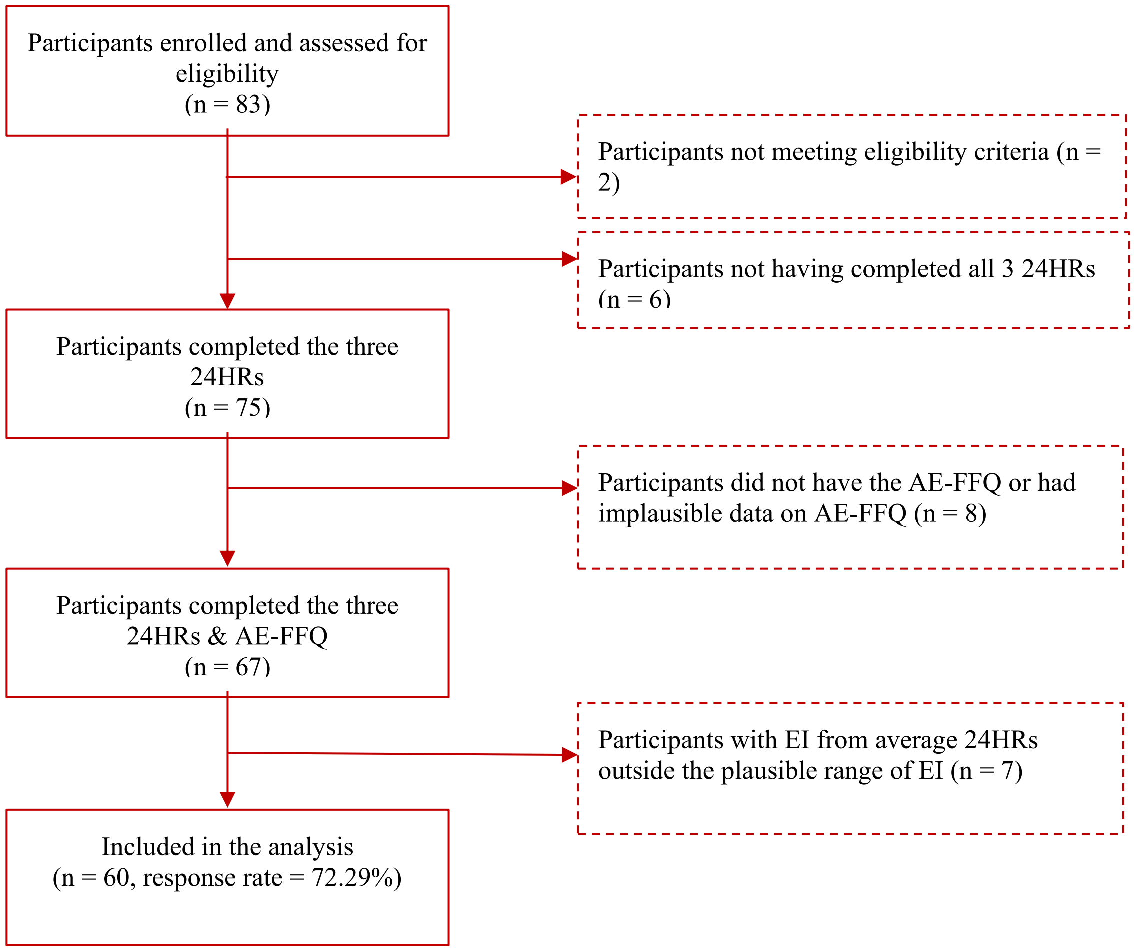


Figure 11: Flow of participants through the validation study

24HR = 24-hour dietary recall; AE-FFQ = Adult Emirati food frequency questionnaire.

- Recruitment materials

During the recruitment period, the participants were given an information sheet about the study and were required to read and sign a consent form (Appendix 9, 10 in Arabic and 11, 12 in English). Consenting participants were asked to complete a demographic questionnaire (Appendix 13), which also included questions about physical activity level (PAL) in order to categorize the participants according to McArdle classification (Table 14). Height was self-reported while weight was measured with a portable digital body weighing scale. All forms provided to the participants were in Arabic language. Of the 83 enrolled UAE nationals, 81 persons (97%) signed the consent form and were eligible to participate in the study. 2 participants were excluded because they had their weight change in the last 3 months due to dieting.

2.4.5 Choice of the reference method

Repeat 24HRs were selected as the most appropriate dietary assessment reference instrument to validate the AE-FFQ. Although WFR is the gold standard of dietary instruments (Carlsen et al., 2010), it was not a practical tool in the context of this study because it was unlikely that the participants recruited would present the motivation and commitment levels required to complete 3 days of WFRs, especially that they were working individuals, which implies that they may not be much involved in the preparation of their meals. The better alternative was to conduct 24HRs on 3 nonconsecutive days to estimate the habitual intakes of the respondents, as a single administration of the 24-hour recall cannot inform about the usual intake because of the normal day-to-day variation in food intake (Willett, 2013). To reduce the extent of underreporting that occurs with 24HRs, the interviews were performed based on the validated protocol of the USDA 5-step MPM of dietary interviewing (Steinfeldt et al., 2013).

- Conducting training on the multiple-pass method

Prior to data collection, the researcher hired a graduate student in nutrition to help with the recruitment and administration of the face to face 24HR interviews. In a four-hour training workshop, the researcher prepared the research assistant in conducting the recall interviews by explaining the methodology used in the multiple-pass protocol. The research assistant was also provided with a recruitment schedule, which required contacting the participants on 3 scheduled (but not notified) occasions over a period of one month. Moreover, the forms and the materials required for conducting the 24HRs (digital food images, a predetermined list of snacks and beverages that consists of a list of frequently forgotten foods (to use in the 2nd pass of the MPM for 24HR interviewing) were also shared with the research assistant.

2.4.6 Collection of data for the validation study

2.4.6.1 Design of the validation study

Three recalls per person were completed over a 30-days period before administering the AE-FFQ. At the end of the 4th week of the study, participants were invited to have the web-based AE-FFQ (Figure 12).

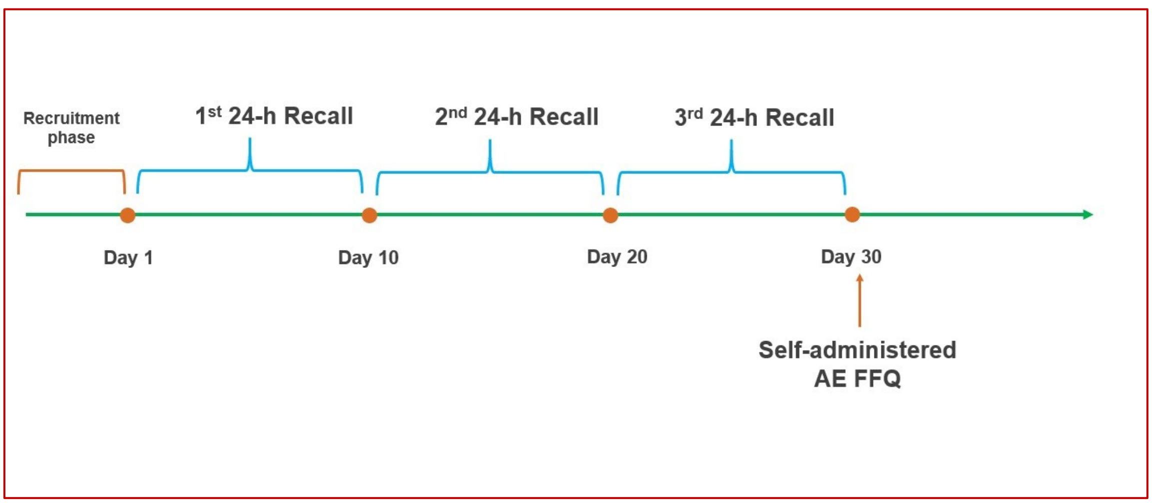


Figure 12: Design of the validation study of the AE-FFQ against three 24HRs among 60 Emirati adults
24HR = 24-hour dietary recall; AE-FFQ = food frequency–adult Emirati food frequency questionnaire.

2.4.6.2 Administration of the three 24HRs

The 24HR interviews were scheduled once every 10 days over a 30-day period, for a total of 3 interviews. At least one of the 3 interviews were scheduled on a Sunday (a working day in the UAE), to collect the reporting of the food intake on the previous Saturday, which is a weekend day in the UAE. The other 2 questionnaires were performed randomly any day from Monday to Thursday to collect the reporting of food intake during weekdays. The 24HR interviews took place at the work location of the participants, during their lunch break.

The respondents' name and surname, age, education level, phone number, email address, and location were entered in an Excel™ sheet. To ensure the anonymity of the participants, unique alphabetical identifiers were generated for each participant. The same ID number generated was used to create a profile on the nutrient analysis software (NAS) when analyzing the 24HRs, and in the AE-FFQ as a personal login ID.

The 5-step MPM 24HR protocol was adapted for use in this study as described in Table 13 below (Steinfeldt et al., 2013).

Table 13: Description of the 5 step MPM adapted to the 24HR interviews

Pass number	Pass name	Description of the type of reporting per pass number/name
First pass	Quick list	Interviewer asks respondents to list every food or beverage they consumed during the previous day; from the time they woke up until the time they went to sleep. The information is noted down without interruption
Second Pass	Forgotten foods	Interviewer reviews the list of foods collected and asks if any of the foods in the forgotten list were consumed (List of forgotten foods used in this study: Juices, dates, nuts and seeds, chips, carbonated drinks, candies).
Third pass	Time and Occasion	Interviewer asks about the chronological order of the foods reported and the situation in which the foods were eaten (e.g., In front of TV, at the restaurant, when visiting a friend, etc.).

Table 13: Description of the 5 step MPM adapted to the 24HR interviews (continued)

Fourth pass	Detailed cycle	Interviewer asks detailed questions about the foods reported and their quantities:	
		Topics of the questions asked	Rationale and example of foods
		Accompanying foods	To include food items commonly served alongside certain foods in the Emirati culture: (e.g., Pickle, fried onion, yoghurt with mixed rice dishes).
		Formulation of the food	To include foods with different formulations as they may contain different amounts of fat or sugar (e.g., low-fat milk or full-fat milk; regular or sugar free candies)
		Method of cooking	Knowledge of the method of cooking used reveals the amount of fat consumed (e.g., stir-fried or deep-fried) and ensures better matching of the food with an adequate match on a FCDB.
		Description of the ingredients	Knowledge of the composition of mixed dishes allows for the creation of recipes to use during the nutrient analysis of the dish. Knowledge of the ingredients of packaged foods ensures a better food matching on FCDB and ensures that fortified foods are not overlooked (e.g., fortified juices
		Time each food was consumed and if consumed between meal	Probing questions on the different eating occasions ensures the capture of forgotten foods (e.g., in the UAE, a specific eating occasion is early morning during the prayer).
		Time each food was consumed	Probing questions on the different eating occasions ensures the capture of forgotten foods (e.g., in the UAE, a specific eating occasion is early morning during the morning prayer).

Table 13: Description of the 5 step MPM adapted to the 24HR interviews (continued)

Pass number	Pass name	Description of the type of reporting per pass number/name
Fifth pass	The final probe	Interviewer reads all the information gathered as an occasion to retrieve any foods that may have been forgotten.

Table adapted from Steinfeldt et al. (2013).
FCDB = Food Composition database; UAE = United Arab Emirates

During the detailed cycle described above, digital food images were used to assist the respondents in reporting the portion sizes of the foods they consumed. To that end, the same food images that were taken for the AE-FFQ were presented to the participants in the 24HRs in a PowerPoint™ slideshow on a laptop. At the end of each 24HR, participants were asked whether the reported food intake was representative of their usual intake, and if not, why not. Often food intake reported during weekends was described by the participants as not representative of their usual intake because it often included foods consumed during family gatherings and outings. Each dietary recall lasted approximately 15 to 20 minutes.

Out of the 81 people initially recruited the total number of participants who committed to responding to all three 24HRs was 75 participants. Four recruits were repeatedly not available after many trials of contacting them, while two others refused to continue with the study because they felt that the questionnaire was lengthy. At the end of the 4th week of the study, participants were invited to have the web-based AE-FFQ. The administration of the AE-FFQ is described below:

2.4.6.3 Administration of the AE-FFQ

To provide access to the web-based AE-FFQ, each participant was sent an invitation via email. The email contained the following information: The participant's individual login and password, the URL to access the online FFQ and a link to a video tutorial that takes the respondent through the different sections of the FFQ.

The administrator website recorded the IDs of the AE-FFQ as soon as they were completed thanks to the timestamp that was saved with each FFQ entry in the database

(Figure 10). This feature allowed the investigator to frequently check the number of FFQs completed and to quickly assist the respondents who had issues with the questionnaire.

At the end of the experiment, 3 participants did not have the AE-FFQ and five others provided implausible data. The corresponding dietary recalls were therefore discarded and the dietary intake data of the remaining 67 participants who had responded to both the three 24HRs and the online AE-FFQ was converted to nutrients using a nutrition analysis software as described below.

2.4.7 Data analysis of nutrients

Obtaining nutrient intake estimates is necessary for studying the effect of individual nutrient risk factors on health (Elmadfa & Meyer, 2010). Given that a designated tool to convert food data to nutrients was not developed in this study as was the case in the EPIC study for which a designated tool was developed to convert foods reported to nutrients (Mulligan et al., 2014), the use of a commercial nutrition analysis software to assess nutrient intake was necessary.

The methodology used to convert food intake data reported in the 24HRs into nutrients is discussed in the following section. It includes the rationale behind the choice of the nutrition analysis software used in this study as well as the procedure used to adapt the nutrition analysis software specifically to the foods reported in the survey in a way that ensured adequate food matching of the foods reported.

2.4.7.1 Choice of the nutrient analysis system

For the needs of this study, three of the most popular nutrition analysis software on the market (CyberSoft, 2016): NutriBase™ (CyberSoft, 2020), Food Processor™

(Hohnstein, 2019) and Nutritionist Pro™ (Axxya-Systems., 2020) were reviewed based on the following set of criteria described by Buzzard, Price and Warren (1991) and Stumbo (2008).

- An updated database

The quality of the FCDB component of a nutrition analysis software is very important for the accuracy of the nutrient estimates obtained. If inadequate, the errors in calculation induced may lead to failure in understanding the relationship between nutrient intake and health (Burlingame, 2003). One commonality between the nutrition analysis software programs reviewed is that they all include the latest release of the USDA SR DB as their primary source of nutrient data because of its high quality and regular updates (CyberSoft, 2016; Stumbo, 2008). Indeed, the USDA SR DB is the most trusted FCDB in the United States and worldwide (Ahuja et al., 2013). Its source of data originates from USDA contracted analyses, the food industry, and the scientific literature (Ahuja et al., 2013). It is updated yearly, and the current version (release 28) contains data on 8,789 food items and up to 150 food components (USDA, 2015).

Software databases are usually updated at least once a year (CyberSoft, 2016; Hohnstein, 2019) to include the yearly updates of the USDA SR DB (Stumbo, 2008) and also to add new foods and ingredients from other sources such as suppliers, manufacturers, and restaurants. The regular updates are also required for the nutrition analysis software to comply with the latest regulatory guidance (e.g. Dietary fiber ingredients that align with the latest Food and Drug Administration (FDA) guidance) (Hohnstein, 2019).

Stumbo (2008) noted that the similarities in updates and features between the different commercial nutrition analysis software makes their evaluation difficult. Indeed, only a few reviews in the literature have compared FCDBs between dietary assessment software programs, with the latest published paper in 1995 (Lee et al., 2008; Stumbo, 2008). Amongst the nutrition analysis software reviewed, Nutritionist Pro™ stood out because it included a higher number of FCDBs from various sources when compared to the other nutrition analysis software pograms (Axxya-Systems., 2020). Some of the high quality FCDBs it included were the USDA SR DB, the Canadian food composition database, the Canadian Nutrient File (CNF), FCDBs from many European countries, such as the United Kingdom's McCance and Widdowson's "composition of foods integrated dataset" (CoFID), the French "ANSES-CIQUAL FCDB", the Danish Frida FCDB etc. Moreover, Nutritionist Pro™ contained databases from other government sources such as 'the food and nutrient database for dietary studies (FNDDS), the USDA school lunch recipes or the USDA recipes for quantity food service, etc.

- A database that contains all the foods and nutrients of interest

All three programs contained an extensive food and nutrient database, with Nutritionist Pro™ software having the lowest number of food items and trackable nutrients for each food item, with about 80,000, and 90 nutrients respectively, while NutriBase™ contained the highest number of food items and nutrients, with more than 760,000 food items and more than 180 nutrients for Nutribase Pro+™ (CyberSoft, 2016). It is worth noting that the high number of food items in NutriBase™ was because of the large database of branded foods which contained more than 540,000 foods and restaurant menus items, while the other software programs contained modest databases of foods and nutrients from restaurants' data and food manufacturers' data (CyberSoft, 2016).

- The ability to add food and nutrients

The food database of each of the software programs reviewed can be expanded by the user, thus offering the possibility of adding an unlimited number of foods, creating recipes, and inputting values to the component data of interest if missing. This feature is of importance to the study at hand because it allows for a greater adaptability of the nutrition analysis software to the specific foods consumed in the UAE that may not be available in the nutrition analysis software program.

- Ease of use of the search engine and data entry

In terms of the efficiency of the search strategy, the three commercial software programs are equipped with user-friendly interfaces that enable an easy search for foods in their databases by entering a food name, food code, database name, brand name, etc. (CyberSoft, 2016). Moreover, the usual serving size (e.g., 3 ounces of an edible portion for chicken breast, or 8 fluid ounce for a cup of milk) are displayed as default servings, while different measurement units can be chosen by the user (grams, kilograms, gallons, cups, milliliters, etc.). The software programs also share nutrition information for all foods and beverages per 100 g by default.

- Educational value of the output

The nutrition analysis software programs compared can all produce food and recipes nutrient data in various formats that are customizable, detailed, and easy to read. The reports generated usually meet the level of detail required for a food consumption survey, which includes calculating individual usual dietary intake for the nutrients of interest. The three nutrition analysis software programs reviewed offer the possibility of visualizing the data in the form of “Myplate” reports, reports in bar or pie charts, and compare the results to dietary intake recommendations and guidelines. Moreover, the reports generated by the nutrition analysis software reviewed can all be extracted in formats suitable for transfer to statistical programs, such as Excel™ spreadsheets or csv formats (CyberSoft, 2016).

- Cost of purchasing and updating the software

Due to the high turnaround, commercial nutrition analysis software programs are sold at affordable prices, ranging from $400 for NutriBase Pro™ to $700 for the Food Processor™, with a cost of annual renewal from free of charge to $300 for Nutritionist Pro™ (CyberSoft, 2016).

In conclusion, it appears that the features contained in the three popular software programs reviewed all fulfill the criteria stated by Stumbo (2008). However, they are distinguishable in terms of the numbers of FCDBs included. While the SR was the main FCDB in all software programs reviewed, Nutritionist Pro™ had a larger choice of FCDBs from different countries. Since the UAE is a country that imports 80 to 90% of its food from all over the world, with the top countries being the United Stated and the United Kingdom (FAS, 2019; World Integrated Trade, 2018), and since it benefits from an international and diverse culinary landscape (Ng et al., 2011), the selected nutrition analysis software program was Nutritionist Pro™ (Axxya Systems LLC, Stafford, TX, USA, version 7.5.0) because it contained a larger choice of FCDBs from around the world, which would increase the chances of finding accurate matches to the foods reported in the survey.

2.4.7.2 Creation of a client profile in the food analysis software

For each respondent, a client profile was created in the software. Unique alphabetical identifiers were assigned in place of the respondents' name and surname to protect their privacy. Other information entered was their date of birth, gender, height, weight, which automatically generated the BMI.

The information entered on age, gender, height, and weight served for the automatic calculation of the BMR based on the Harris-Benedict equation (Harris & Benedict, 1918), personal communication with Nutritionist Pro™). The total daily energy expenditure (TDEE) was also automatically obtained by multiplying the BMR by an activity level multiplier (The Katch-McArdle multipliers) (McArdle et al., 2006). The different Katch-McArdle multipliers used in the nutrition analysis software were: 20% for sedentary, 30% for very light activity, 40% for moderately heavy activity, 50% for heavy activity and 75% for very heavy activity.

Participants were asked to describe their daily physical activity routine during the first 24HR interview. Accordingly, they were assigned to one of the five levels of physical activity in the nutrition analysis software (sedentary, light, moderately heavy, or heavy activity) defined as follows (FAO., nd) (Table 14).

Table 14: Description of physical activity levels based on Mcardle multipliers

Level of physical activity	Description of level of physical activity	Corresponding Mcardle multiplier on the NAS
Sedentary	Individuals engaging only in very light activity, typically as part of their day-to-day routine, such as a desk job, or sitting around the house, with no additional exercise	20%
Very light activity:	Individuals who engage in exercise at a light to moderate level once to three times per week such as walking for 20 to 30 min or engaging in light housework or gardening	30%
Moderately heavy activity	Individuals who exercise at a moderate to high level three to five times per week and those who have a job that requires them to spend most of the day on their feet	40%
Heavy activity	People who engage in vigorous activity 6 to 7 times a week.	50%

Table adapted from FAO (nd).
NAS = Nutrition Analysis Software.

Once a respondent's profile was created, a diet records' folder was opened within the profile to enter the foods reported on each of the 3 days of the 24HRs and match them to the most similar foods in the FCDBs of the nutrition analysis software.

2.4.7.3 Methodology of matching the foods reported in the 24HRs

Although Nutritionist Pro™ contained many FCDBs, none was specific to the Emirati or Middle-Eastern diets. Consequently, to adequately match the foods reported in the survey, the use of multiple sources of data was required. To that end, FAO/INFOODS guidelines for food matching were followed (FAO/INFOODS., 2012d). According to these guidelines, a food reported from a survey should be linked to a food match on an FCT/FCDB that has an identical or similar food name and edible form as well as a complete list of nutrient values of interest that are expressed in standardized definitions, expressions, units, and denominators (FAO/INFOODS, 2012b). When a perfect food match was not possible, a consistent and standardized stepwise approach was implemented to ensure the best possible food match. This rigorous approach was based on the FAO/INFOODS recommendations for food matching (FAO/INFOODS, 2012b). The process involved the fulfillment of the following three consecutive steps: 1) ensuring that matched foods are similar by comparing the name, description, edible parts, and water and fat contents; 2) ensuring that there are no missing values; and 3) ensuring that standardized food component values are uniformly used for all reported foods and that they are expressed in the same definitions, expressions, units, and denominators.

Because the SR DB was used as the reference DB in the study, the same expressions, definitions, units, and denominators that were used in the SR DB were also required for all the nutrients reported in the three 24HRs. Therefore, when the use of nutrient data sources other than the SR DB was required, component values were converted if they were not presented in the same expressions, definitions, units, and denominators used in the standard format of the SR DB. The main nutrients that required a conversion if taken from other data sources are presented in Table 15.

Table 15: Main nutrients that required a conversion and their data sources

Characteristic of the nutrient	Example of Nutrient	Standard format in USDA SR DB	Format in some other nutrient data sources	Conversions or actions required
Expression	Carbohydrate	Total carbohydrate, determined as the difference between 100 and the sum of water, protein, total lipid, ash, and alcohol content, expressed in grams[a,b].	Available carbohydrate in the UK DB, measured by direct analysis and expressed as MSE Fiber not included in the estimation of carbohydrates[a,b].	Recalculate carbohydrates as "total carbohydrate" by difference. Recalculate the energy value of the food to account for the new value of total carbohydrate, using the general Atwater factor of 4/g of carbohydrate instead of the conversion factor of 3.75/g used for carbohydrate MSE[a,b].
Units	IU (vitamin A, vitamin, vitamin E)	mcg RAE (vitamin A), mcg (vitamin D) or mg (vitamin E)	IU, usually in supplements or product labels containing these vitamins(a,b).	For vitamin D, use the conversion factor from IU to mcg: IU/40 = mcg. Other conversion factors can be found under this link https://dietarysupplementdatabase.usda.nih.gov/ingredient_calculator/help.php(d).
	Vitamin E	α- tocopherol	α-TEs in FCDB of most European countries[c].	only alpha-tocopherol values, and not α-TEs values should be used if foods are matched with (or borrowed from) European databases[a].

Table 15: Main nutrients that required a conversion and their data sources (continued)

Characteristic of the nutrient	Example of Nutrient	Standard format in USDA SR DB	Format in some other nutrient data sources	Conversions or actions required
Definition	Vitamin A	RAE	RE	The conversion to RAE can be done if the values of retinol, ß- carotene and other ß- carotene are available, by using the calculation: Vitamin A mcg RAE = mcg retinol + 1/12 mcg ß-carotene + 1/24 mcg other provitamins A[(b)].
Denominators	Per 100 g of EP on a FW	Food component data are presented per 100 g of EP on a FW basis for both foods and beverages (and not per 100 mL) [(b)].	Nutrient values from the literature often reported per 100 g of DM[(b)].	Values reported in DM can be recalculated to FW if the DM value or the water value of the fresh food is given. To calculate values from per DM to per 100 g EP: Nutrient value (NV) (g/100 g EP) = NV (g/100 g DM) x (100-water)/100[(b)].
Units	Beverages	grams	mL from recipes, food labels or HH measurements.	Use the conversion factors provided by INFOODS' density database to convert volume into weight[(e)].

Table compiled from EFSA, 2015(c). INFOODS/FAO, 2012a(e); INFOODS/FAO, 2012b(a); INFOODS/FAO, 2012c(b); USDA (2017)(d).
α-TEs = α-tocopherol equivalents; DM = Dry matter; EP: Edible portion; FW = Fresh weight; HH: Household; IU = International unit; MSE = Monosaccharide equivalent; RAE = Retinol activity equivalent; RE = Retinol equivalent.

To match the foods reported in the survey, the following sources of food composition data were used: The food data sources in the nutrition analysis software, the FoodEXplorer^{TM} interface, regional FCTs, a PhD thesis, and finally recipe calculations. The rationale of the choice of each data source is described below (Figure 13).

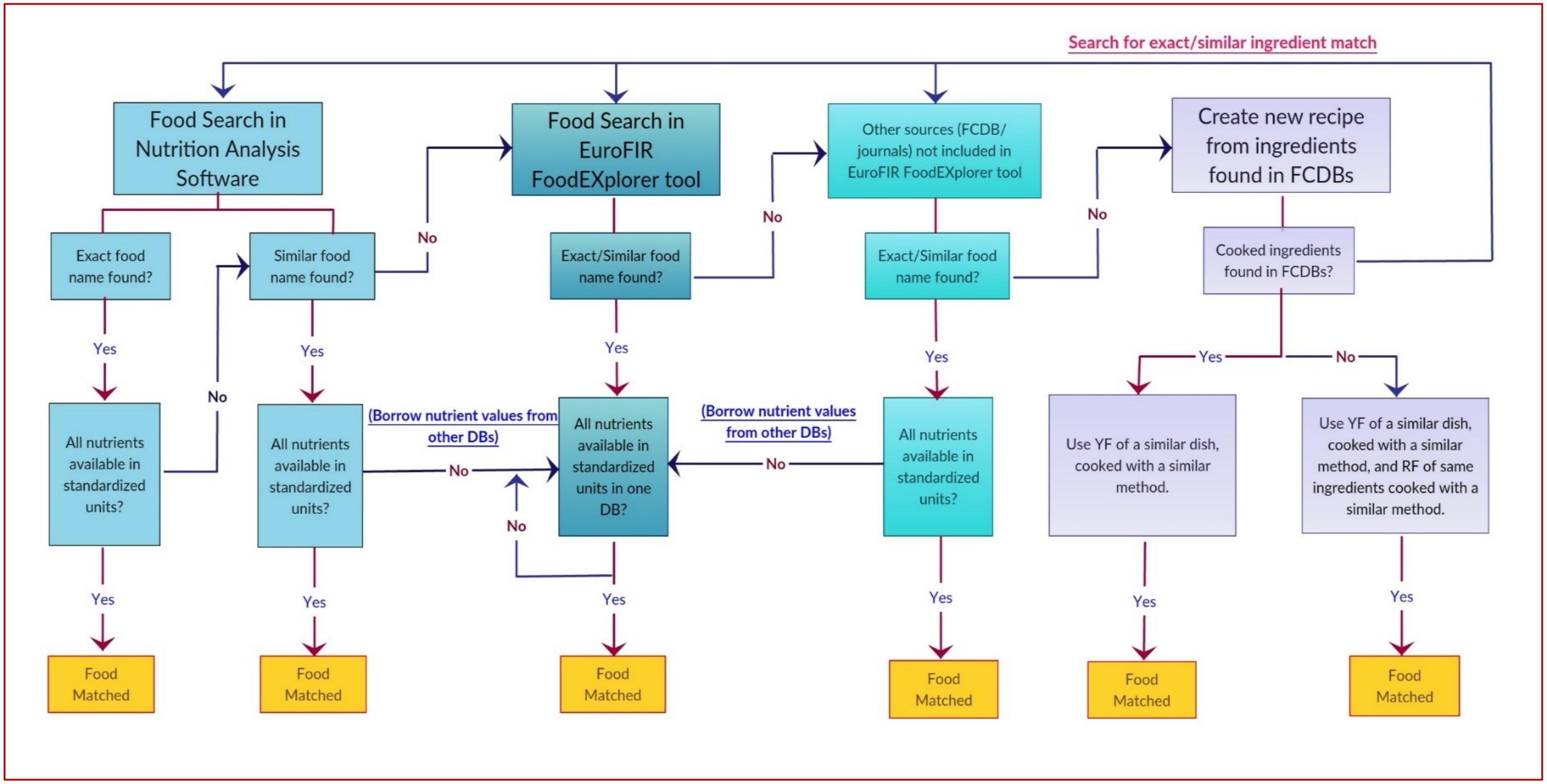


Figure 13: Flowchart of the process of matching the reported foods in the three 24HRs

2.4.7.3.1 Foods matched exclusively on the nutrition analysis software program

The SR DB was the predominant DB in terms of the number of foods in the nutrition analysis software, with 9,342 food items in the software version used in this study. The food search in the SR DB was prioritized over other DBs for the reasons discussed above (Ahuja et al., 2013). The SR DB was used for adequately matching single ingredient foods in various forms, e.g., fruits and vegetables in their raw or boiled form, milk in its skimmed, low fat, or full fat form, meat by its different cut types, and presence or absence of skin and its mode of cooking (e.g., chicken breast, boneless, meat only, grilled; lamb, Australian, shoulder, whole, separable lean and fat, 1/8"). The SR DB was also used to adequately match basic multi-ingredient foods (e.g., breads, ice cream, etc.). Some foods from restaurant chains could be matched with the exact food name and complete values for all nutrients of interest in the SR DB, e.g., different types of pizzas from Pizza Hut™, burgers from McDonalds™ or KFC™. This was not the case when the same foods were matched with data sources provided by restaurants because these sources only displayed a few nutrients. Although the SR DB is regularly updated, only a few popular branded foods (e.g., Twix™ cookie bar) reported in the survey could be matched with the exact food name and a complete list of food components of interest. Instead, most branded foods were matched with generic foods in the SR DB, e.g., Soft drinks and different brands of ketchup or mayonnaise reported in the survey were matched with the generic foods “Soda, cola,” “Ketchup or Tomato Catsup,” or “Mayonnaise, Regular,” respectively, because the differences in nutrient values between the reported and generic foods were minimal. In other situations, as when matching a local brand of food reported in the survey with a generic food, large differences in nutrients were found, such as when a reported food contained a higher level of nutrients added as part of the fortification or supplementation of the product, or a lower level of nutrients if the product was a low-fat or a low-sodium version of a branded food (e.g., Al Rawabi™ "Orange juice, Rich in Calcium" had a calcium content of 100 mg/100 mL, while its closest match on the SR DB "Orange juice, chilled, including from concentrate" had a calcium content of 11 mg/100 g). Not taking into account such discrepancies could impact the accuracy of the nutrient data obtained. To resolve this issue, a four-step process was created to match reported local brands of foods with generic foods found in the nutrition analysis software databases and ensure the obtention of nutrient values for all components of interest. This process was adapted from the INFOODS guidelines as follows (FAO/INFOODS, 2012b):

1. Matching the name of the reported branded food with the generic food name in the FCDB on the nutrition analysis software program;
2. Since water content is not displayed on food labels and therefore cannot be compared with the water content of generic foods in an FCDB, as recommended by FAO/INFOODS guidelines (FAO/INFOODS, 2012b), an alternative method was used which involved comparing the macronutrients on the nutrition facts label with the macronutrients of the matched food. Only generic foods with a difference of less than 10% for each of the three macronutrients were considered possible food matches;
3. Creating a new combination food name in the nutrition analysis software, with the distinctive added code "_24HR", in which the components values displayed on the food label were included because they are more specific to the food product reported;
4. Borrowing the missing values in the reported branded food from the generic food in the FCDB on the nutrition analysis software program and adding them to the newly

created combination food to complete the values of the components of interest, thus ensuring that the new combination food does not have any missing values.

The example below illustrates the process of matching a popular branded food product sold in the UAE with a generic food from the SR DB to include nonlabel component values of interest:

Fresh Laban Full Fat (Laban is buttermilk in Arabic), particularly from the Brand Al Marai™, was frequently reported in this survey. The best food match found was the generic food milk, buttermilk, fluid, whole from the USDA SR DB (Table 16). Based on the algorithm created for matching local branded foods, the food matching process was conducted according to the following steps:

1. Conversion of the denominator from mL to mg.

   The specific conversion factor for buttermilk (1.02) was obtained from the FAO/INFOODS density DB resource (FAO/INFOODS., 2012a); thus, 100 g of the "Fresh Laban Full Fat Al Marai™" corresponded to a volume of 97.84 mL. Therefore, all nutrient values from the food label were multiplied by the conversion factor of 1.02 to obtain their corresponding value per 100 g of edible part (EP).

2. Comparison of the macronutrients of the branded food and generic matched food in the SR DB. In this case, the macronutrient values were extremely similar in the foods compared (<10% difference).

3. Recalculation of the energetic value of the branded food to account for the change due to density conversion, using the general Atwater factors of 4 for carbohydrates and protein and 9 for fat (FAO/INFOODS., 2012c).

4. Conversion of the micronutrient units for vitamins A and D from IU to the standardized units used in the study (for vitamin D, IU/40 = mcg, for vitamin A from animal source, the conversion factor used was IU/3.33 = mcg RAE (USDA., 2017).
5. Creation of the new combination food, which used the components on the label in a standard format and the missing nonlabel values from the generic food from the SR DB. Table 16 shows the value of vitamin B12 borrowed from the generic food added to the new combination food “Laban Full Fat 24H”, which was used every time full fat buttermilk from the brand Al Marai™ was reported.

Table 16: Creation of a new combination food from the components on the label of the "Fresh Laban Full Fat" from Al Marai™ and the non-label components from the generic food "buttermilk, fluid, whole" on the USDA SR DB

Food component	Fresh Laban Full Fat from Al Marai™ (nutrition facts label) per 100 mL (labels' units)	Fresh Laban Full Fat from Al Marai™ per 100 g (standard units)	Milk, buttermilk, fluid, whole USDA SR DB (standard units)	Laban Full Fat 24H New combination food (standard units)
Calories	60 (Kcal)	62 (Kcal)	62 (Kcal)	62 (Kcal)
Protein	3 (g)	3.07 (g)	3.21 (g)	3.07 (g)
Total carbohydrate	4.7 (g)	4.8 (g)	4.88 (g)	4.8 (g)
Fat	3.3 (g)	3.37 (g)	3.31 (g)	3.37 (g)
Vitamin D	40 (IU)	1.02 (mcg)	1.30 (mcg)	1.02 (mcg)
Vitamin A	125 (IU)	38.37 (mcg)	47 mcg)	38.37 (mcg)
Calcium	100 (mg)	102.21 (mg)	115 (mg)	102.21 (mg)
Vitamin B12	-	-	0.46 (mcg)	0.46 (mcg)

USDA SR DB = United States Department of Agriculture Standard reference database

Other high-quality FCDBs included in the nutrition analysis software program that could be used in the same way are the FNDSS and CNF. These FCDBs were much less represented in the nutrition analysis software program compared to the SR DB (6531 foods for the CNF and 939 for the FNDDS). They only contributed minimally to the food matching process. The FNDSS, being custom-built for surveys (Montville et al., 2013), contained more of the convenience foods and recipes, and was useful for matching foods like 'Crepes, Chocolate Filled' or 'Frankfurter or hot dog sandwich, beef, plain, on white bun'.A low level of completeness was observed for certain nutrients of interest in all other FCDBs included in the nutrition analysis software program (e.g. Total sugar and Folates were consistently missing from all other DBs).

To match the rest of the foods that could not be matched by name and/or adequacy of the components of interest, external sources of reliable and comprehensive FCDBs had to be identified. Finding FCDBs that share the same food name, mode of expression and definitions of nutrients is a difficult task. Indeed, standardized food DB structures are still not the norm because they are usually compiled independently for national use in country-specific tables (Kapsokefalou et al., 2019; Slimani et al., 2007). The need for harmonized FCTs for between-country comparisons prompted many international organizations to engage in collaborative projects with the aim of improving the standardization and harmonization of FCDBs so that values from different datasets can be of comparable quality. One such project was conducted by INFOODS (Kapsokefalou et al., 2019). From this project emerged EuroFIR AISBL, the European regional data coordinator for INFOODS, which aimed to improve the quality, availability, reliability, and use of food composition data (Kapsokefalou et al., 2019). EuroFIR developed the EuroFIR FoodEXplorer tool, which is an innovative interface that can be assessed online and allows users to simultaneously search standardized and specialized FCDBs from > 39 countries (EuroFIR., 2014). The interface's unique advantage is the incorporation of the Langual™ thesaurus which helped in removing the ambiguity in food description, and the EuroFIR thesaurus which provided a description of the food components in the proper definition, expression and units (Finglas et al., 2014).

2.4.7.3.2 Foods matched using the EuroFIR FoodEXplorer interface

In light of the above, the EuroFIR FoodEXplorer interface was the second source for food matching because it was useful for 1) borrowing missing values for foods matched by name but not by the adequacy of the list of components of interest on Nutritionist Pro™ and 2) finding food matches to foods that were not matched by name on any of the FCDBs on Nutritionist Pro™.

2.4.7.3.2.1 Borrowing missing values for foods matched by name on Nutritionist Pro™

Although the SR DB is updated yearly, it contains missing nutrients for which data are incomplete for some of the foods. Such was the case for the food "Pudding, rice, ready to eat", which was missing the value of vitamin E in Nutritionist Pro. Applying the step-wise approach adapted from FAO/INFOODS, (2012; 2012d) (Figure 13), the best food match was first searched on the FoodEXplorer Interface by food name and food description. The food match "Rice pudding" from the Greek FCDB was found on the FoodEXplorer Interface with a complete list of all nutrients of interest. Second, the comparability of the water and fat contents were checked, and third, the comparability of the definition and unit of the value of the missing component to borrow (Vitamin E defined as α-tocopherol, in mg) was assessed. After checking all the steps, the calculated vitamin E value was borrowed for use for the food "Pudding, rice, ready to eat" from the SR DB.

The example below illustrates the process of borrowing a missing value in a food in the SR DB (pudding, rice, ready to eat) from a food with the same name and description from another DB (the Greek DB on the FoodEXplorer Interface in this example (Table. 17).

1. Comparing the food name and its description

FAO/INFOODS (2012b) recommends that both the food name and cooking method should be similar when borrowing a missing value from another FCBD. Since the FoodEXplorer Interface uses the LanguaL™ system for food description, it provided information that the rice pudding in the Greek DB was made with milk and heated, which is consistent with the description of "pudding, rice, ready to eat" from the SR DB.

2. Comparing water and fat content

In this example, the difference in water content was < 10% (100 − [76.9 × 100/73.34] = 4.85%), which indicates that the food matched can be used without adjusting all nutrient values. However, the difference in fat content was > 10% (difference was 39.53%), indicating that the values of any fat-soluble components (e.g., vitamin E) that were borrowed must be adjusted before being copied.

The rice pudding selected from the Greek DB had the closest values of water and fat compared with other FCDBs. For comparison, the fat content in the food "pudding, rice, homemade, with whole milk" from the UK DB was 6.5 g, which amounts to a difference of > 202% with the corresponding food from the SR DB.

3. Borrowing the value of vitamin E

Vitamin E is expressed in European DBs as α-tocopherol equivalents (α-TEs), which is not the expression used in the SR DB (EFSA_Panel_on_NDA., 2015). In this example, vitamin E was defined as α-TEs (not as α-tocopherol). However, since the value of vitamin E in this case is small and vitamin E activity of other isomers is assumed to be minimal, the vitamin E value of α-TEs was borrowed for the food matched in the SR DB.

Borrowing the value of vitamin E required adjusting it as a percentage of the fat content in the Greek DB before using it in the matched food from the USDA SR DB. This calculation (2.15 × 0.08/3) yielded a vitamin E value of 0.06 mcg.

Table 17: Comparison of components of pudding and rice and imputation of vitamin E between the USDA SR DB and Greek DB

Component values, per 100 g	Pudding, rice, ready to eat USDA SR DB (standard units)	Rice pudding Greek DB (FoodEXplorer) (units)
Water	73.34 (g)	76.9 (g)
Fat	2.150 (g)	3 (g)
Vitamin E	Adjusted borrowed value = 0.06 (mg)	0.08 (α-TEs)

USDA SR DB: United States Department of Agriculture Standard Reference Database, α-TEs: alpha tocopherol equivalents.

2.4.7.3.2.2 Finding food matches for foods not matched by name on the nutrition analysis software program

To ensure adequate food matching of all the foods reported in the survey with the best possible food matches, the use of other high-quality FCDBs was necessary when the food could not be matched by name on the nutrition analysis software program. Thus, the UK DB was used for its high data quality because it regularly updates its DB with analytical data of foods reported from food consumption surveys (Roe et al., 2015). The use of the UK DB was relevant to this study because it contains many of the Middle-Eastern and Indian foods that are popular in the UAE and that were frequently reported in this survey (e.g., the Indian sweet “Gulab Jamen,” or the popular Middle-Eastern cheese “Halloumi”). The CoFID was also useful because of the diversity of foods and high range of cooking methods it included, such as frying, pan-frying, or grilling (Deharveng et al., 1999; Roe et al., 2015). By contrast, the SR DB mostly used the cooking methods of boiling and stewing.

The CoFID presents a challenge because it expresses carbohydrate as “carbohydrate monosaccharide equivalents (MSEs)” and not as “total carbohydrate,” which is the expression used in the USDA SR DB, the reference DB in this study. As opposed to the SR DB, in the CoFID, fiber is excluded in the estimation of carbohydrates, and the “available carbohydrate” is measured via direct analysis (FAO/INFOODS., 2012c). This difference in expression also influences the energy value of the food: while the conversion of “total carbohydrate” to Kcal uses the conventional general Atwater factor of 4, for carbohydrate MSE, the conversion factor to Kcal is 3.75 (FAO/INFOODS, 2012b). Consequently, when the use of carbohydrate values from the UK DB was required, the calculation of total carbohydrate and energy was performed to match the standard expression used in the SR DB.

The example below illustrates the process of converting the available carbohydrate values expressed in MSEs in the CoFID to total carbohydrate as expressed in the USDA SR DB for the Indian sweet “Gulab Jamen, (retail)” as presented in the UK DB FoodEXplorer Interface. The calculations and conversions required for energy and available sugar are also provided (FAO/INFOODS., 2012c).

- Total carbohydrate values for foods in the USDA SR DB are determined by difference as follows:

[100 - water (g/100 g) + protein (g/100 g) + fat (g/100 g) + alcohol (g/100 g) + ash (g/100 g)].

- Ash value is unavailable in the UK DB and should therefore be calculated by summing the values of individual minerals, which should then be transformed from mg to g (FAO/INFOODS., 2012b, 2012c). FAO/INFOODS guidelines allow discarding the values of selenium and iodine because their contribution to ash is insignificant (FAO/INFOODS., 2012b, 2012c).

Ash value (g/100 g EP) = (Ca (mg) + Fe (mg) + Mg (mg)+ P (mg) + K (mg) + Na (mg) + Zn (mg)+ Cu (mg) + Mn (mg) + Cl (mg))/1000

In this example, the mineral values are as follows: calcium = 249 mg, chloride = 196 mg, copper = 0.06 mg, iron = 0.26 mg, magnesium = 26 mg, manganese = 0.06 mg, phosphorus = 191 mg, potassium = 323 mg, sodium = 106 mg, and zinc = 0.9 mg.

Ash value (g/100 g EP) from the sum of values of all minerals in "Gulab Jamen" = 1.09 g.

Knowing that water content of the food "Gulab Jamen, (retail)" = 37 g/100 g, protein = 7.2 g/100 g, and fat = 12.8 g/100 g, total carbohydrates can be calculated as follows:

100 – [37 +7.2+12.8+0+1.09]

Total carbohydrates = 41.91 g/100 g (as opposed to 43.3 MSEs per 100 g in the CoFID).

The new value of carbohydrates implies a change in the energy value of the food. Using the Atwater general factor of 4 for carbohydrate (instead of 3.75 for carbohydrates expressed in MSEs), the energy value of the food in Kcal becomes 167.64 + 28.8 +115.2 = 312 Kcal/100 g instead of 306 Kcal when carbohydrates are expressed in MSEs.

- Total sugar value was obtained from individual available carbohydrates as follows. Individual carbohydrate values are also expressed in MSE in the UK DB. To convert the individual carbohydrate values from MSEs to individual available carbohydrate by weight as g/100 g, the following conversion factors were used (FAO/INFOODS., 2012b, 2012c): Monosaccharides: factor = 1; Disaccharides: factor = 1/1.05; Starch = 1/1.10.

  The individual values for sugar in "Gulab Jamen" in the UK DB are as follows: Glucose: 0 MSEs, Sucrose: 29.6 MSEs, Lactose: 9.3 MSEs, and starch: 4.4 MSEs.

  Individual carbohydrates (g/100 g EP) = Individual carbohydrates (MSE/100 g EP) × Conversion factor = (29.6/1.05) + (8.86/1.05) + (4.4/1.1) = 28.19 + 8.86 + 4

  Individual carbohydrates = 41.05 g/100 g EP (instead of the value of 38.9 MSE).

<u>Other DBs from the FoodExplorer Interface used in the study</u>

The New Zealand DB (NZ DB) was another high-quality DB in the FoodEXplorer Interface that was used for food matching because it contained cooked dishes not found in the CoFID and many of the branded foods reported in the survey. For example, food products such as Pringles™, "Spread hazelnut Nutella Ferrero™", or "Indomie Maggie™ Chicken Noodles" were all best matched in the NZ DB. Another benefit of using the New Zealand DB was that carbohydrate was presented in the FoodEXplorer Interface both as total carbohydrate and available carbohydrate in MSE, therefore removing the step of converting carbohydrate from MSE to carbohydrate by difference (EuroFIR., 2014).

2.4.7.3.3 Foods matched using regional food composition data sources

Matching Middle-Eastern foods reported in the survey required the use of regional FCTs. Two resources were available, a Ph.D. thesis which included the chemical analysis of 23 traditional Emirati foods (Muhamad, 2016), and the Kuwaiti FCT which contained about hundred traditional foods from the Gulf Region and the Middle-East, but which has not been updated recently (Al-Amiri et al., 2009). Food composition data from the PhD thesis were used to adequately match 8 traditional Emirati foods: Qurus Bread, Arabic bread, Khameer bread, Chebab bread, Rgag bread, a local cheese (Chami cheese) and the desserts (Balaleet (Sweet vermicelli) and Lgeimat (Cardamom fritters). These foods fulfilled the criteria of similarity of food name and food components because all nutrient values were presented according to the USDA SR DB standards.

Matching other traditional foods using the Kuwaiti FCT was more challenging. Besides being last updated more than 10 years ago, the Kuwaiti FCT did not use standard units for some components of interest (e.g., vitamins A was presented in IU), which required the use of conversion factors to obtain values in the standard unit (RAE), a task that was not possible because the values of retinol and ß-carotene were not provided by the Kuwaiti FCT. Moreover, the value of total sugar was not reported in the Kuwaiti FCT, making it impossible to match the traditional sweets Kunafa" or "Tamriya" reported in the survey and matched by name in the Kuwaiti FCT. These foods were not matched with any other nutrient data source; therefore, their nutrient composition was obtained by recipe calculation. Alternatively, the sweet "Baklawa," which was found in both the Kuwaiti FCT and the Greek DB, was ultimately matched on the Greek DB on FoodExplorer Interface because the latter DB included the value of total sugar.

2.4.7.3.4 Unmatched foods requiring recipe calculation

For the reported foods that were not matched on any nutrient data source, recipe calculation was necessary. Nutrition analysis software programs usually perform recipe calculation automatically once all ingredients and their corresponding weights are entered. Simple recipe calculation was applied when the ingredients involved did not require any additional preparation other than mixing e.g. green salads or smoothies. However, most recipes require applying some form of preparation and heat to their ingredients. This process generates changes in weight and nutrients, which strongly influences the nutritive value of the cooked dish as opposed to its raw form (Bergström, 1994; Bognár, 2002). There are many recipe calculation procedures in the literature, such as the INFOODS method, the British method, the method used in EPIC or the USDA method, etc. (EuroFIR., 2008). Schakel et al. (1997) reported that a comparison of calculated and analytical values of mixed dishes conducted by the Human Nutrition Information Service of USDA showed a difference in nutrient content between calculated and analyzed values of less than 10%, suggesting that a rigorous calculation can be a valid substitute for chemical analysis. Bognár and Piekarski (2000) noted that a rigorous calculation can only be achieved if the changes in weight and nutrients during cooking are considered. Accordingly, recipe calculation in this study accounted for changes in weight and nutrients when necessary, as described below.

2.4.7.3.4.1 Accounting for the change in weight during cooking

Information about weight change is usually not provided in cookbook recipes. It is therefore necessary to determine the weight yield by other means. Since recipes usually follow cultural norms and cooking methods specific to a country or a community, the preferred method for determining the weight yield is by weighing and summing the raw ingredients in their edible, ready-to-cook form, cooking the dish, and then weighing the cooked dish in its ready-to-serve condition (FAO/INFOODS, 2012a). The yield factor (YF) (weight change in foods or recipes due to cooking) can then be calculated using the following formula (Bognár, 2002):

$$YF = \text{total cooked weight (g)}/\text{total weight of raw ingredients (g)}$$

It is not always possible to weigh all the foods reported in a nutrition survey, and since the YFs specific to composite dishes consumed in the UAE are still not available in the literature, the YFs of similar foods and dishes were therefore borrowed from the published literature. For the current study, the tables of weight YFs provided by the USDA (2012), Bognár (2002), EuroFIR (2008) , and Bergström (1994). These references contain the YFs for hundreds of foods and dishes that underwent different cooking procedures.

2.4.7.3.4.2 Accounting for the change in nutrients during cooking

The changes in fat and water observed during cooking, and the different treatments that food undergoes before and during cooking can influence the nutrient content of foods (Bergström, 1994; Bognár, 2002). To account for these changes, a retention factor (RF) (a term used for the nutrient content that remains after food preparation) must be applied to the nutrient values of a food or ingredient to calculate the amount of nutrients remaining in its cooked form (Bergström, 1994; Bognár, 2002).

Research in this field has found that the nutrient retention of foods are similar after cooking under the same conditions, e.g., red meat, whether baked or roasted, is cooked by dry heat in both cases (EuroFIR., 2008). Consequently, nutrient RFs have been assigned according to the three main cooking methods, namely, "cooked by dry heat," "cooked by moist heat," and "cooked with fat or oil" and all other methods of cooking are assigned to the best match within these three cooking methods (EuroFIR, 2008). Some of the published sources of RFs are Bognár (2002), the USDA's table of nutrient retention factors, Release 6 (USDA., 2007), and EuroFIR (2008).

The United Nations University recommends correcting ingredients for the effect of cooking either by using the YF (to adjust from raw to cooked weights) if data for cooked ingredients are available in FCTs/FCDBs, or by applying both the YF and RF if data for cooked ingredients are not available (Rand et al., 1991).

2.4.7.3.4.2.1 Examples of corrections applied to recipes for which ingredients are available in their cooked form in FCDBs

Although the availability of cooked ingredients in FCDBs simplifies the creation of recipes, a few steps must be followed to create an adequate recipe, such as 1) conversion to grams of any measurement units used in the recipe, 2) conversion of the foods into their edible form in grams before matching them with a food in an FCDB, 3) finding the most adequate YF to each cooked ingredient in the published references, 4) finding the appropriate food match to each cooked ingredient in a nutrient data source.

The example below illustrates the calculation of the recipe "Beef Macaroni with Béchamel Sauce" from cooked ingredients matched in different FCDBs. The recipe used was shared by an experienced chef. Table 18. shows the calculations made to reach the final weight of each cooked ingredient based on the amounts and ingredients of raw foods in the original recipe.

Table 18: Calculation of a recipe for beef macaroni with Béchamel sauce from cooked ingredients

Name of raw ingredient in recipe (translated from Arabic)	Amount and measurement in recipe	Converted amount and edible parts in grams	YF used	Name of the cooked food corresponding to the YF used	Source of YF	Best food match	Country's DB	Final weight of ingredient in grams
Pasta Macaroni	3 cups*	315 3 × (105)	1.3	Macaroni, boiled	(Bergström, 1994)	Macaroni, unenriched, cooked	USDA SR DB	409.5
Minced beef	500 grams	500	0.62	Beef, ground, high fat (>22%), crumbles fried in pan, sautéed, or stir-fried	(USDA., 2012)	Beef, ground, 70% lean/30% fat, crumbles pan-browned	USDA SR DB	310

Table 18: Calculation of a recipe for beef macaroni with Béchamel sauce from cooked ingredients (Continued)

Name of raw ingredient in recipe (translated from Arabic)	Amount and measurement in recipe	Converted amount and edible parts in grams	YF used	Name of the cooked food corresponding to the YF used	Source of YF	Best food match	Country's DB	Final weight of ingredient in grams
Vegetable oil	2 TS*	27.2 (13.6 × 2)	NA	NA	NA	Oil, corn	USDA SR DB	27.2
Onion, chopped	2 medium pieces*	220 2 × (110)	0.5	Onion, medium, braised	(Bergström, 1994)	Onion, yellow, sautéed	USDA SR DB	110
Tomato paste, canned	2 TS*	32.8 2 × (16.4)	NA	NA	NA	Paste, tomato, canned	USDA SR DB	32.8

Table 18: Calculation of a recipe for beef macaroni with Béchamel sauce from cooked ingredients (Continued)

Name of raw ingredient in recipe (translated from Arabic)	Amount and measurement in recipe	Converted amount and edible parts in grams	YF used	Name of the cooked food corresponding to the YF used	Source of YF	Best food match	Country's DB	Final weight of ingredient in grams
Tomato, peeled, diced	1 piece*	120 1 × (120)	0.88	Tomato, cooked	(Bergström, 1994)	Tomato, fried in corn oil	UK DB	105.6
Garlic cloves, minced	3 pieces*	9 3 × 3	NA	NA	NA	NA	USDA SR DB	9
Oregano, dried	2 ts*	3.6 2 × (1.8)	NA	NA	NA	Oregano, ground	USDA SR DB	3.6
Salt, table	1 ts*	6 1 × (6)	NA	NA	NA	Salt, table	USDA SR DB	6

Table 18: Calculation of a recipe for beef macaroni with Béchamel sauce from cooked ingredients (Continued)

Name of raw ingredient in recipe (translated from Arabic)	Amount and measurement in recipe	Converted amount and edible parts in grams	YF used	Name of the cooked food corresponding to the YF used	Source of YF	Best food match	Country's DB	Final weight of ingredient in grams
Pepper, ground	1/2 ts*	1.05 ½ (2.1)	NA	NA	NA	Pepper, black, ground	USDA SR DB	1.05
Mozzarella, shredded	1 cup*	112 1 × 112	NA	NA	NA	Cheese, mozzarella, whole milk	USDA SR DB	112
Sauce Béchamel	1000 grams	1000	NA	NA	NA	Sauce, white, medium, homemade	USDA SR DB	1000

*Weight of measurement units provided by the NAS, which are sourced from the USDA SR DB (2015).
NA = Non-applicable; NAS = Nutrition Analysis software; Ts = teaspoon; TS = tablespoon; USDA SR DB = United States Department of Agriculture Standard Reference database; YF = Yield Factor

As per the recipe's directions, after cooking all the ingredients together, sauce béchamel (also called white sauce) is added to the mixture as the final step, and the dish is cooked in the oven for an additional 20 min. The moisture loss due to this last step was accounted for by applying a YF of 0.91, which corresponds to the cooked food "Macaroni cheese boiled, baked, grilled" (Bergström, 1994).

2.4.7.3.4.2.2 Example of corrections applied to recipes for which ingredients were not available in their cooked form in a nutrient data source

To calculate recipes from raw ingredients, the recipe calculation harmonization procedure developed by the EuroFIR AISBL was followed (EuroFIR., 2008). EuroFIR's guidelines for recipe calculation recommend applying the YF at the recipe level and the RFs at the ingredient level. Since some ingredients may undergo more than one cooking treatment in a given recipe (e.g., broccoli is often blanched/steamed before being stir-fried), applying the appropriate RF to each step of making the recipe can provide a more accurate estimate of the nutrient content of the end product (EuroFIR., 2008).

EuroFIR website provides a practical example of recipe calculation along with a detailed explanation of each of its steps in a downloadable excel template (http://www.eurofir.org/2015/12/16/eurofir-recipe-guideline/). The initial validation of calculated data with this method has shown that the method was valid as long as the ingredient data are reported accurately (Machackova et al., 2018). This template was used to build an Excel™ sheet recipe calculation matrix to calculate the recipes from raw ingredients in this study.

The example below illustrates the calculation of a recipe for "Ma'moul cookie" (a traditional Arabian flattened cookie filled with dates), from raw ingredients, using specific

YFs and RFs to account for the loss of weight and nutrients due to cooking based, on EuroFIR recipe calculation method (2008). Ma'amoul recipe consumed in the UAE was obtained from Emirati volunteers. Appendix 14 describes the recipe calculation procedure performed on the Excel™ sheet matrix.

- Steps to the calculation of the recipe of "Ma'amoul cookie" from raw ingredients described in Appendix 14. are listed below:

  1. List all the ingredients.

  2. Determine the amount of ingredients in the recipe in grams.

  3. Sum the weight of all raw ingredients.

  4. Determine the cooked weight of the ingredients using the appropriate YF of a similar dish from the published literature. In this example, the cooked weight was determined by using a YF of 0.8 for the food "Biscuit, short crust" from the Bognár tables (2002). The cooked weight was obtained by multiplying the weight of the raw ingredients by the YF (in this example, raw ingredients weight = 1139 g × YF of 0.8 = 911.5 g of cooked weight in edible form).

  5. Add the values of the nutrients of interest of the input ingredients corresponding to the adequate ingredient match chosen from a FCDB (in this example, nutrients from the ingredient "Flour, All Purpose Wheat, White, Unenriched' from the USDA SR DB).

  6. For each ingredient, calculate the value of each nutrient per 100 g of cooked ingredient.

  In this example, the content of the nutrient (protein) in the ingredient (flour) in the cooked form of the ingredient per 100 g was calculated as follows:

(Nutrient content per 100 g ingredient * Raw weight of ingredient (g))

Total cooked weight (g)

$$= \frac{10.33*187.5}{911.5} = 2.125 \text{ g of protein in 100g of cooked flour}$$

7. Collect data abowiut RFs for vitamins and minerals, considering the cooking procedure used.

The RFs applied to the nutrients in the flour used in the recipe were extracted from the ingredient "flour/meal, bake" found in the reference "USDA table of nutrient retention factors, Release 6" (USDA., 2007). In this example, the corresponding RFs were 0.9 for vitamin A and 0.8 for thiamin.

Less specific RFs were used for ingredients for which a similar food match was not found in any of the RF tables. For example, there was no specific food match for dates in any of the RF tables; therefore, RFs for "fruits (dried), baked" (USDA, 2007) was used for dates baked in the recipe.

8. Sum up all the macro and micronutrients contributed by the ingredients in their cooked form per 100 g of cooked food.

9. Calculate the caloric value per 100 g of cooked food using the Atwater general factors for macronutrients (FAO/INFOODS, 2012a): cooked food in Kcal/100 g = 4 × protein (per 100 g) + 9 × fat (per 100 g) + 4 × carbohydrates (per 100 g).

2.4.7.4 Steps to estimating the daily nutrient intake from the 24HRs

The steps described above ensured that 97% of the 532 foods reported in the three 24HRs were adequately matched with an exact or equivalent food name derived from a high-quality DB or obtained by recipe calculation from ingredients derived from high quality databases. Energy and nutrient estimates generated from the foods reported in the 24HRs in their corresponding portion sizes were downloaded in Excel^{TM} sheets for each participant and the average daily intake was obtained by averaging the energy and nutrients from the 3 days of recalls. Participants having reported EIs from the three 24HRs outside of the range of 1000 to 4000 Kcal for men or 800 to 3500 kcal for women were excluded from the final analysis (Zamora et al., 2010). Nutrient profiles of all participants were then organized in one Excel^{TM} sheet and prepared for data analysis.

The development of the nutrient table for the AE-FFQ is described in the following section. It includes the methodology used to assign nutrient values to single food line-items and multiple food line-items in the AE-FFQ.

2.4.8 Development of the nutrient table for the AE-FFQ

Developing a table of nutrients for the AE-FFQ is required for comparing the average daily nutrient intake estimated by the FFQ and that obtained by the three 24HRs for the validation study and for translating the information derived from the AE-FFQ into estimates of nutrient intake and for nutritional risk assessment.

2.4.8.1 Allocation of nutrients to single food line-items

The assignment of nutrients to single food line-items was based on data from the 2009/2010 national survey, the only national food consumption survey in the UAE. The food codes that were used to match the reported foods in this dataset were mostly generic codes that did not present enough description to discriminate between varieties of a food item. For example, all apples reported in the 2009/2010 survey were matched with the food description “Apples, fresh, medium”. Similarly, fried fish was reported as ‘Fried

Fish' matched in the Kuwaiti DB without description of the types of fish used or the different types of frying (e.g., with or without batter). Consequently, the methodology recommended by Block et al. (1986) of using the nutrients obtained by calculating the median nutrients per 100 g of all the varieties of a food (e.g. different varieties of apples) for a single line food-item could not be fully applied for this study.

Given the lack of more discriminative food consumption data sources, food matching of single food line-items in the AE-FFQ was mostly based on generic foods. For example, the line-item for green peas was matched with 'Peas, Green, Frozen, Boiled, Drained, with Salt Added' in the SR DB. Similarly, french fries were matched with the generic food code for 'French Fries, Fried in Vegetable Oil, Fast Food'. Other foods from the AE-FFQ were matched with foods from the FoodExplorer interface that were added to the nutrition analysis software for matching foods reported in the 24HRs, e.g. the food line-item for 'Paratha' was matched on the CoFID on FoodExplorer interface. Similarly, the Kuwaiti DB was used to match 'Maleh Fish' reported in both the 24HRs and the corresponding single line-item in the AE-FFQ (Al-Amiri et al., 2009). The recipes developed for foods such as Um Ali or Ma'amoul cookies were also used for matching both the reporting on the 24HRs and the corresponding single line-items on the AE-FFQ. In total, 92 foods were matched with a generic food as described above, which corresponds to 66% of the total number of lines in the AE-FFQ.

2.4.8.2 Allocation of nutrients to composite food line-items

The remaining 47 food lines in the AE-FFQ (34%) were composite food line-items comprised of foods aggregated based on the similarity of their nutrient content and the manner of serving (e.g. oranges and tangerines in the same composite line) (Cade et al., 2004). There is no consensus on the methodology to use for assigning nutrient values to composite food line-items (Subar et al., 2000), however, using the weighted average of the nutrient profiles of all foods aggregated in a line provides the most accurate estimates when nationally representative data are available (Block et al., 1986; Subar et al., 2000). Consequently, to obtain more accurate nutrient estimates of composite food lines, the 2009/2010 national survey was consulted to determine Emirati females' relative weights of each of the foods aggregated in composite food line-items. To remedy the lack of national food consumption data on adult Emirati males, food intake data of male participants from the 24HRs (the reference method) was used to determine men's relative weights for the food items aggregated within composite food lines. Although the methodology of using the reference instrument of the validation study to derive weighted averages of food lines may induce biased correlations between the 24h recalls and the AE-FFQ, it was applied because there was no other data available on Emirati males' food consumption in the literature. A similar approach was reported by Sanjeevi et al. (2017), where the reference instrument data was used to determine the weighted average of aggregated food line-items. To ensure that any correlations between the AE-FFQ and the reference method are not inflated due to the use of this methodology, an additional correlation analysis was performed based on Willett's et al., approach (1985) where the most frequently consumed food in a line-item of aggregated foods was used to represent the nutrient composition of the whole line (Shahar et al., 2003; Willett et al., 1985; Wolongevicz et al., 2010). A new AE-FFQ nutrient table based on Willett et al.'s method (1985) was therefore developed to allow for a secondary analysis.

The foods aggregated within each composite food line were obtained from the cumulative frequencies of intake from both the 2009/2010 national survey and the 24HRs data of men participants. For example, the "Shawarma" line included both varieties of meat and chicken Shawarma, the line depicting lamb consumed in mixed rice dishes included "lamb trimmed to ¼ fat and to ⅛ fat" because these were the only 2 options available in the SR DB that depict the amount of fat around lamb meat. To calculate the weighted average of a composite food line, the relative consumption of each food within the line was calculated based on the formula:

Relative consumption of food X = (Consumption of X/Total consumption of all foods in the line)

The relative consumption of the food X was then multiplied by 100 to obtain the percentage contribution of the food item in the line, so that the sum of all foods included totaled 100%. The nutrient values for each food were then weighted by its proportion, making the total weight of the composite line equals 100 g, which is the default weight in which nutrient values are usually reported in nutrition analysis software programs.

- Example of weighted average calculation:

For the line containing yogurt, full-fat (FF) and low-fat (LF), the frequency of consumption of each type of yogurt was identified from the nutrition surveys described above. The 2009/2010 national survey showed that 99 out of 108 women consumed plain FF yogurt, while 6 consumed LF yogurt. 2 women reported consuming fruit yogurt, but since they contributed minimally to the overall reported consumption of yogurt, they were discarded. For men, data from the three 24HR revealed that 18 men consumed yogurt, with 15 consuming FF and 3 consuming LF type of yogurt, while no one reported consuming fruit yogurt. Applying the formula described above the percentage contribution of yogurt FF and LF for women was 94.28 % and 5.71% respectively, while for men, 88.81% of the food line was represented by FF yogurt and 16.66% by LF yogurt. According to the UAE's demographic statistics (Statistics-Centre., 2019), Emirati men and women represent each about 50% of the UAE national population. Consequently, estimates of consumption of yogurt FF and LF at the population level were 88.81% and 11.19% respectively (Table 19).

Table 19: Weight computations for yogurt

Foods in the composite food Line	Foods within the line	N1: Women consumption (2009/2010 national survey)	Relative weight of each food item for women (%)	N2: Men consumption (three 24HRs)	Relative weight of each food item for men (%)	Percentage of contribution for both men and women (N1+N2/2)
Yoghurt, Full fat (FF) and Low fat (LW)	Yoghurt FF	99	99/105 (94.28%)	15	15/18 (83.33%)	88.81%
	Yoghurt LF	6	6/105 (5.71%)	3	3/18 (16.66%)	11.19%
Total	-	105	105/105 (100%)	18	18/18 (100%)	100%

24HR = 24h recall; FF = Full-Fat; LF = Low-Fat; YF = Yield Factor

The same approach was applied to all the composite food line-items in the AE-FFQ. In total, the 47 aggregated lines of the AE-FFQ were expanded into 116 single food items, each of which was assigned a relative weight and a nutrient value, making the total number of foods in expanded food list 208 foods.

2.4.8.3 Creation of a "FFQ profile" in Nutritionist Pro™

To obtain a nutrient table for the FFQ, an "FFQ profile" was created in the nutrition analysis software in a similar way a client profile was created to obtain nutrients values of the foods reported by the participants in the 24HRs. A folder was created to enter all the foods in the AE-FFQ in the nutrition analysis software. Each food listed in the AE-FFQ was carefully matched to the best match possible from the foods in the nutrition analysis software as described earlier, with nutrients values of interest in their desired definitions and expressions, ensuring that the final AE-FFQ nutrients table did not contain any missing nutrient values. To assign nutrient values to composite line-items, all foods within the line were matched together in the nutrition analysis software in the form of a recipe (to create a dataset comprised of the nutrient profile of all the foods in the line) in their relative weight in the line, in such a way that summing the weights of the nutrient values of all foods in the line yielded the nutrient values of the weighted mean of the composite line totaling a weight of 100 g.

Two nutrient tables were developed, because two methodologies of obtaining the nutrient table were conducted: The first table used the calculated weighted average of the nutrients profiles in the composite food lines, while the other used the nutrient values of the most frequently consumed food in the aggregated food lines for the secondary analysis. Once all foods from the FFQ were entered in the nutrition analysis software, the nutrient composition table generated was exported in an Excel™ sheet and used for the calculation of the nutrient intake of the respondents of the AE-FFQ, which was done manually.

- Steps to estimating the daily nutrient intake from the FFQ responses

The AE-FFQ responses were downloaded from the administrator website of the online AE-FFQ in the form of Excel™ sheets. The food line-items reported by the participants in the response forms were identified as displaying a tick mark for the portion size selected, and another tick mark for the frequency of consumption selected. Unlike for the calculation of nutrient intake reported in the 24HRs, which is reported per day, estimating the calories and nutrient consumption of a respondent from an FFQ required taking into consideration the proper estimation of the portion size and the conversion of the frequency of consumption to a daily frequency.

Using the mathematical functions of Excel™, the reported PSs and frequencies of consumption for each line were converted to daily intake in grams, which were then converted into daily nutrient values that when summed across all reported foods, yielded an estimated average total daily nutrient intake. The calculation of the portion size for each food line and the daily frequency of consumption were done as follows.

- Estimation of portion size

Estimating the weight of a selected portion size in a line-item of an FFQ depends on whether the food line-item depicts one food or multiple foods. In the case in which a food line-item depicts one single food, the weight of the PS selected can be used directly for the next step of estimating the daily nutrient intake. However, when a food line-item is a composite of many foods, then the weight of a portion size should reflect the portion sizes of all foods within the line and their relative weights. Consequently, each of the portion sizes options of a composite food line-item was calculated as the sum of the relative weights (%) of each of the foods within the line (obtained by summing the relative frequencies of consumption of men and women) multiplied by the weight of the portion size. This calculation is illustrated in Table 20 below with the example of the citrus fruits line.

As shown in Table 20, the "Citrus fruits" line-item is composed of the three portions of both oranges and tangerines, each in a quarter, half, and a whole fruit depicting the small, medium and large portion sizes respectively. Since the relative frequency of intake is different between both the fruits, with oranges making 73% of the citrus consumption and tangerines making the other 27% of citrus fruits consumption, the weight of the three portion sizes of oranges and tangerines was each calculated based on their relative frequency of intake (obtained by summing the relative frequencies of consumption of men and women) multiplied by the weight of the respective portion size of each fruit. The Citrus fruit line's weight for each portion size corresponds to the sum of the relative weights of the portion sizes of both the fruits, as shown in the table below (Table 20).

Table 20: Calculation of the average weight for the citrus fruits line based on the relative frequencies reported in surveys

Orange or tangerine or grapefruit	Relative weight of the EP in line (%)§	Relative weight of the small PS (in grams)	Relative weight of the medium PS (in grams)	Relative weight of large PS (in grams)
Orange*	73	45 x 73/100 = 32.85	85 x 73/100 = 62.05	170 x 73/100 = 124.1
Tangerine**	27	22 x 27/100 = 5.94	45 x 27/100 = 12.15	90 x 27/100 = 24.3
Total	100	38.79	74.2	148.4

*Weight of an orange (EP): small portion = 45 g, medium portion = 85 g, Large portion = 170 g (as measured by the researcher)
**Weight of a tangerine (EP), small portion = 22 g, medium portion = 45 g, large portion = 90 g (as measured by the researcher)
§ The relative weights correspond to the sum of the relative frequencies of both men and women, assuming each gender represents 50% of the population.

EP = Edible part; PS = Portion size.

- Calculation of the daily nutrient intake in the AE-FFQ

After obtention of the portion size reported for a line item in the AE-FFQ, the calculation of the daily nutrient intake was done as follows:

Daily nutrient intake in grams = Sum [(Daily frequency of consumption of a food-line item) x (Weighted average portion size consumed of that food-line item (in grams) x component value/100 g).

The daily frequencies of consumption were obtained by multiplying the frequencies reported in the AE-FFQ by a specific factor (e.g. Never = 0; 1–2/month = 0.05; 1/week = 0.14; 2–4/week = 0.43; 5–6/ week = 0.79; 1/day = 1.0; 3/day = 3) (Marks et al., 2006).

The daily nutrients intakes of the participants who completed both the three 24HRs and AE-FFQ were organized in Excel™ sheets for further analysis.

2.4.9 Analysis of food groups

2.4.9.1 Rationale of the choice of food groups for the validation study

The food groups assessed in the validation study were similar to the ones used in other studies sharing the same objective of validating an FFQ aimed for use in research on dietary risk factors of CVDs, such as the Food4me validation study (Fallaize et al., 2014), the study comparing the online Food4me FFQ to the EPIC FFQ (Forster et al., 2014), and the Dutch EPIC Food study on validation of food groups (Ocké et al., 1997). The 139 food items of the AE-FFQ were assigned to 31 food groups most of which were evidenced to have potential protective or adverse effect in relation to NCDs (Afshin et al., 2019; Micha et al., 2017; Mozaffarian, 2016).

Moreover, in line with the new advances in nutritional epidemiology that recognizes the role of dietary patterns and the overall quality of diets as risk factors of NCDs ((Mozaffarian, 2016), the grouping of the foods included in the AE-FFQ was also constructed with the intention to include the food groups that compose the Mediterranean diet score (MDS), in order to allow the AE-FFQ to be used for estimating the Emirati diet quality based on the MDS. Indeed, the MDS is one of the few health diet indices to have been associated with reduced risk of mortality and CVD incidence in various populations (Dinu et al., 2018; Miller et al., 2020). It was therefore chosen as the dietary metric of choice for assessing the quality of the Emirati diet given the important influence of the latter by Mediterranean styles of cuisine, such as the Lebanese cuisine and other Middle-Eastern countries' cuisine, all of which are neighboring countries to the UAE. Food groups composing the MDS (legumes, wholegrains, fruits, nuts, vegetables, meat, processed meat, fish, dairy products) were therefore all exhibited in the grouping of the AE-FFQ.

2.4.9.2 Methodology of assigning foods reported in the 24HRs and AE-FFQ to different food groups

2.4.9.2.1 Assigning foods reported in the 24HRs to food groups

The list of 31 food groups was tabulated on Excel™ worksheets created for each of the participants, and the reported foods in their respective PS for each of the 24HRs were assigned to the respective food groups. When a reported food did not fit the exact food group description, it was assigned to the closest group, e.g. "hash browns" were assigned to the 'French fries' group. Composite foods in their cooked form were split into their basic ingredients and then assigned to their corresponding food group. The ingredients of foods reported from fast food chains were obtained directly from the company's website. For example, the ingredients and weights of 'Spicy McChicken™' burger were obtained from McDonald's™ nutrition facts webpage (McDonald's, 2020) and were assigned to their respective food groups. This burger was also used as the generic burger for all reported chicken burgers because of its popularity. Alternatively, when a participant described not consuming one of the constituent ingredients of a burger (e.g. chicken burger without cheese), the ingredient was removed from the ingredients list and only the ingredients reported by the participant were assigned to their corresponding food groups. Examples of allocation of ingredients of composite foods to their respective food groups are given in Table 21 below.

Table 21: Examples of composite dishes reported in the 24h recalls and their corresponding food groups

Composite dish name	Composite dish ingredients	Weight of the reported portion in grams	Name of the assigned food group
Chicken burger medium (Spicy Mc chicken)	Whole dish	199	--
	Bun	60	White breads (Samoon, sliced bread, buns)
	Chicken breaded	75	Chicken
	Cheddar cheese	25	Cheeses hard and spreadable
	Lettuce	28	Green leafy vegetables
Bechamel Chicken Pasta	Whole dish	200	-
	Cooked pasta	47	Pasta and other cereal dishes
	Cooked chicken	50	Chicken
	Boiled mushroom	17	Other vegetables
	Mozzarella cheese	16.5	Cheeses hard and spreadable

Once the foods reported and their respective weights from each of the three 24HRs were assigned to their respective food groups, the weight of all items per food group per day were obtained by summing up the reporting of the 3 days of 24HRs and then averaging the results. Data was then prepared for statistical analysis.

2.4.9.2.2 Assigning foods reported in the AE-FFQ to food groups

The methodology used for assigning the foods reported in the 24HRs described above was also applied to the reporting from the AE-FFQ. This required the prior step of obtaining the daily food intake from the reported food line-items, which was done following the same methodology described before, where multiplying the reported portion size of a food line-item by the frequency conversion factor was necessary. For composite food lines, if a composite food line-item included foods that can be assigned to the same food group (e.g., both oranges and tangerines are assigned to the 'Fresh fruits' group), then the weighted average portion size of the composite food line-item could be used as the portion size selected by the participant. If, however, the composite food line-item included foods that belonged to different food groups (e.g., Shawarma food line contained both 'Chicken Shawarma' and 'Meat Shawarma'), then the ingredients and their relative weights for the portion size selected required to be assigned to different food groups (Bread, meat, chicken, separately). Examples of foods assigned to each of the 31 foods groups are provided in Appendix 15. Once the daily weights of the foods selected in the AE-FFQ were assigned to their respective food groups, the weight of all items per food group were summed up to obtain daily food group intake. Data was then prepared for statistical analysis.

2.5 Statistical analysis

Due to the lengthy process of food matching and recipe creation, data entry and food coding of the three 24HRs was done after the dispatching of the online AE-FFQ to all the 75 participants who have completed the three 24HRs. Only the participants who completed both the instruments were considered for inclusion in the validation study (Figure 12).

2.5.1 Excluding misreporters before the statistical analysis

Before data analysis, misreporters on the 24HRs were discarded to ensure that the 24HRs used for the validation study were more representative of true intake because not accounting for misreporting could result in a poor validity also affecting any associations between dietary intakes and health outcomes (Subar et al., 2015). Out of the 67 remaining participants, 5 men with energy intake <1000 or >4000 kcal and 2 women with energy intake between <800 or >3500 kcal were excluded (Zamora et al., 2010). Therefore, data from 60 participants (72.29% of all invited) was used in subsequent statistical analyses.

2.5.2 Descriptive statistics

Frequencies and relative percentages were used for categorical variables to describe the demographics of the participants and to compare the reporting of the frequencies of intake of selected food groups (vegetables, fruits, fruit juices, fast foods, and fish and Seafish) between the main FFQ (Section 1) and the cross-check questions (Section 3).

The relative validity of the AE-FFQ was assessed by comparing the nutrients and food groups values of the AE-FFQ with their corresponding values from the three 24HRs.

2.5.3 Tests of normality

Normality tests (Shapiro–Wilk test, Kolmogorov–Smirnoff test and Q-Q plot) performed at the beginning of the data analysis for all nutrients and food groups of the AE-FFQ and the three 24HRs showed a clear deviation from normality for most variables. Consequently, validity was assessed with non-parametric tests, except for Bland Altman analysis. The interpretation of the validity tests done was done based on the guidelines outlined by Lombard et al. (2015).

2.5.4 Relative validity at the group level

Mean, standard deviations (SD), median and interquartile range (IQR) were calculated for energy, crude and energy-adjusted nutrients and food group intakes. To reduce the effect of confounding due to EI, analyses were carried out on energy-adjusted variables obtained by the residual method where the energy-adjusted intake estimate is the residual from a regression model in which total EI is the independent variable and absolute nutrient intake is the dependent variable (Willett et al., 1997). Wilcoxon signed rank sum test was used to compare differences between the matched measures in a statistically significant manner. Agreement between the AE-FFQ and three 24HR was assessed by calculating the percentage difference of the means of energy, nutrient and food groups between AE-FFQ and the three 24HRs based on the formula ([Mean (AE-FFQ – three 24HR)]/[mean (three 24HR)*100), and a percentage of the mean differences lesser than 10% signaled a good agreement between the methods based on Lombard et al. criteria.

Agreement between the two methods at the group level was assessed by Bland-Altman analysis. Given that data was not normal, natural-log (ln) transformations were performed as recommended by Bland and Altman (1986) Analyses were carried out on energy-adjusted variables. Visualization of the limits of agreement (LOA) (ln mean difference± 1.96 SD) between the methods was done by plotting the difference between the AE-FFQ and the three 24HRs against the (ln) mean of the two methods. A good agreement between the methods was obtained when 95% of the differences fall within the LOA (Lombard et al., 2015). Linear regression analysis was undertaken where the differences between the 2 methods were plotted against their mean to investigate whether there was any dependency between the 2 methods (Bland & Altman, 1999).

2.5.5 Relative validity at the individual level

The strength and the direction of the association at the individual levels between energy, nutrients and food groups reported by the 2 methods was assessed using crude, de-attenuated, energy-adjusted and de-attenuated energy adjusted Spearman CCs. Spearman's coefficient was used because it is more robust than Pearson test to deviations from normality and can be used as a non-parametric alternative to the Pearson test (Gibson, 2005).

To remedy the random error due to day-to-day variation in the three 24HRs, de-attenuated Spearman CCs were obtained by multiplying each crude Spearman CC by a de-attenuation coefficient obtained using the formula:

$$\sqrt{1 + [(\sigma w2/ \sigma b2)/n]},$$

where σw2 is the within person variance, σb2 is the between-person variance, and n is the number of replicates of the reference instrument.

For the study at hand, n = 3, representing each of the 24HRs (Willett et al., 1985) The energy-adjusted and de-attenuated energy-adjusted Spearman CCs were calculated using the residual method. To interpret the strength and direction of the association, the categorization of Lombard et al. (2015) was used where Spearman CC ≥ 0.50 indicates a good agreement, 0.29 < Spearman CC < 0.49 is acceptable agreement and an Spearman CC < 0.20 means poor agreement.

Categorical agreement between the methods was assessed by using quartile classification of energy-adjusted intake of each nutrient and food group from both the methods to estimate the percentage of participants that were correctly categorized into the same or adjacent (± 1) quartiles or misclassified into the extreme (opposite) quartile (Gibson, 2005). Lombard et al (2015) consider an outcome as good when more than 50% of the participants are classified into the same quartile and less than 10% of the participants are misclassified into the opposite quartile.

All statistical analyses were performed using Python 3.7.7 and SPSS program, version 23.0 for windows (SPSS Inc, Chicago IL). A $p < 0.05$ was considered significant, all tests were performed two sided.

In summary, based on Lombard et al. (2015) validation criteria, the AE-FFQ would have an acceptable to good relative validity if 1) the percentages of the mean differences are less than 10%, 2) 95% of the differences fall within the LOA, 3) Spearman CCs are found to be above 0.2 and 4) if more than 50% of subjects are correctly classified into the same quartile and less than 10% of the subjects are grossly misclassified.

Chapter 3: Results

3.1 Descriptive analyses

3.1.1 Participant characteristics

Participant characteristics can be seen in Table 22. There was a higher proportion of female participants compared to males (60% vs. 40%). Half of the study participants were younger adults having less than 30 years. The mean age of male participants was about 33.13 years and that of females was 32.87 years. Older adults were not much represented in the study with only 5% being 51 or older. Most of the participants were educated, with 42% having an undergraduate degree and only 2% not having a high school degree. The average BMI of the study participants was slightly in the overweight category, at a BMI of 25.78 Kg/m^2. Most (55%) of the study participants were within the “Normal” BMI range.

Table 22: Sociodemographic profile of the 60 study participants

Characteristics	Males n (%)	Females n (%)	Total n (%)
Age in years (Mean ± SD)	33.13 ± 10.119	32.69 ± 7.41	32.87 ± 8.5
Age groups (Years)			
21-30	13 (54.2)	17 (47.2)	30 (50.0)
31-40	5 (20.8)	13 (36.1)	18 (30.0)
41-50	3 (12.5)	6 (16.7)	9 (15.0)
51-60	3 (12.5)	0 (0)	3 (5.0)
Education			
Graduate	6 (25.0)	2 (5.6)	8 (13.33)
Undergraduate	13 (54.2)	29 (80.6)	42 (70.0)
High School	3 (12.5)	5 (13.9)	8 (13.33)
Less than high school	2 (8.3)	0 (0)	2 (3.33)
BMI ($Kg/Meter^2$) (Mean SD)	26.66 ± (5.60)	25.19 ± (4.28)	25.78 ± (4.86)
BMI ($Kg/Meter^2$) Categories			
<24.9 (Normal)	11 (45.8)	22 (61.1)	33 (55.0)
25-29.9 (Overweight)	6 (25.0)	9 (25.0)	15 (25.0)
30 or more (Obese)	7 (29.2)	5 (13.9)	12 (20.0)
Total (%)	24 (40.0)	36 (60.0)	60 (100.0)

BMI = body mass index (Kg/m^2); SD = standard deviation.

3.1.2 Cross-check questions

Table 23 shows the numbers and relative percentages of male and female participants having reported matching categories of frequencies in the main FFQ (section 1) and the cross-check questions (section 3) which queried about the 5 general frequency options “never or less than once a month”, “monthly”, “weekly” and “daily”. Results show that 61%, 64%, 58%, 67% and 72% of female participants and 63%, 46%, 71%, 42% and 83% of male participants reported matching frequencies between the main FFQ and the cross-check questions for the vegetables, fruits, fruit juices, fast foods, and fish and Seafish food groups respectively. Less than 50% of males reported matching frequencies for the fruits and fast foods groups. Fish and seafish was the food group with the highest frequency for both males and females.

Table 23: Reporting of frequencies of intake of selected food groups between Section 1 and Section 3 of the AE-FFQ (n = 60)

Participants	Matched vs. not-matched between section 1 and section 3	Vegetables (n)	Fruits (n)	fruit juices (n)	fast foods (n)	Fish and Seafish (n)
Female participants (n = 36)	matched	22	23	21	24	26
	not-matched	14	13	15	12	10
Male participants (n = 24)	matched	15	11	17	10	20
	not-matched	9	13	7	14	4
Total participants (n = 60)	Total matched	37	34	38	34	46
	Total not-matched	23	26	22	26	14
% of correct matching for females		61.11%	63.89%	58.33%	66.67%	72.22%
% of correct matching for males		62.5%	45.83%	70.83%	41.67%	83.33%
% of correct matching in total		61.67%	56.67%	63.33%	56.67%	76.67%

Section 1 relates to the main Food frequency questionnaire; Section 3 relates to the cross-check questions.

3.2 Measurements of relative validity

3.2.1 Testing data distributions for normality

The normality of the distribution of nutrients and food groups was assessed by both Shapiro-Wilk and Kolmogorov-Smirnov tests. For energy, nutrients and food groups measures, the majority of Shapiro-Wilk tests were statistically-significant as were the majority of the results from the Kolmogorov-Smirnov test. For this reason, the correlations between average 24HDR and FFQ intakes were based on Spearman correlations and Wilcoxon signed-rank tests, two types of non-parametric tests. Figure 14 depicts the comparative histograms, Q-Q plots and boxplots of energy intake for both the AE-FFQ and the average three 24HRs.

3.2.2 Measure of relative validity at the group level

3.2.2.1 Comparison of the estimated intake of energy, nutrients and food groups

Group mean and median comparison of energy and nutrient intakes estimated by the three 24HR and the AE-FFQ are shown in Table 24. Group mean and median comparison of food groups are shown in Table 25. The percentage differences between the 2 methods are also provided for the purpose of comparison.

In general, the AE-FFQ significantly overestimated ($p < 0.05$, Wilcoxon rank sum test) energy and most nutrients compared to the three 24HRs, with the exception of vitamin E which was slightly but significantly underestimated (-6%). The mean difference between energy intakes was relatively high (+ 779 Kcal/day), corresponding to a percentage difference of 36%. All nutrients showed a significant difference, the lowest being for vitamin E (-6%) and Iron (+11%). For food groups, 17 out of 31 food groups were significantly overestimated ($p < 0.05$, Wilcoxon rank sum test). 3 of the remaining 14 food groups that did not show a significant difference were slightly underestimated by the AE-FFQ as compared to the three 24HRs, those were fruit juices (-15%), soft drinks (-21%), and french fries (-1%) groups. The highest significant discrepancies were observed for the fish and seafood group (210%), whole grain bread (143%), fruits group (127%) and cruciferous vegetables group (196%), conversely, the lowest non-significant differences ($p > 0.05$, Wilcoxon rank sum test) were observed for the groups: French fries (-1%), savory snacks (Fatayer, Pies, pizza, falafel, samosa, croissants) (+1%) sweet snacks (biscuits, cakes, muffins, doughnuts, fruit pies, including Arabic sweets) (+1%) and the sweets, candies and chocolates group (+2%). After energy-adjustment, there was a decrease in mean percent difference for most nutrients and food groups but the percentage difference between the 2 methods remained high for most nutrients and food groups and there was a nonsignificant difference between the methods only for the nutrients Iron and vitamin E ($p > 0.05$, Wilcoxon rank sum test) and 9 food groups: chicken dishes, sweets and candies, French fries, fruit juices, meat products, red meat dishes, savory snacks, sweet snacks and yoghurt ($p > 0.05$, Wilcoxon rank sum test).

The evaluation of the adequacy of the AE-FFQ for use as a tool to determine the quality of the Emirati diet was performed by assessing the relative validity of the energy-adjusted group median values of the nutrients and food groups from the AE-FFQ that compose the Mediterranean diet score (MDS), because the scoring of the MDS is based on energy-adjusted group median values of the components of the score. To be qualified as adequate, components of the MDS from the AE-FFQ must present a non-significant difference ($p > 0.05$, Wilcoxon rank sum test) when compared to the three 24HRs, indicating agreement between the methods.

In the AE-FFQ, only the food groups "Dairy drinks" ($p = 0.161$), "yoghurts" ($p = 0.627$), "red meat" ($p = 0.059$), "processed meats" ($p = 0.576$) and "nuts and seeds" ($p = 0.462$) showed non-significant differences based on Wilcoxon-signed rank test. All other constituents of the MDS included in the AE-FFQ; the nutrients (SFA, MUFA), and the food groups (vegetables, fruits and legumes) showed significant differences in the AE-FFQ ($p < 0.05$) when compared to the three 24HRs.

3.2.2.2 Bland-Altman Analysis

Results of the Bland-Altman analysis is summarized in Table 26 for energy and nutrients, and Table 27 for food groups. The visual inspection of Bland Altman scatter plots for energy, nutrients and food groups revealed that most of the points fell within the 95% of the limits of agreement, with an average of four observations outside the limits of agreement for most of the plots, suggesting an overall fair agreement between the methods. However, the mean difference was non-significant for only 12 of the 31 food groups and 8 of the 21 nutrients indicating absence of bias ($p > 0.05$).

Most mean differences were positive, for both nutrients and food groups, implying an overestimation of intake by the AE-FFQ, except for 4 food groups (Soft drinks, Savory snacks, Sweet snacks and Meat products) and 2 nutrients (Calcium and Vitamin E), for which the mean differences were negative, suggesting underestimation by the AE-FFQ (Figures 15.a and 15.b). The regression coefficient of the 24HRs as a predictor of the AE-FFQ showed that there was a proportional bias for most food groups, with the steepest negative slope coefficient observed for the food group “Green leafy vegetables” and the nutrients Vitamin E and Sodium (as the mean of intake increased, the agreement between the methods increased) (Figures 15.a, 15.b, 15.c). The steepest positive slope coefficient was observed for the food groups “chips” and Energy intake (as the intake increased, the agreement between the methods decreased) (Figures 15.e, 15.f). A flat line (coefficient < 0.2) was observed for the food groups “Meat products” and “French fries” and the nutrients Sodium and Pyridoxine indicating that the difference between the methods did not vary with true intake (Figures 15.b and 15.c). These foods and nutrients showed the smallest bias (mean difference closer to zero bias line) and narrower LOA. Macronutrients scatter plots showed narrower LOA compared to most micronutrients (Figures 15g and 15h).

3.3 Measures of validity at the individual level

3.3.1 Spearman Correlation Coefficient

Table 26 and Table 27 show the Spearman CC of estimates for energy, nutrient, and food groups respectively. Regarding the nutrient’s intake, the unadjusted Spearman CC for macronutrients ranged from 0.33 for SFA to 0.60 for total sugar and the Spearman CC for micronutrients ranged from 0.11 (Vitamin A) to 0.53 (sodium), with a median Spearman CC value of 0.42. Correlations were significant for 15 (68%) of the 22 nutrients and energy ($p < 0.05$) except for Iron, Vitamin D, Vitamin E, Thiamin, Riboflavin, Vitamin B12 and Vitamin A which showed non-significant correlations ($p > 0.05$). Accounting for the day-to-day variation in intakes resulted in a de-attenuated median

Spearman CC of 0.47, and Spearman CC ranging from 0.12 (Vitamin A) to 0.65 (Total sugar).

Energy-adjustment reduced the correlations of the majority of the nutrients, except for cholesterol, vitamin D, folates and fiber, for which the correlations were not much affected. Energy-adjusted and de-attenuated Spearman CC ranged from 0.06 (Iron) to 0.62 (Fiber), with a 0.39 median value. The de-attenuated, energy-adjusted correlations of vitamin E (0.09), riboflavin (0.18) and macronutrients (proteins (0.39), fat (0.29) and carbohydrate (0.32) were the most decreased when compared to the crude de-attenuated correlations. There was clear no increase in correlations for any nutrient.

For food groups, the crude correlations ranged from 0.22 (white bread) to 0.68 (eggs), with a 0.45 median value. Correlation of 28 (90%) out of a total of 31 food groups were statistically significant ($p < 0.05$), except those for the cheese, savory snacks, potatoes, and cruciferous vegetables groups (Table 26 and 27).

As observed with nutrients, de-attenuation increased the median correlation slightly (0.46) ranging from 0.23 (white bread) to 0.71 (Rice). The median correlation decreased to 0.41 for energy adjusted de-attenuated Spearman CC, with correlations ranging from -0.01 for cruciferous vegetables to 0.64 for eggs food group. The de-attenuated, energy-adjusted correlations of cruciferous vegetables (-0.01), chips (0.27) and fruits (0.37) were the most decreased when compared to the crude de-attenuated correlations, a clear increase was observed in the diet soft drinks group (0.43).

Results of the correlation analysis between the 2 methods conducted as a secondary analysis, where the nutrient values of composite food line-items of the AE-FFQ were obtained exclusively from the most frequently reported food in the line (Willett et al., 1985) is provided in Appendix 16.

3.3.2 Cross-classification

The results of the cross-classification of the energy-adjusted nutrient intakes and food group intakes estimated from the AE-FFQ and the three 24HRs are outlined in Table 26 and 27 respectively.

The percentage of participants classified into quartiles of exact agreement ranged from 15% (Vitamin B12) to 46% (sodium) (median 36%). When the percentages of the participants classified into quartiles of exact and adjacent agreement were added, they ranged from 34% (Vitamin B12) to 78% (Pyridoxine), (median 69%). The median percentage of participants classified into extreme quartiles of disagreement was 8 %, ranging from 5% for total sugar and PUFA to 19% for Iron. Although nutrients did not reach the 50% threshold required by Lombard et al. (2015), the percentage of participants classified in opposite quartiles was within the guidelines for most nutrients.

For food groups, the percentage of participants classified into quartiles of exact agreement ranged from 22% (Chocolate and candies) to 48% (Yoghurt) (median 33%). The percentage of participants classified into the same or adjacent quartile ranged from 55% for diet soft drinks to 87% for soft drinks (median 67%). The median percentage of participants classified into opposite quartiles ranged from 3% for yoghurt to 23% for cruciferous vegetables and 22% for diet soft drinks (median 10%, which is the percentage that would be expected by chance alone). The percentage of participants classified in opposite quartiles exceeded 20% for cruciferous vegetables and diet soft drinks.

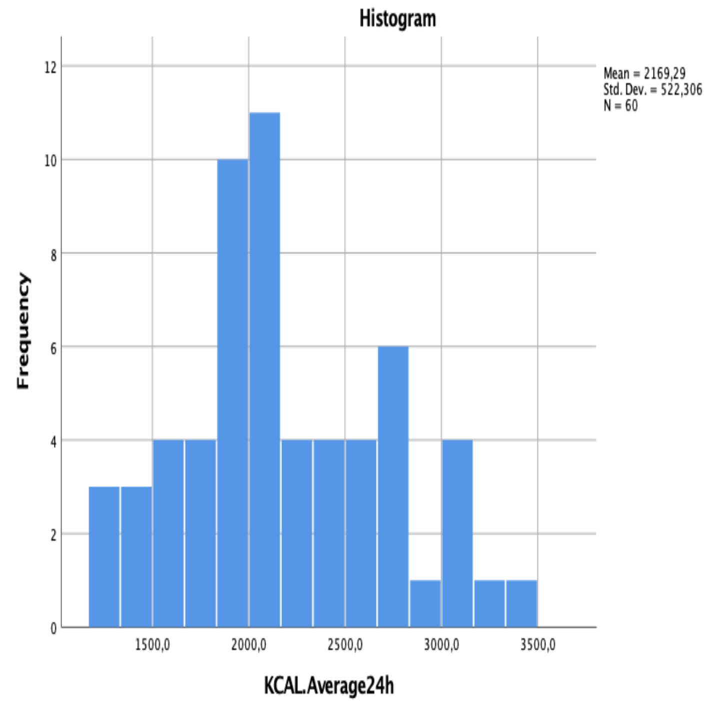
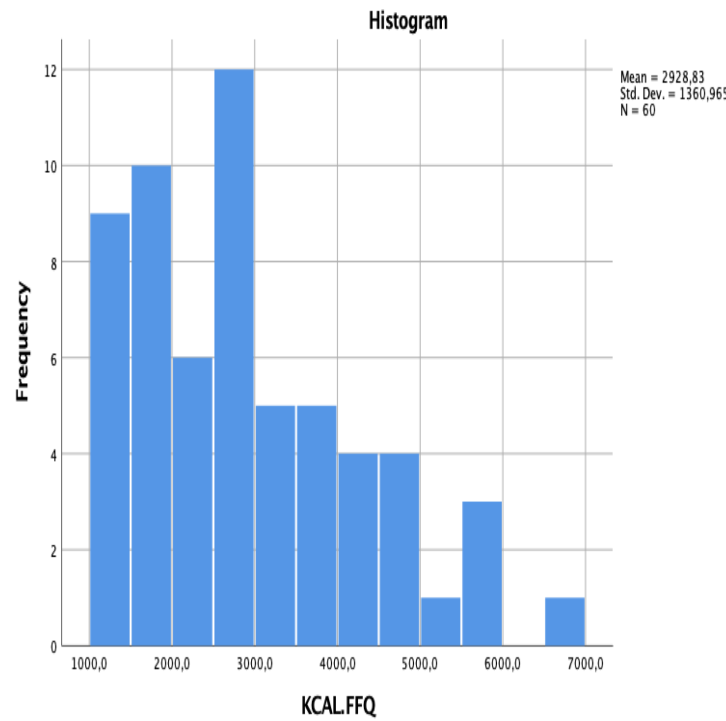
Average 24HRs	AE-FFQ
	

Figure 14: Comparative histograms, Q-Q plots and boxplots of energy intake for both the AE-FFQ and the average three 24HRs

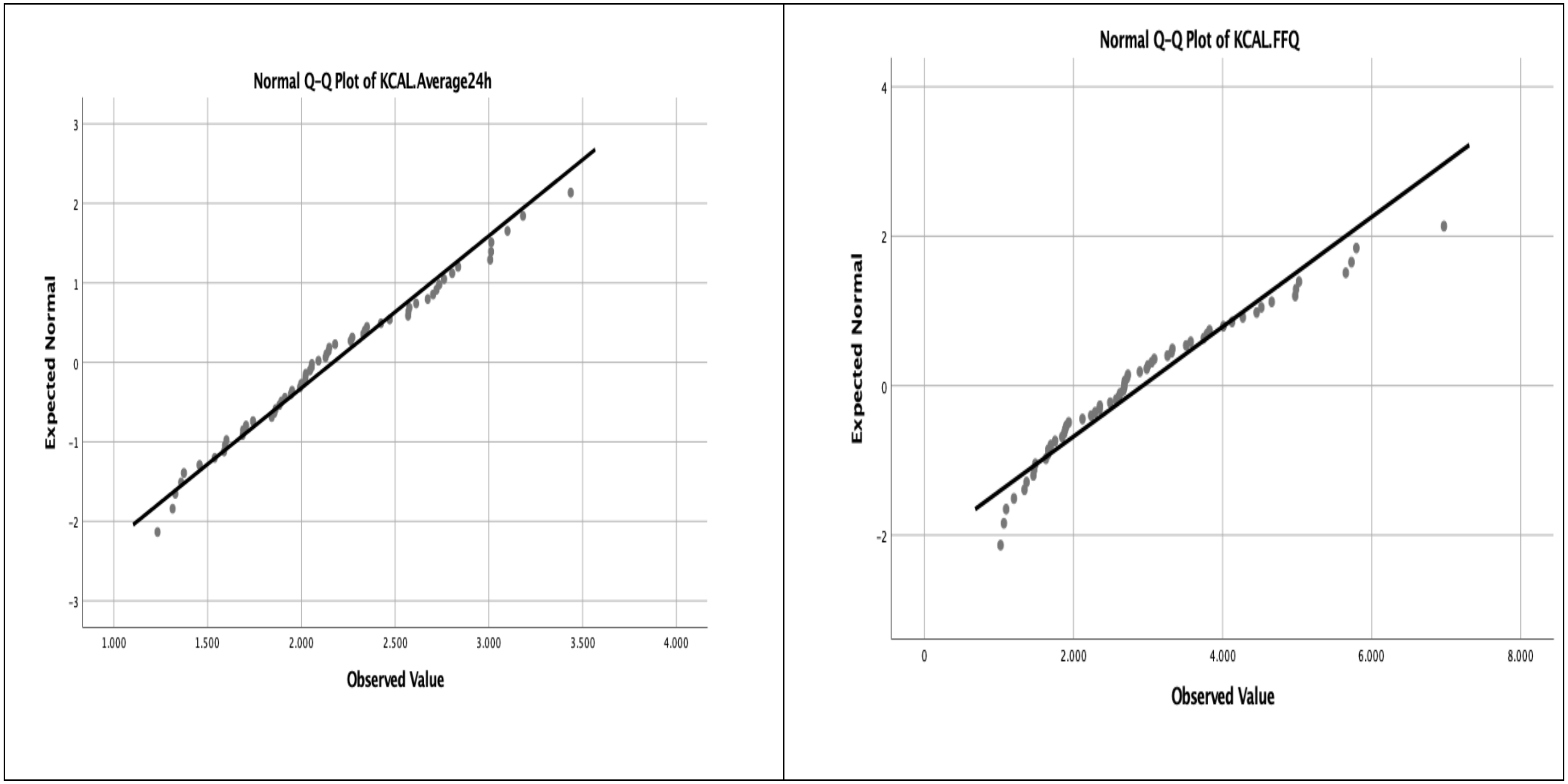


Figure 14: Comparative histograms, Q-Q plots and boxplots of energy intake for both the AE-FFQ and the average three 24HRs (continued)

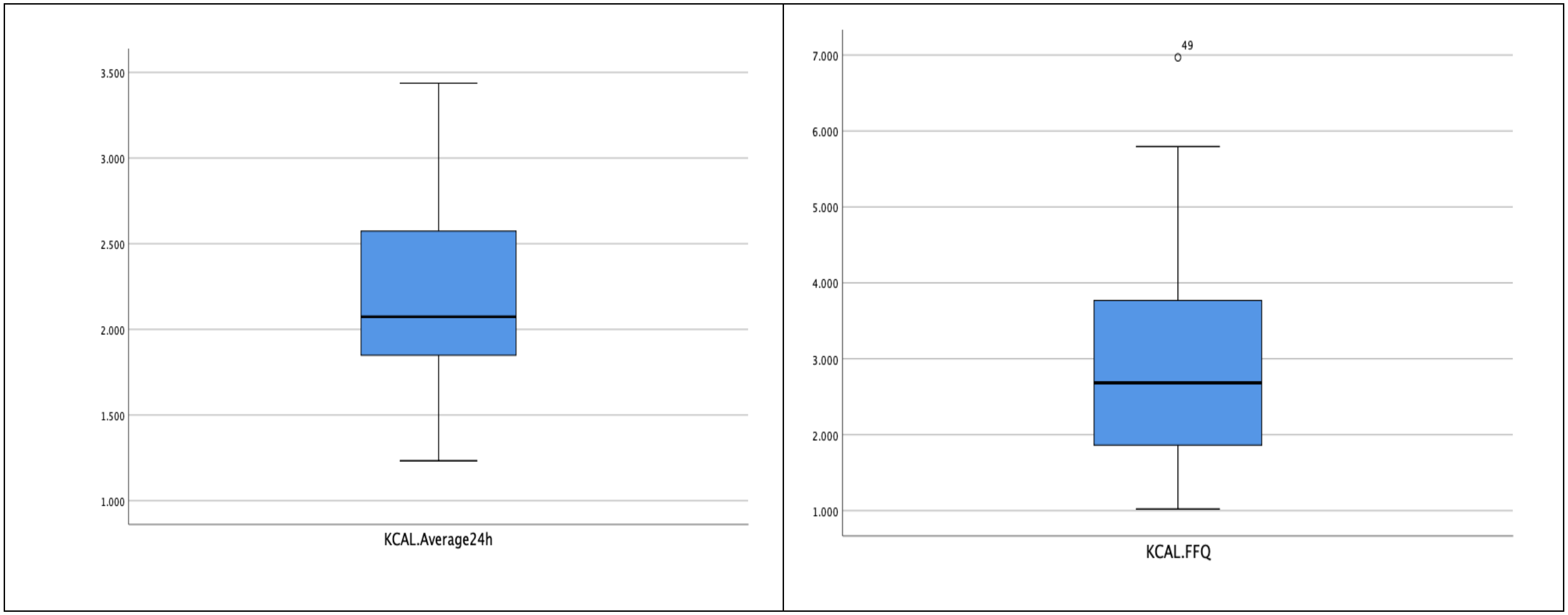


Figure 14: Comparative histograms, Q-Q plots and boxplots of energy intake for both the AE-FFQ and the average three 24HRs (continued)
24HR = 24h recalls; AE-FFQ = Adult Emirati food frequency questionnaire

Table 24: Mean daily energy and nutrients intakes estimated by the AE-FFQ and three 24HRs (n = 60)

Nutrients	AE-FFQ				Three 24-hour Recalls				p value	% mean difference	p value (Energy-adjusted)	% mean difference (Energy-adjusted
	Mean ± SD	Mean Energy-adjusted ± SD	Median	25th – 75th Percentile	Mean ± SD	Mean Energy-adjusted ± SD	Median	25th – 75th Percentile				
Energy (kcal)	2948.3 ± 1346.6	--	2682.3	1854.9 - 3777.1	2169.3 ± 522.3	--	2073.7	1845.3 - 2574.8	<0.001	36	--	--
Protein (g)	121.49 ± 72.68	121.89 ± 73.23	100.2	67.8 - 157.9	84.48 ± 29.19	84.55 ± 29.43	80.5	64.4 - 98.9	<0.001	44	<0.001	44
CHO (g)	383.70 ± 173.23	110 ± 55.9	364.2	248.7 - 478.0	282.2 ± 70.01	87.54 ± 27.1	273.9	228.0 - 330.5	<0.001	36	<0.001	26
Fat (g)	110.71 ± 55.46	109.52 ± 56.92	105.3	64.5 - 141.8	82.38 ± 24.66	81.6 ± 26.24	82.7	67.5 – 99.9	0.001	35	<0.001	34
Total Sugar (g)	119.70 ± 60.72	136.76 ± 58.18	100.5	78.3 - 159.3	90.49 ± 33.43	94.62 ± 33.69	83.5	67.0 – 104.9	<0.001	32	<0.001	45
SFA (g)	39.26 ± 20.53	46.64 ± 19.51	37.0	22.2 - 48.9	28.06 ± 8.82	28.23 ± 8.79	27.1	21.5 – 33.4	<0.001	40	<0.001	65
MUFA (g)	37.94 ± 19.76	22.17 ± 9.55	35.5	23.2 - 50.1	30.60 ± 10.13	37.27 ± 16.09	28.9	23.4 – 36.3	0.013	24	<0.001	-41

Table 24: Mean daily energy and nutrients intakes estimated by the AE-FFQ and three 24HRs (n = 60) (continued)

Nutrients	AE-FFQ				Three 24-hour Recalls				p value	% mean difference	p value (Energy-adjusted)	% mean difference (Energy-adjusted
PUFA (g)	25.03 ± 14.62	30.62 ± 13.61	22.9	13.8 - 32.0	18.32 ± 6.72	19.86 ± 6.77	17.4	14.1 – 22.6	0.001	37	<0.001	54
Fiber (g)	29.52 ± 14.61	31.32 ± 14.76	25.5	18.4 - 42.6	18.36 ± 6.57	19.58 ± 6.55	17.3	14.2 – 21.0	<0.001	61	<0.001	60
Cholesterol (mg)	419.63 ± 282.43	463.03 ± 324.91	371.9	219.3 - 550.5	284.12 ± 119.74	281.92 ± 123.58	272.8	189.0 – 361.7	<0.001	48	<0.001	64
Sodium (mg)	4548.7 ± 2046.20	4672.22 ± 2127.1	4202.1	3070.2 - 5682.9	3103.10 ± 1069.40	1576.4 ± 1721.1	2939.7	2269.7 - 3566.3	<0.001	47	<0.001	196
Calcium (mg)	1057.4 ± 524.08	1147.93 ± 536.54	1010.3	605.1 - 1377.3	707.50 ± 204.96	699.73 ± 222.09	703.2	589.7 - 840.6	<0.001	49	<0.001	64
Iron (mg)	19.77 ± 9.72	22.17 ± 9.55	18.1	11.9 - 25.3	17.81± 18.16	23.52 ± 17.94	14.3	10.6 - 18.5	0.005	11	0.74	-6
Vitamin A (mcg)	1072.0 ± 543.96	1238.9 ± 521.7	1023.3	695.9 - 1231.5	781.98 ± 569.14	1088.2 ± 485.6	618.7	481.2 - 832.8	<0.001	37	0.023	14
Vitamin B12 (mcg)	8.32 ± 5.89	10.6231 ± 5.64	7.6	3.8 - 10.6	4.60 ± 4.53	6.71± 4.03	3.2	2.1 - 5.2	<0.001	81	<0.001	58

Table 24: Mean daily energy and nutrients intakes estimated by the AE-FFQ and three 24HRs (n = 60) (continued)

Nutrients	AE-FFQ				Three 24-hour Recalls				p value	% mean difference	p value (Energy-adjusted)	% mean difference (Energy-adjusted
Vitamin C (mg)	251.84 ± 151.55	300.57 ± 144.12	213.9	150.3 - 363.3	144.17 ± 120.70	205.01 ± 109.69	110.3	73.7 - 164.5	<0.001	75	<0.001	47
Vitamin D (mcg)	6.90 ± 5.35	9.56 ± 4.67	5.8	2.8 - 9.8	4.95 ± 4.19	7.11 ± 3.64	3.5	2.0 - 6.3	0.034	40	0.004	34
Vitamin E (mg)	12.65 ± 8.28	16.25 ± 7.54	10.0	7.2 - 15.6	13.421 ± 31.80	23.59 ± 32.55	8.3	6.6 - 11.2	0.006	-6	0.077	-31
Thiamine (mg)	4.24 ± 2.98	5.23 ± 2.83	3.6	2.0 - 5.3	3.23 ± 2.05	3.7 ± 1.76	2.5	1.8 - 4.9	0.016	31	<0.001	41
Riboflavin (mg)	5.07 ± 6.35	8.16 ± 5.72	2.7	1.7 - 6.4	2.94 ± 5.23	5.43 ± 4.89	1.5	1.2 - 2.1	<0.001	73	<0.001	50
Pyridoxine (mg)	3.54 ± 1.89	3.13 ± 1.82	3.3	2.0 - 4.4	2.51± 1.08	2.75 ± 1.06	2.2	1.8 - 2.9	<0.001	41	<0.001	14
Folate (mcg)	433.95 ± 266.28	553.99 ± 241.69	326.6	244.7 - 549.9	255.60 ± 132.10	280.01 ± 133.16	232.6	178.5 - 287.3	<0.001	70	<0.001	98

% difference between both methods = (mean difference/mean three 24HRs). The *p* value is based on the Wilcoxon signed-rank test.24HR = 24-hour dietary recall; AE-FFQ = Adult Emirati food frequency questionnaire; CHO = Carbohydrate; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; SD = standard deviation; SFA = saturated fatty acids

Table 25: Mean food group intakes estimated by the AE-FFQ and three 24HRs (n = 60)

Food Groups (in grams)	AE-FFQ				three 24-hour Recall				p value	% mean difference	p value (Energy-adjusted)	% mean difference Energy-adjusted
	Mean ± SD	Mean Energy-adjusted ± SD	Median	$25^{th} - 75^{th}$ Percentile	Mean ± SD	Mean Energy-adjusted ± SD	Median	$25^{th} - 75^{th}$ Percentile				
Dairy drinks	140.34 ± 203.98	210.82 ± 128.2	101.6	14.5 - 161.6	104.43 ± 111.84	137.8 ± 72.68	64.3	0.0 – 166.6	0.08	34	0.161	53
Cheeses (Hard and spreadable)	38.47 ± 35.26	46.25 ± 23.93	30.4	10.9 - 54.9	20.93 ± 16.80	24.04 ± 11.89	16.8	10.3 - 29.8	0.001	37	<0.001	92
Yoghurts	61.37 ± 74.51	86.32 ± 42.48	42.5	4.4 - 85.2	59.50 ± 74.68	81.43 ± 49.44	30.8	0.0 – 113.3	0.705	3	0.627	6
Rice dishes	334.96 ± 319.05	410.45 ± 211.1	263.0	154.3 - 393.3	210.65 ± 146.06	227.05 ± 118.9	190.0	100.0 – 300.0	<0.001	59	<0.001	81
Pasta and other cereals dishes	45.73 ± 48.77	61.49 ± 25.7	27.4	18.0 - 53.9	29.20 ± 47.82	49.92 ± 24.87	3.4	0.0 – 31.6	<0.001	57	<0.001	23
White breads	119.60 ± 87.54	133.42 ± 64.09	98.8	48.5 - 165.3	93.92 ± 59.83	97.89 ± 52.89	93.2	46.9 – 130.1	0.035	27	0.001	36

Table 25: Mean food group intakes estimated by the AE-FFQ and three 24HRs (n = 60) (continued)

Food Groups (in grams)	AE-FFQ				three 24-hour Recall				p value	% mean difference	p value (Energy-adjusted)	% mean difference Energy-adjusted
	Mean ± SD	Mean Energy-adjusted ± SD	Median	25th – 75th Percentile	Mean ± SD	Mean Energy-adjusted ± SD	Median	25th – 75th Percentile				
Wholegrain breads	11.54 ± 23.90	22.39 ± 14.02	0.0	0.0 - 15.7	4.75 ± 12.58	10.49 ± 8.31	0.0	0.0 - 0.00	0.018	143	<0.001	113
Legumes	35.10 ± 44.44	51.52 ± 22.97	19.4	6.2 – 41.3	17.80 ± 26.51	28.3 ± 14.46	1.5	0.0 - 31.0	<0.001	97	<0.001	82
Eggs	35.62 ± 36.82	46.74 ± 20.64	24.8	7.7 - 49.5	24.12 ± 33.97	35.01 ± 22.33	15.3	0.0 - 33.3	0.001	48	<0.001	34
Red meat (excluding processed meat)	40.73 ± 36.82	58.41 ± 49.24	25.1	9.0 - 52.2	30.03 ± 44.90	48.19 ± 23.88	9.0	0.0 - 43.0	0.057	36	0.059	21
Meat products (Hot dogs, sausages)	49.34 ± 63.74	68.3 ± 42.36	29.2	10.1 - 70.0	48.27 ± 59.83	69.24 ± 32.9	26.8	0.0 - 81.0	0.906	2	0.576	-1
Chicken dishes	68.84± 72.19	89.48 ± 43.43	55.0	24.8 - 84.5	64.85 ± 54.23	72.88 ± 42.63	53.3	20.4 - 100.3	0.985	6	0.053	23

Table 25: Mean food group intakes estimated by the AE-FFQ and three 24HRs (n = 60) (continued)

Food Groups (in grams)	AE-FFQ				three 24-hour Recall				p value	% mean difference	p value (Energy-adjusted)	% mean difference Energy-adjusted
	Mean ± SD	Mean Energy-adjusted ± SD	Median	25th – 75th Percentile	Mean ± SD	Mean Energy-adjusted ± SD	Median	25th – 75th Percentile				
Fish and Seafood	78.31 ± 112.54	113.89 ± 75.56	37.8	13.0 – 102.6	25.23 ±40.89	43.92 ± 19.07	0.0	0.0 - 40.0	<0.001	210	<0.001	159
Total vegetables	250.80 ± 237.96	301.06 ± 168.57	181.0	86.0 - 330.6	118.82 ±106.67	145.59 ± 64.46	90.8	53.9 - 158.6	<0.001	111	<0.001	107
Green leafy vegetables	25.66 ± 29.71	32.85 ± 21.31	18.2	7.0 - 34.9	15.85 ±14.86	19.53 ± 9.48	12.0	4.4 - 25.3	0.003	62	<0.001	68
Cruciferous vegetables	16.49 ± 27.81	28.37 ± 15.21	4.0	0.0 - 20.0	5.57 ± 13.29	11.52 ± 8.52	0.0	0.0 - 6.3	0.001	196	<0.001	146
Red or yellow vegetables	68.87 ± 66.73	82.39 ± 48.71	50.0	15.3 – 180.0	41.80 ± 32.20	46.63 ± 24.57	38.7	16.8 - 58.9	0.002	65	<0.001	77
Potatoes	21.93 ± 34.31	35.2 ± 20.16	7.4	1.5 – 30.0	11.70 ± 22.52	21.41 ± 13.43	0.0	0.0 -15.8	0.035	87	<0.001	64
Other vegetables	117.84 ± 138.41	159.35 ± 86.34	68.7	24.3 - 150.5	43.85 ± 58.31	60.37 ± 40.58	32.5	10.3 - 61.4	<0.001	169	<0.001	164

Table 25: Mean food group intakes estimated by the AE-FFQ and three 24HRs (n = 60) (continued)

Food Groups (in grams)	AE-FFQ				three 24-hour Recall				p value	% mean difference	p value (Energy-adjusted)	% mean difference Energy-adjusted
	Mean ± SD	Mean Energy-adjusted ± SD	Median	25th – 75th Percentile	Mean ± SD	Mean Energy-adjusted ± SD	Median	25th – 75th Percentile				
Savory snacks (Fatayer, falafel, croissants)	46.50 ± 60.84	52.71 ± 25.32	37.1	21.1 – 60.0	45.99 ± 36.27	65.93 ± 38.49	26.5	0.0 - 60.0	0.612	1	0.022	-20
Fruits	224.44 ± 185.49	259.17 ± 131.62	157.6	95.0 – 328.8	98.72 ± 111.94	131.62 ± 69.32	68.2	24.2 – 142.3	<0.001	127	<0.001	97
Dried fruits	20.30 ± 25.74	28.14± 16.63	7.8	2.0 – 30.7	14.45 ± 19.96	20.6 ± 13.33	9.0	0.0 – 21.8	0.015	40	<0.001	37
Soft drinks	58.89 ± 151.30	113.89 ± 115.01	4.1	0.0 – 68.7	74.60 ± 117.50	127.14 ± 54.95	0.0	0.0 – 109.9	0.065	-21	0.005	-10
Diet soft drinks	7.1 ± 32.86	19.04 ± 27.25	0.0	0.0 – 0.00	4.32 ± 26.97	12.23 ± 24.37	0.0	0.0 – 0.00	0.600	64	<0.001	56
Fruit juices, smoothies	118.08 ± 156.61	180.25 ± 75.27	52.8	15.0 – 157.0	138.± 158.68	181.56 ± 105.41	87.8	0.0 – 205.8	0.181	-15	0.696	-1

Table 25: Mean food group intakes estimated by the AE-FFQ and three 24HRs (n = 60) (continued)

Food Groups (in grams)	AE-FFQ				three 24-hour Recall				p value	% mean difference	p value (Energy-adjusted)	% mean difference Energy-adjusted
	Mean ± SD	Mean Energy-adjusted ± SD	Median	25th – 75th Percentile	Mean ± SD	Mean Energy-adjusted ± SD	Median	25th – 75th Percentile				
Sugar, syrups, jams, honey	16.17 ± 16.50	20.39 ± 10.75	12.2	6.3 – 19.7	9.25 ± 7.66	10.38 ± 5.94	8.3	2.9 – 14.3	<0.001	75	<0.001	96
French fries	26.52 ± 35.23	40.65 ± 16.6	10.4	1.5 – 15.2	26.70 ±32.42	36.8 ± 19.9	10.0	0.0 – 50.0	0.821	-1	0.155	10
Sweet snacks	38.31 ± 34.13	44.04 ± 26.16	29.9	9.9 – 61.5	37.88 ± 38.53	47.51 ±25.52	30.0	0.0 – 62.5	0.960	1	0.377	-7
Sweets, candies, and Chocolates	12.11 ± 23.92	22.15 ± 14.91	5.3	0.0 – 7.4	11.83 ± 16.90	18.11 ± 9.77	6.8	0.0 – 14.8	0.766	2	0.095	22
Chips	7.60 ±13.34	15.09 ± 11.09	1.8	0.0 – 11.4	4.98 ± 8.40	10.44 ± 6.41	0.0	0.0 – 5.0	0.242	53	<0.001	45
Nuts and seeds	14.58 ± 23.79	24.03 ± 13.96	5.6	0.8 – 16.8	10.98 ± 17.81	17.27 ± 11.53	5.0	0.0 – 15.1	0.320	33	0.462	39

% difference between both methods = (mean difference/mean three 24HRs).

The *p* value is based on the Wilcoxon signed-rank test.

24HR = 24-hour dietary recall; AE-FFQ = Adult Emirati food frequency questionnaire.

Table 26: Comparison of energy and nutrient intakes using the AE-FFQ and three 24HRs based on correlations, joint classification by quartile and agreement by Bland–Altman analysis (n = 60)

Energy and nutrients	Spearman Correlation Coefficient				Cross-Classification Concordance Energy adjusted (%)			Bland-Altman Energy adjusted**			
	Crude	Deattenuated	Energy-adjusted	Energy-adjusted and Deattenuated	Same Q (%)	Adjacent Q (%)	Extreme Q (%)	Mean	CI	LOA	Slope
Energy (Kcal)	0.54	0.59	--	--	37.28	32.2	8.40	0.13	0.05, 0.22	−0.51, 0.77	2.56
CHO (g)	0.42	0.46	0.29*	0.32	30.5	33.89	8.48	0.10	0.05, 0.14	−0.26, 0.46	0.64
Protein (g)	0.52	0.57	0.36	0.39	38.98	37.29	8.50	0.10	0.02, 0.17	−0.44, 0.63	0.80
Fat (g)	0.42	0.46	0.29*	0.32	37.29	37.29	1.69	0.09	0.06, 0.13	−0.25, 0.55	0.70
Cholesterol (mg)	0.48	0.53	0.49	0.54	25.42	35.6	13.55	0.15	0.04, 0.26	−0.66, 0.96	0.74
SFA (g)	0.33	0.37	0.23*	0.26	32.2	40.67	8.47	0.20	0.13, 0.26	−0.29, 0.68	0.62
MUFA (g)	0.38	0.41	0.36	0.38	42.37	28.81	5.08	0.08	0.00, 0.16	−0.53, 0.68	1.17
PUFA (g)	0.46	0.50	0.41	0.44	45.76	23.72	8.48	0.14	0.04, 0.24	−0.60, 0.89	1.51
Sodium (mg)	0.53	0.62	0.49	0.57	32.20	37.28	6.77	0.17	0.09, 0.24	−0.42, 0.75	0.17

Table 26: Comparison of energy and nutrient intakes using the AE-FFQ and three 24HRs based on correlations, joint classification by quartile and agreement by Bland–Altman analysis (n = 60) (continued)

Energy and nutrients	Spearman Correlation Coefficient				Cross-Classification Concordance Energy adjusted (%)			Bland-Altman Energy adjusted**			
	Crude	Deattenuated	Energy-adjusted	Energy-adjusted and Deattenuated	Same Q (%)	Adjacent Q (%)	Extreme Q (%)	Mean	CI	LOA	Slope
Vitamin C (mg)	0.42	0.48	0.41	0.47	35.50	33.80	10.10	0.19	0.05, 0.33	−0.88, 1.27	−0.65
Calcium (mg)	0.42	0.50	0.37	0.44	25.42	37.29	18.64	0.18	0.11, 0.25	−0.36, 0.72	0.77
Iron (mg)	0.13*	0.13	0.06*	0.06	32.20	27.11	11.60	0.00	- 0.11, 0.11	−0.80, 0.81	−0.46
Vitamin D (mcg)	0.19*	0.20	0.19*	0.19	20.33	44.06	6.70	0.13	0.03, 0.23	−0.60, 0.86	0.03
Vitamin E (mg)	0.49*	0.49	0.09*	0.09	42.37	27.12	8.5	−0.05	−0.17, 0.06	−0.91, 0.81	−0.70
Thiamine (mg)	0.26*	0.27	0.25*	0.26	30.50	25.42	16.94	0.15	0.02, 0.28	−0.84, 1.14	−0.17
Riboflavin (mg)	0.32*	0.33	0.18*	0.18	37.28	40.67	6.77	0.20	0.07, 0.33	−0.77, 1.17	−0.10
Pyridoxin (mg)	0.40	0.44	0.41	0.45	35.60	28.81	15.25	0.18	0.10, 0.26	−0.41, 0.76	−0.18
Folic Acid (mcg)	0.40	0.47	0.42	0.49	15.3	18.6	5.1	0.29	0.22, 0.35	−0.18, 0.75	0.36

Table 26: Comparison of energy and nutrient intakes using the AE-FFQ and three 24HRs based on correlations, joint classification by quartile and agreement by Bland–Altman analysis (n = 60) (continued)

Energy and nutrients	Spearman Correlation Coefficient				Cross-Classification Concordance Energy adjusted (%)			Bland-Altman Energy adjusted**			
	Crude	Deattenuated	Energy-adjusted	Energy-adjusted and Deattenuated	Same Q (%)	Adjacent Q (%)	Extreme Q (%)	Mean	CI	LOA	Slope
Vitamin B12 (mcg)	0.42*	0.47	0.39*	0.43	35.59	35.6	8.47	0.23	0.13, 0.33	−0.55, 1.01	−0.20
Dietary Fiber (g)	0.50	0.61	0.51	0.62	38.98	37.28	5.00	0.16	0.08, 0.24	−0.44, 0.76	0.93
Total Sugar (g)	0.60	0.65	0.55	0.60	32.20	30.50	13.55	0.14	0.06, 0.21	−0.41, 0.68	0.48
Vitamin A (mcg)	0.11*	0.12	0.09*	0.10	32.56	32.36	8.33	0.04	−0.03, 0.12	−0.53, 0.62	0.58
Median	0.42	0.47	0.38	0.39	35.5	33.89	8.48	--	--	--	--

*p > 0.05; **Calculated based on log-transformed variables with adjustment for total energy intake using the residual method.
24HR = 24-hour dietary recall; CHO= carbohydrate; CI = confidence interval; Q = Quartile; AE-FFQ = Adult Emirati food frequency questionnaire; LOA = limits of agreement; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; SD = standard deviation; SFA = saturated fatty acids.

Table 27: Comparison of food group intakes using the AE-FFQ and three 24HRs based on correlations, joint classification by quartile and agreement by Bland–Altman analysis (n = 60)

Food groups (in grams)	Spearman Correlation Coefficient				Cross-Classification Concordance Energy adjusted (%)			Bland-Altman Energy adjusted**			
	Crude	Deattenuated	Energy-adjusted	Energy-adjusted and Deattenuated	Same Q (%)	Adjacent Q (%)	Extreme Q (%)	Mean	CI	LOA	Slope
Dairy drinks	0.47	0.48	0.41	0.42	36.66	40.00	5.00	0.19	0.07, 0.32	−0.77, 1.16	0.05
Cheeses (Hard and spreads)	0.34*	0.37	0.34	0.37	30.00	40.00	15.00	0.31	0.17, 0.44	−0.71, 0.32	−0.64
Yoghurts	0.46	0.46	0.46	0.46	48.33	33.33	3.33	0.07	−0.04, 017	−0.71, 0.84	−0.41
Rice dishes	0.67	0.71	0.59	0.62	38.33	28.33	13.33	0.28	0.15, 0.40	−0.68, 1.23	−0.39
Pasta and other cereals dishes	0.54	0.56	0.46	0.47	40	41.66	5.00	0.12	0.01, 0.22	−0.66, 0.89	−0.50
White breads	0.22*	0.23	0.21	0.22*	33.33	35.00	11.66	0.16	0.05, 0.27	−0.66, 0.98	−0.17
Whole grain	0.44	0.45	0.34	0.35	30.00	33.33	16.66	0.39	0.25, 0.53	−0.67, 1.45	−0.51

Table 27: Comparison of food group intakes using the AE-FFQ and three 24HRs based on correlations, joint classification by quartile and agreement by Bland–Altman analysis (n = 60) (continued)

Food groups (in grams)	Spearman Correlation Coefficient				Cross-Classification Concordance Energy adjusted (%)			Bland-Altman Energy adjusted**			
	Crude	Deattenuated	Energy-adjusted	Energy-adjusted and Deattenuated	Same Q (%)	Adjacent Q (%)	Extreme Q (%)	Mean	CI	LOA	Slope
legumes	0.44	0.46	0.38	0.41	30.00	31.66	11.66	0.27	0.17, 0.36	−0.46, 0.99	0.17
Eggs	0.68	0.70	0.63	0.65	38.33	43.33	5.00	0.13	0.03, 0.23	−0.61, 0.87	0.22
Red meat (not including processed meat, sausages)	0.45	0.46	0.40	0.41	28.33	40.00	8.30	0.05	−0.08, 0.18	−0.92, 1.02	0.22
Meat products (Hot dogs, sausages)	0.52*	0.52	0.43	0.43*	40.00	43.33	3.30	−0.02	−0.12, 0.09	−0.81, 0.77	0.14
Chicken dishes	0.41	0.41	0.31	0.31	30.00	36.60	5.00	0.14	−0.02, 0.30	−1.04, 1.32	−0.61
Fish and seafood	0.50	0.54	0.45	0.49	26.66	35.00	16.66	0.38	0.27, 0.49	−0.46, 1.22	0.25

Table 27: Comparison of food group intakes using the AE-FFQ and three 24HRs based on correlations, joint classification by quartile and agreement by Bland–Altman analysis (n = 60) (continued)

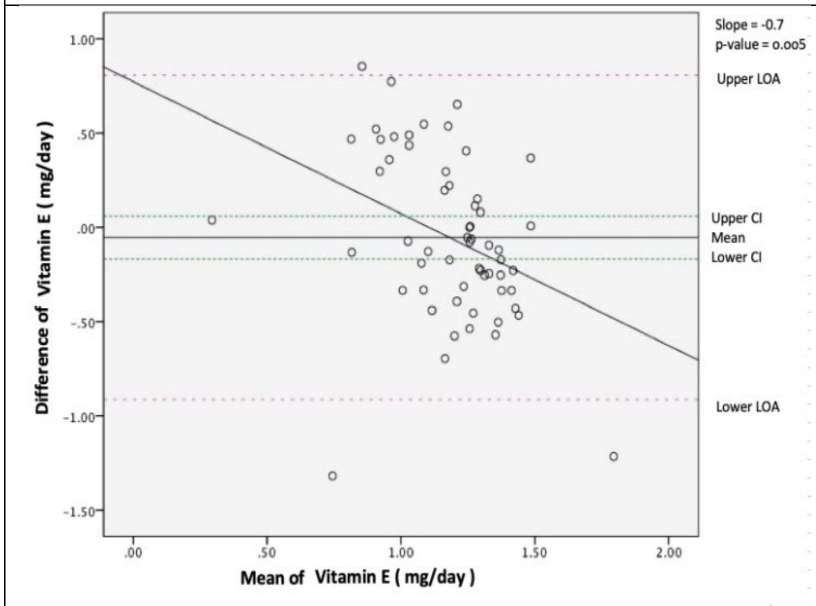
Food groups (in grams)	Spearman Correlation Coefficient				Cross-Classification Concordance Energy adjusted (%)			Bland-Altman Energy adjusted**			
	Crude	Deattenuated	Energy-adjusted	Energy-adjusted and Deattenuated	Same Q (%)	Adjacent Q (%)	Extreme Q (%)	Mean	CI	LOA	Slope
Greens	0.50	0.53	0.45	0.47	26.66	35	6.66	0.25	0.11, 0.39	−0.81, 1.31	−0.83
Total vegetables	0.57	0.64	0.50	0.56	40	21.66	13.33	0.27	0.16, 0.37	−0.52, 1.06	0.57
Cruciferous vegetables	0.31*	0.33	−0.02	−0.02*	25	50	23.33	0.43	0.33, 0.54	−0.40, 1.26	−0.43
Red or yellow vegetables	0.46	0.49	0.40	0.42	31.66	31.66	10	0.20	0.06, 0.34	−0.85, 1.25	0.58
Potatoes	0.36*	0.37	0.31	0.32*	25	36.66	16.66	0.24	0.15, 0.33	−0.46, 0.94	−0.25
Other vegetables	0.40	0.45	0.38	0.42*	28.33	31.66	18.33	0.42	0.28, 0.56	−0.65, 1.48	0.28
Savory snacks	0.35	0.35	0.31	0.31*	35	46.66	5.00	−0.13	−0.27, 0.02	−1.23, 0.98	0.35
Fruits	0.42	0.49	0.32	0.36	33.33	31.66	13.33	0.31	0.19, 0.43	−0.58, 1.20	−0.20
Dried fruits	0.62	0.63	0.59	0.60	40.00	36.67	5.00	0.10	−0.01, 0.21	−0.76, 0.96	0.41

Table 27: Comparison of food group intakes using the AE-FFQ and three 24HRs based on correlations, joint classification by quartile and agreement by Bland–Altman analysis (n = 60) (continued)

Food groups (in grams)	Spearman Correlation Coefficient				Cross-Classification Concordance Energy adjusted (%)			Bland-Altman Energy adjusted**			
	Crude	Deattenuated	Energy-adjusted	Energy-adjusted and Deattenuated	Same Q (%)	Adjacent Q (%)	Extreme Q (%)	Mean	CI	LOA	Slope
soft drinks	0.54	0.54	0.60	0.60	46.66	40.00	1.66	−0.13	−0.26, −0.01	−1.08, 0.82	0.37
diet soft drinks	0.30	0.30	0.43	0.43	25	30	21.66	0.27	0.19, 0.35	−0.36, 0.89	−0.59
Fruit juices	0.35	0.35	0.34	0.34	36.66	30	11.66	0.05	−0.08, 0.18	−0.95, 1.05	−0.25
sugar, syrups	0.50	0.54	0.44	0.47	40	26.66	15	0.29	0.17, 0.41	−0.63, 1.21	0.20
French fries	0.48	0.48	0.39	0.39	33.33	41.66	8.3	0.05	−0.06, 0.17	−0.81, 0.92	0.11
Sweet snacks	0.44	0.44	0.38	0.38	35	38.33	5	−0.08	−0.22, 0.06	−1.17, 1.01	0.34
Sweets, candies	0.31	0.31	0.21	0.21	21.66	43.33	6.6	0.11	−0.01, 0.23	−0.79, 1.00	−0.42
Chips	0.46	0.47	0.27	0.27	33.33	36.66	16.66	0.11	−0.01, 0.23	−0.44, 1.00	1.12
Nuts and seeds	0.44	0.45	0.35	0.35	26.66	38.33	6.6	0.17	0.04, 0.31	−0.84, 1.19	−0.24
Median	0.45	0.46	0.39	0.41	33.33	36.66	10	--	--	--	--

*p > 0.05; **Calculated based on log-transformed variables with adjustment for total energy intake using the residual method.
24HR = 24-hour dietary recall; CI = confidence interval; Q = Quartile; AE-FFQ = Adult Emirati food frequency questionnaire; LOA = limits of agreement.

a. Vitamin E



b. Meat products

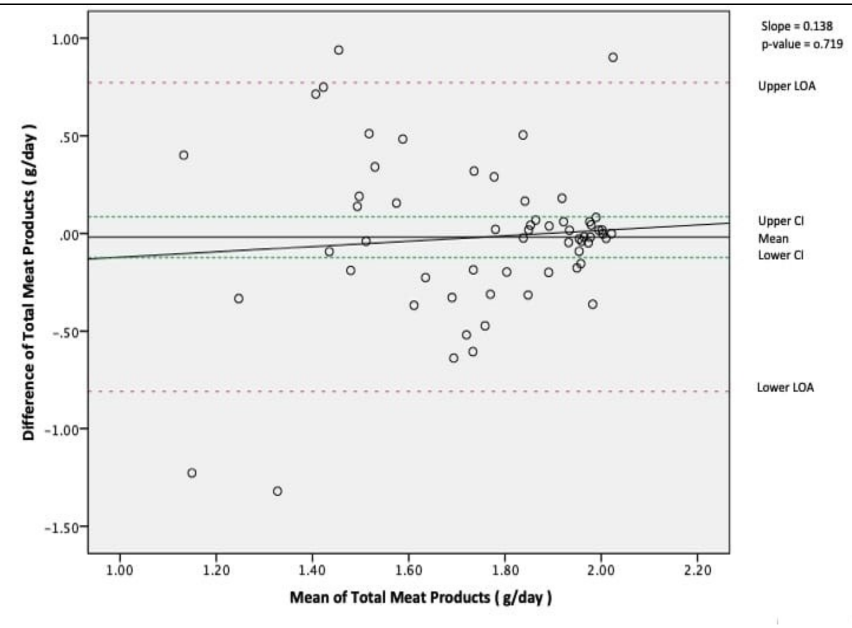
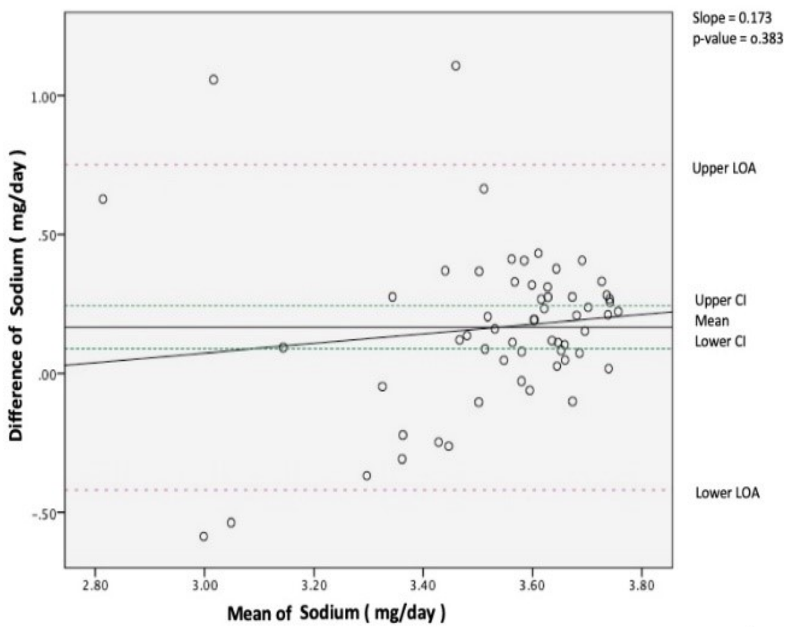


Figure 15: Bland–Altman plots for energy intake, selected energy-adjusted nutrient and food group intakes, with varying levels of agreement obtained between mean (ln) and differences in intakes measured by the AE-FFQ and the three 24HRs: (a) Vitamin E, (b) Meat products (g/day)

c. Sodium



d. Green leafy vegetables

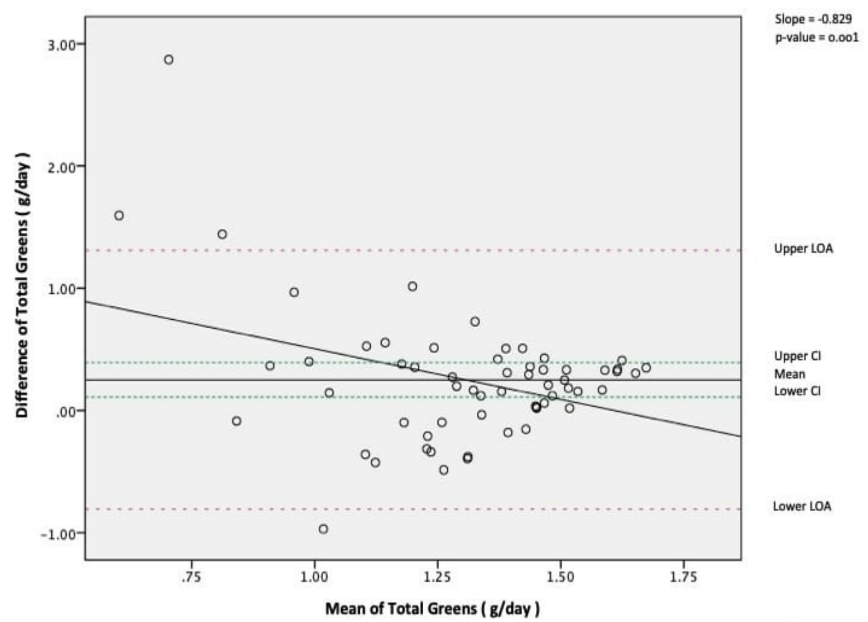
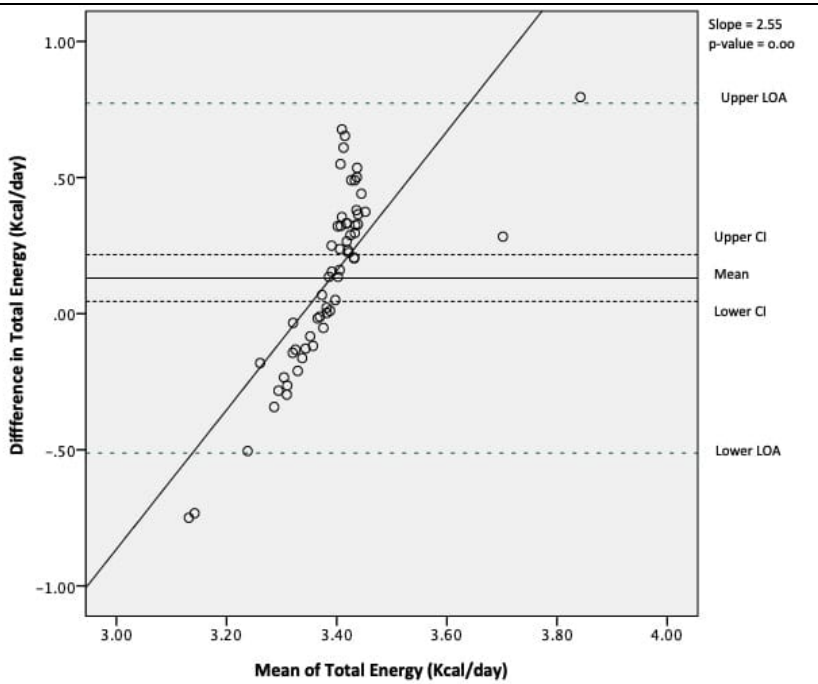


Figure 15: Bland–Altman plots for energy intake, selected energy-adjusted nutrient and food group intakes, with varying levels of agreement obtained between mean (ln) and differences in intakes measured by the AE-FFQ and the three 24HRs: (c) sodium (mg/day); (d) green leafy vegetables (g/day) (continued)

e. Energy Intake



f. Chips

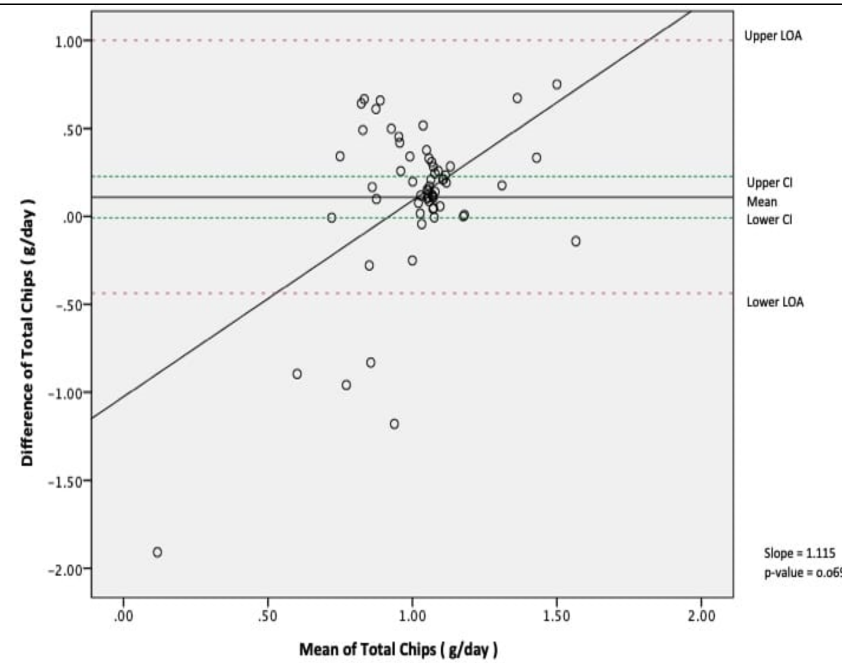


Figure 15: Bland–Altman plots for energy intake, selected energy-adjusted nutrient and food group intakes, with varying levels of agreement obtained between mean (ln) and differences in intakes measured by the AE-FFQ and the three 24HRs: (e) energy intake (Kcal/day); (f) chips (g/day) (continued)

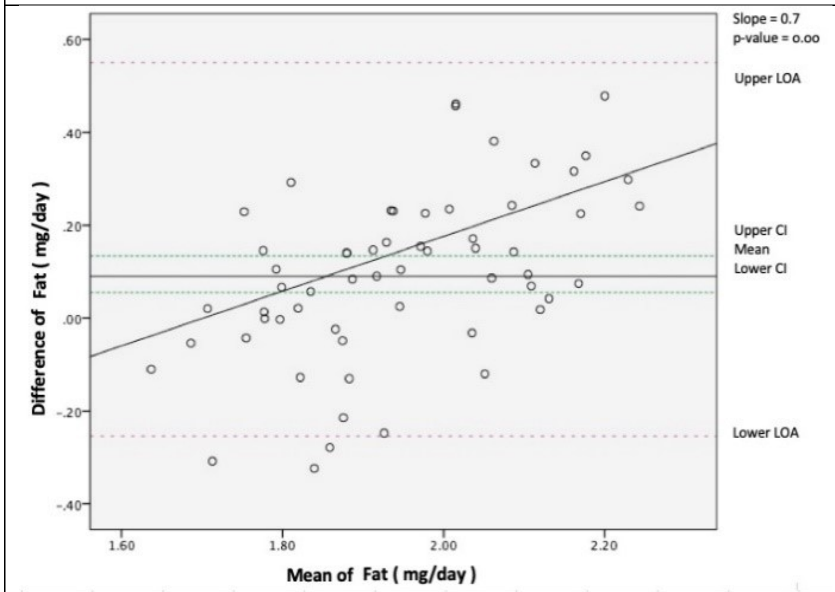
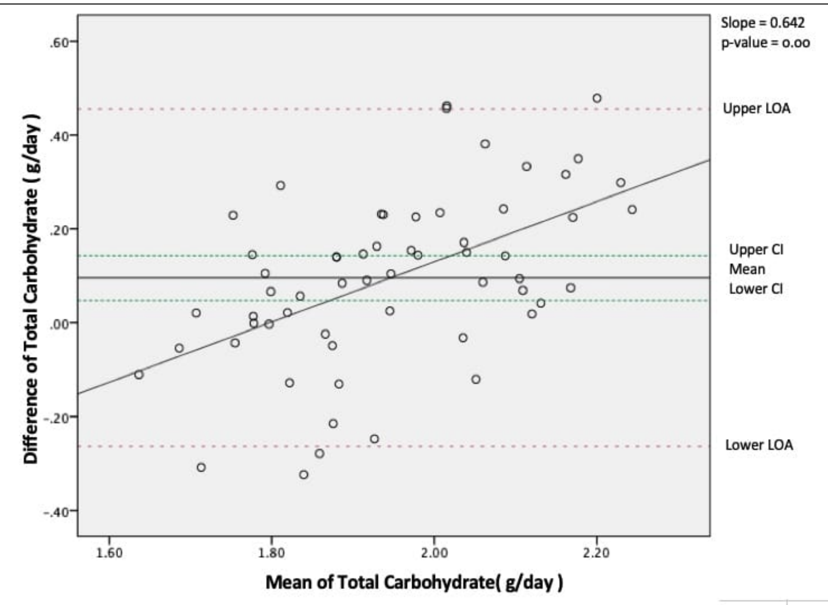
g. Fat	h. Carbohydrate
	

Figure 15: Bland–Altman plots for energy intake, selected energy-adjusted nutrient and food group intakes, with varying levels of agreement obtained between mean (ln) and differences in intakes measured by the AE-FFQ and the three 24HRs: (g) fat (g/day); (h) carbohydrate (g/day) (continued)

24HR = 24-hour dietary recall; AE-FFQ = Adult Emirati food frequency questionnaire; ln = natural log.

Chapter 4: Discussion

This study was successful in developing the first web-based FFQ that is specifically designed for the UAE population. Although an FFQ was developed for both the UAE and Kuwait in the past (Dehghan et al., 2005), it was not validated in the Emirati population (Dehghan, 2009). Consequently, and in the light of the critical need for a DAT that can assess nutritional status and advance the nutrition research related to NCDs specifically in the adult Emirati population, the development of a specific and culturally appropriate DAT was warranted.

The usability of the AE-FFQ as reported by the participants, the specificities of its different sections, the results of the validation study and the advantages and limitations of the design of the AE-FFQ and of the validation study are discussed.

In general, the questionnaire took approximately 30 min to complete. Opinions about the usability of the AE-FFQ ranged from easy to fill out to difficult to use. The AE-FFQ was reported as comprehensible and logically structured by 46 participants (77%), all of which had an undergraduate degree or higher. The researcher or her assistant helped 4 male and 6 female participants (17%) in filling the questionnaire because of reported low literacy or incomprehension of the questionnaire. Moreover, the researcher assisted 2 more participants because they did not own a laptop and therefore could not access the questionnaire URL.

The choice of the web-based format for the AE-FFQ was made because of its many advantages when compared to print FFQs, including flexibility of completion at any time and location, less missing data, automated data entry, immediate generation of dietary outputs, etc. (Fallaize et al., 2014; Falomir et al., 2012), and the reported preference of web-based FFQs over print FFQs in usability studies (Beasley et al., 2009; Christensen et al., 2013; Eldridge et al., 2018), which coincides with the high number of active internet users in the UAE (98.98%) (GMI., 2017). The design of the different sections of the AE-FFQ contained specific features intended to improve the usability, clarity and validity of the tool based on the peculiarities of the adult Emirati population. The homepage of the AE-FFQ provided clear instructions; a slideshow of the images of the dinnerware used for the food photographs with measurements in order to provide the participants with an idea of scale of the tableware size; and a video tutorial in Arabic on how to take the FFQ at every step. Section 1. "The main FFQ" contained a food list that was comprehensive in order to capture total EI (Willett et al., 1997), and representative of a typical Emirati diet, which included traditional Emirati foods, Middle-Eastern cuisine, International cuisine and various Arabic and Western fast foods and snacks, as reported by previous studies (Dehghan et al., 2005; Musaiger & Abuirmeileh, 1998; Ng et al., 2011) and confirmed by the team of experts (An expert chef, two Emirati nutritionists, four Emirati dietetics students). The frequencies used were also based on feedback from the pilot-testing of the draft FFQ and as such, included 2 monthly frequencies (1 -2/ month and 3x/month) and a maximum frequency of 3 x per day in section 1 of the FFQ while the foods that were reportedly consumed daily (water, evaporated milk, added sugar and salt added at the table) were queried separately in Section 3 of the FFQ as foods composing daily habits, which had the double advantage of providing more clarity to the participants and enabling a more accurate estimation of foods such as salt and sugar that are evidenced as risk factors of NCDs (Gupta et al., 2018). Because there was no empirical population-based data from which to derive portion sizes that are specific to the population of interest, a large range of portion sizes was included, where three food images depicting portions of increasing size and an additional four portion sizes options were included in the AE-FFQ. Indeed, Nelson and Haraldsdóttir (1998) reported that the use of a large number of photographs improves the accuracy of the reporting of dietary intake. Moreover, to enable a more accurate estimation of the foods queried, a total of 101 series of foods images (73%) depicted portion sizes in individual units, e.g. in the form of packaged foods, household measurements or pieces of fruits and vegetables. Based on Nelson and Haraldsdóttir (1998) recommendations, 20 foods of irregular shapes or sizes were pre-tested in a group of volunteers to ascertain the adequacy of the portion sizes included. Additionally, the AE-FFQ provided a live chat option to offer support to the participants at every stage of the questionnaire, however, only 2 participants reached out for clarification using this function. In section 2 of the AE-FFQ, the use of hand images as PSEA was found to be an acceptably accurate method of estimating portion sizes by Gibson et al. (2016). The only other FFQ in the literature that has reported using hands as PSEA is a Tanzanian FFQ, which included a "handful" as a PSEA because eating by hand is a common practice in that country (Zack et al., 2018). The analysis of the responses of the cross-check questions assessing the accuracy of the reporting of the frequencies of consumption of different food groups of interest revealed that matching reporting frequencies between the main FFQ (Section 1) and the cross-check questions (Section 3) was low, with 57% of the participants (for fruits and fast foods) to 77% of the participants (for Fish group) reporting matching frequencies, indicating that reporting frequencies of food intake can be challenging.

Overall, results of the validation study showed an acceptable validity of the AE-FFQ when compared with the three 24HR in the city of Al Ain, UAE. At the group level, a low to moderate agreement between the methods was obtained because most nutrients and food groups showed a percentage of mean differences larger than the 10% threshold that determines good agreement between the methods (Lombard et al., 2015). A higher percentage of mean differences in the FFQ was also reported in a study from Lebanon (Tueni et al., 2018). The AE-FFQ significantly overestimated energy (mean difference: + 779 Kcal/day) and most nutrients compared to the three 24HRs. Tayyem et al. (2014) and Dehghan et al. (2009) also reported high EI discrepancies. Overestimation of intake is a tendency that is often expected in comprehensive FFQs, more specifically when the number of food items exceeds 100 (Cade et al., 2002), as has also been reported in FFQ validation studies from neighboring countries (Aoun, Daher, et al., 2019; El Kinany et al., 2018; Harmouche-Karaki et al., 2020; Mumu et al., 2020; Tayyem et al., 2014) and in web-based FFQs (Du et al., 2015; Fallaize et al., 2014; Feng et al., 2016). Conversely, other web-based FFQs reported underestimation (Beasley et al., 2009; Kato et al., 2017; Kristal et al., 2014), or no difference in the estimation of energy and nutrient intake (Labonté et al., 2012). The large percentage difference observed with vitamin B12 (+81%) may have been due to the fact that organ meat (the highest source of vitamin B12 in the AE-FFQ) is rarely consumed. A similar explanation can be given for the overestimation of the reporting of fish (+210%) and brown bread (+143%). Indeed, Dehghan et al. (2005) and Musaiger and Abuirmeileh, (1998) reported that meat and chicken, but not fish are the most predominant sources of animal proteins in the Emirati diet. Other Web-based FFQ validation studies have also reported an overestimation of fish intake by the FFQ

(Affret et al., 2018), while others found a good correlation for fish intake despite the fact that it was eaten less frequently (Fallaize et al., 2014). Similarly, brown bread is much less popular in the UAE, as per the reporting from the reference instrument and the representation of breads observed in supermarkets. The trend of overestimation of foods that are consumed less frequently has been reported in other Web-based FFQs (Apovian et al., 2010; Labonté et al., 2012). Likewise, foods that showed the highest agreement between the methods were foods that were known to be frequently consumed (sweet and savory snacks, french fries, fruit juices, soft drinks). Earlier studies have reported the popularity of snacks and fruit juices in the Emirati population (Ng et al., 2011). The overreporting of fruits and vegetables by the AE-FFQ is another bias commonly found in validation studies of comprehensive FFQs (Cade et al., 2002). The long list of fruits and vegetables may also explain the overestimation observed with Fiber (+61%), Vitamin A (+37%) and Vitamin C (+75%), all markers of high fruits and vegetable intake (Harding et al., 2008). A similar positive association was reported elsewhere (Harmouche-Karaki et al., 2020). Given the overestimation of EI observed, the mean percent difference was also calculated for energy-adjusted nutrient and food group intakes in order to account for any confounding due to energy, because it may bias nutrient and food exposures in studies assessing diet-disease relationships (Willett et al., 1997). In general, the percentage differences between the methods decreased, resulting in a higher number of foods groups showing agreement between the methods. Indeed, the nutrient iron and the food groups: Yoghurt, meat products, soft drinks, fruit juices, french fries and sweet snacks all showed good agreement between the methods after energy-adjustment (mean difference ≤ 10%)

(Lombard et al., 2015). Previous studies have also reported a decrease in the mean percent difference of energy-adjusted measures of intake (Harmouche-Karaki et al., 2020).

The strength and direction of the association between the AE-FFQ and the average 24HRs at the individual level for energy, nutrients and food groups was measured by Spearman CC. Based on Lombard's interpretation criteria, both crude and de-attenuated correlations showed acceptable to good validity for energy, 17 of the 21 nutrients and all the 31 food groups. Moreover, after de-attenuation, energy intake, 7 nutrients and 10 food groups presented a good level of association because they were greater than 0.5 (Lombard et al., 2015). When comparing the range of de-attenuated unadjusted correlations obtained for nutrients and food groups with validation studies of FFQs having used 24HRs as their reference instrument, the range obtained: 0.12 - 0.65 for nutrients in this study were comparable to those obtained in previous Web-based FFQ validation studies, range: 0.14-0.78 (Beasley et al., 2009; Kristal et al., 2014; Verger et al., 2017) and in FFQs from other Arabic or neighboring countries, range: 0.02 - 0.73 (Dehghan, 2009; Mumu et al., 2020; Tayyem et al., 2014). For food groups, the range obtained: 0.22 - 0.68 was similar to those obtained in other web-based FFQ validation studies, range: 0.11 - 0.73 (Fallaize et al., 2014; Feng et al., 2016; Matthys et al., 2007). Foods with the highest correlations were foods that were consumed almost daily in the Emirati diet (eggs, rice and dried fruits in the form of dates). Similarly, food groups with the lowest correlations ("Cruciferous vegetables" and "Diet soda drinks") were not frequently reported in the reference instrument. Conversely, despite the high popularity of potatoes in the Emirati diet, the low correlation (0.37) of this group may be the result of the difficulty in quantifying the intake of foods that are usually consumed as part of mixed dishes, specifically because potato is the main vegetable added to staple mixed dishes in the UAE. A similar issue was observed in the French food frequency e-questionnaire (FfeQ) (Affret et al., 2018).

The correlations of energy, nutrients and food groups obtained may have been inflated because of the use of the 24HR as the reference instrument, which shares memory bias as a potential source of error (Willett, 2013). However, the AE-FFQ investigates long-term memory, while the 24HR assesses short-term memory (Willett, 2013). Other differences between the 2 instruments are that the AE-FFQ is web-based, self-administered and contains close-ended questions, while the 24HR is interview based, and uses open-ended questions (Willett, 2013). Such differences let us assume that despite both methods relying on memory, the 24HR is an adequate reference instrument, especially when used on multiple days (Gibson, 2005). Other errors that may have inflated the correlation results are the use of the same food images to depict the portion sizes and the same nutrient data source for both the instruments compared in this study. Given the possibility of correlated errors between the two instruments, correlations of energy-adjusted nutrients and food groups values were performed (Willett et al., 1997). Energy-adjustment decreased the median Spearman CC of almost all nutrients and food groups to 0.39 and 0.41 respectively. Correlations were less than acceptable (< 0.2) for a total of 5 nutrients with iron, vitamin E and riboflavin correlations showing the largest decrease. For food groups, an acceptable level of validation was maintained for all groups (> 0.2), except for the cruciferous vegetables group (-0.02). Frequently consumed food groups (eggs, rice, soft drinks, dried fruits) maintained a good correlation (> 0.5). The decrease in median correlation observed after energy-adjustment for both nutrients and food groups may be due to a systematic error of under/overestimation of reported food consumption in the AE-FFQ rather than a high energy intake of participants (Beaton et al., 1979). Previous validation studies of web-based FFQs (Beasley et al., 2009; Verger et al., 2017), and validation studies of FFQs from Arabic or neighboring countries (Dehghan, 2009; El Kinany et al., 2018; Mumu et al., 2020) have also reported that energy-adjusted estimates were decreased after energy-adjustment.

The Bland Altman analysis showed a fair agreement in general (Almost observations were within the LOA), however, the AE-FFQ underestimated or overestimated intake for energy and most nutrients and food groups, except for the nutrients Pyridoxine, Sodium and the foods groups meat products and red meat for which the bias was closer to zero. The AE-FFQ did not perform well for assessing higher intake for most food groups and nutrients, especially EI. This may be because the 24HR was not an appropriate reference method, as it is not considered the gold standard of reference instruments in validation studies (Willett, 2013). This finding suggests that the AE-FFQ is not suitable for assessing absolute intake in the adult Emirati population, however, it can be used to rank individuals based on their nutrient and food groups intake, as evidenced by the results of the cross-classification analysis where a fairly acceptable agreement was observed with most participants (69 % and 67 %) being correctly classified into the same or adjacent quartile of adjusted nutrient and food group intakes respectively, while only 8% and 10% participants were classified in opposite quartiles for nutrients and food groups respectively. Other studies (Christensen et al., 2013; Dehghan, 2009; Kato et al., 2017; Mumu et al., 2020) have also reported obtaining a good agreement at the group level 248herein nutrients were correctly classified into quartiles, although the agreement in assessing absolute intake was poor. It is more important for an FFQ to be able to rank individuals correctly across the distribution of intake than to assess absolute intake because the effect of dietary exposures is most frequently quantified as odds ratio or relative risk in nutritional epidemiology (Beaton et al., 1979).

Measuring nutrients and food groups in isolation as described above have resulted in important discoveries, such as the adverse associations of red meat, saturated fat with coronary heart disease risk (Mente et al., 2009), however, these measures do not account for the diversity of food choices of free living individuals and the complex synergistic effects between nutrients (Mozaffarian, 2016). Consequently, the ability of the AE-FFQ to estimate the overall diet quality was also assessed.

Given that the AE-FFQ is only suitable for assessing 3 of the 8 components of the Mediterranean diet score that are applicable to the UAE (considering that alcohol (the 9th component of the MDS), is not consumed for religious reasons), the AE-FFQ does not seem to be adequate for measuring the quality of the Emirati diet based on the MDS, indicating that further improvements to the AE-FFQ are required to ensure relative validity of all the components of the MDS included in the AE-FFQ.

Although many published studies have reported using a validated FFQ to assess the quality of the diet based on the MDS (e.g. the widely used Norfolk EPIC FFQ (Bamia et al., 2017; Tong et al., 2016), the Block FFQ (Shikany et al., 2018), or a validated FFQ in Lebanon (Aoun, Papazian, et al., 2019), it is not clear if each of the components of the MDS included in these validated FFQ were individually assessed for their relative validity before the use of the FFQ for measuring diet quality based on the MDS. Numerous other studies have used non-validated FFQs to construct MDS (Benítez-Arciniega et al., 2011; Flor-Alemany et al., 2020), thus compromising the judgment of the quality of the diet based on the results of the MDS. Others have reported designing new questionnaires or screeners specifically to assess the MDS and did not rely on FFQs or other dietary assessment tools such as 24HRs or DRs (Bishop et al., 2019; Martínez-González et al., 2012; Weaver et al., 2020).

This study presents a number of strengths and limitations both in the development of the AE-FFQ and in the design of the validation study. There was a low response rate in Section 2 “Additional foods” of the AE-FFQ, consequently, results were not included in the final data analysis, as only 9 of the 60 participants (15%) filled this section, out of which, 6 participants entered foods already included in the main FFQ (e.g. rice dishes and chocolates), which indicates that participants did not memorize the foods included in the main list. Moreover, since this section was not mandatory, participants may have skipped it because they did not consume additional foods or because they wanted to finish the questionnaire more quickly. Qualitative questions in “Section 3” of the AE-FFQ querying about the type of fats used in cooking or the frequency of consumption of fast foods were also not accounted for in the final data analysis. These sections could be used in future studies if qualitative information about these dietary habits are required. Similarly, results from “Section 4” of the AE-FFQ could not be interpreted because of the lack of a designated DSs database. Only 17 of the 60 participants voluntarily filled this section, out of which, 12 participants (70 %) matched the reporting of the corresponding 24HRs. The few results obtained highlighted the popularity of the use of vitamin D supplements (reported by 9 female and 1 male participants). Finally, given the technical skills required, the AE-FFQ may not be advisable for use in people with low literacy skills because they may not be confident using a computer.

Regarding the limitations of the validation study, there were many limitations that should be taken into consideration when interpreting the results. A major limitation is that the reproducibility of the AE-FFQ was not assessed along with the validation study. There were several reasons that hindered the conduct of a reproducibility study. Indeed, a reproducibility study of the AE-FFQ was planned by re-administering the questionnaire at 4 weeks from the initial administration as this is a long enough time for the participants to forget their previous responses but within a reasonable period that does not lead to major changes in dietary habits. However, there were delays during the in-house testing phase of the web-based AE-FFQ to reach the desired standard for the external users to self-complete the AE-FFQ without technical errors. Moreover, the month following the AE-FFQ administration coincided with the Islamic month of Ramadan which is dedicated to religious fasting and can involve drastic changes in the dietary habits. For this reason, the second administration of the AE-FFQ was delayed until the end of the month after Ramadan. However, when the participants were contacted for the reproducibility study, more than 75% of the participants were not reachable by phone or email due to travel in the summer months of July and August. Thus, a minimum number of participants that would have allowed running a reproducibility study with sufficient precision was not reached. For example, Cade et al. (2002) recommends a minimum sample size of 50 individuals to allow the limits of agreement to be estimated when assessed by Bland-Altman method. Therefore, due to the above reasons, unfortunately, the reproducibility was not assessed, and only the results obtained from the study on the relative validity of the AE-FFQ are reported. Cade et al. (2002) reported in their review of published FFQ validation studies that 53% of validation studies did not report a repeatability study.

The AE-FFQ presented a few other limitations. Because it was the first of its kind in an Arabic country, the AE-FFQ could not be compared with other validation studies conducted in the UAE because no such studies exist. Although the print FFQs developed for both UAE and Kuwait (Dehghan et al., 2005), were validated in Kuwaiti adults, it was not tested in the UAE (Dehghan, 2009). Moreover, although the use of three replicates of the 24HR as the reference instrument in this study is supported by many studies (Cade et al., 2002; Du et al., 2015; Ma et al., 2009), a larger number of replicates may have helped improve the validity of the AE-FFQ, given that micronutrients showed a consistently lower validity across all statistical tests compared with macronutrients. However, more replicates may also have increased the burden on the participants and may have induced a higher attrition rate. The use of recovery and/or concentration biomarkers, which have uncorrelated errors may have added valuable information about the validity of the AE-FFQ (Willett, 2013). Another limitation is the use of a convenience sample of volunteers in the city of Al Ain, with most participants being educated, young, and female; therefore, this study population lacks generalizability to the Emirati population more broadly. Because the AE-FFQ was a Web-based FFQ, it may not be advisable for use in people with low literacy skills or in older age groups because they may not be confident using a computer.

Some of the strengths of this study lie in the Web-based format of the AE-FFQ, which ensured a fully automated and immediate data output after completion of the AE-FFQ, with no double data entry, and no requirement for data cleaning, thus making the AE-FFQ, to date, the only fully automated self-administered web-based FFQ in the Arab world. The tool did not take more than 30 minutes to complete and was easy to use by the educated participants. Moreover, the tool included a wide range of food photographs to help with estimation of intake because it has previously been shown that the use of a large number of food photographs improves the ability of an individual to more accurately report dietary intakes (Nelson et al., 1996). In addition, the use of nonparametric methods (Spearman correlation coefficient, Wilcoxon signed-rank test) that are more robust than parametric tests may have accounted for the small sample size because the observed associations were fair and statistically significant overall (Gibson, 2005).

Another important strength of the validation study is that it used a rigorous step-wise approach using high-quality DBs to overcome the lack of a designated nutrient data source needed to obtain energy and nutrient estimates for the food consumption data obtained. Indeed, 97% of all foods reported in the three 24HRs were adequately matched using primarily the USDA SR DB, which was used to match a total of 302 (52%) of the foods reported. Only 14 foods (3% of all foods) were lacking some of the component values of interest (e.g. dry lemon, some brands of juices that could not be matched with generic juices, spices, etc.). These foods were reported in only small quantities and therefore the missing component values were negligible and should not affect the final nutrient intake estimates. High-quality DBs sourced from FoodExplorer (mainly the UK DB, New-Zealand DB) were used for matching another 12% of all foods reported. The use of FoodExplorer Interface was instrumental because it removed the ambiguity of food description and description of food components thanks to the incorporation of Langual™ and EuroFIR thesaurus (Finglas et al., 2014). Recipe calculation accounted for matching 29% of the foods that were not matched in any source of nutrient data. Given that the UAE is a country that imports a large number of branded foods from different countries, the use of different high quality DBs was necessary and preferable to borrowing component values as this latter method is more susceptible to introducing bias due to the errors in calculations that can be generated.

Finally, given that the validation study used the reference instrument to determine weighted mean of composite food-line items of male participants, which may have biased the validity of the FFQ, a secondary analysis where nutrient values of composite food line-items were obtained from the most frequently reported food in the line (Willett technique) was performed (Willett et al., 1985). The secondary analysis revealed slightly higher but comparable crude Spearman CC nutrients values, with a median of 0.43 for the secondary analysis vs. a median Spearman CC of 0.42 in the first analysis, confirming the that the most frequently reported foods were indeed largely predominant in the composite food line-items in the first analysis, and therefore the adequacy of the approach used.

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Chapter 5: Conclusion and Future Direction

The paucity of food consumption data observed in the UAE was the driver to the objectives of the present study which were: To develop a culturally-appropriate and comprehensive quantitative web-based FFQ that is able to inform on the intake of the nutrients and food groups that have been evidenced as potential protective or adverse factors influencing NCDs specifically in the adult Emirati population; develop an accompanying table of nutrient data to convert food intake into nutrient data and validate the AE-FFQ in the population of interest.

This thesis also outlined the methodological insights, challenges faced, and solutions adopted for the development of a novel FFQ and its associated nutrients table in the context of the lack of representative empirical national food consumption data.

The novel AE-FFQ was a 139-item desktop-based online FFQ depicting 3 portion size food images within each food line. For the validation study, comparing the AE-FFQ to a three 24HRs revealed that the AE-FFQ had a good relative validity for ranking individuals by dietary intake because it was able to rank participants according to their intake for most nutrients. However, despite good overall median correlations, the AE-FFQ presented a systematic bias and overestimated intake of energy and most nutrients, as if often the case with comprehensive FFQs (Cade et al., 2002). It is therefore not suitable for assessing absolute nutrient intake for most nutrients. However, the AE-FFQ is a valid tool for use in epidemiological studies to assess the relationship between dietary intake and nutrition related risk factors in the Emirati adult population.

❖ Future direction

Overall, it is critical to improve the AE-FFQ in the future based on sound data from national nutrition surveys on the foods consumed in the UAE and their age and gender specific portion sizes, and to develop a nutrient data for the AE-FFQ that is derived from an established national FCT developed specifically for the UAE. Indeed, the chemical analysis of more Emirati foods is warranted because not all foods can be borrowed from international DBs. The verification of the reproducibility of the AE-FFQ should also be conducted as the next step. Moreover, future work should aim at refining the AE-FFQ by removing some of the high calorie, low density foods such as sweet snacks in order to reduce the overestimation of EI by the AE-FFQ. The use of biomarkers such as DLW and recovery biomarkers to assess the misreporting and better validate other nutrients should also be considered in the future.

Since the AE-FFQ is a novel FFQ, further analysis should be conducted in other study groups from other Emirates and on a larger sample of participants. Moreover, given the observed lower popularity of laptops compared to mobile applications, the development of the AE-FFQ for mobile devices is warranted.

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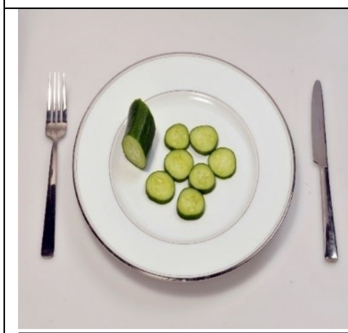
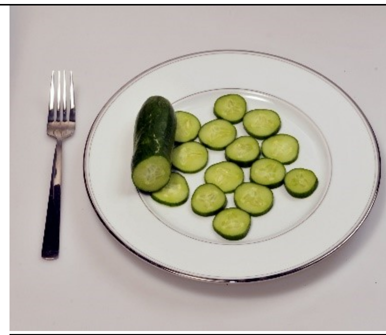
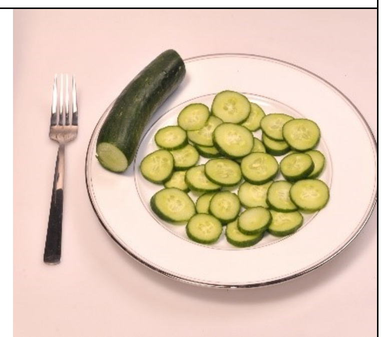
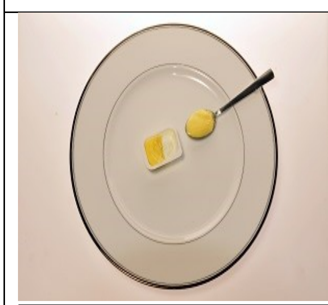
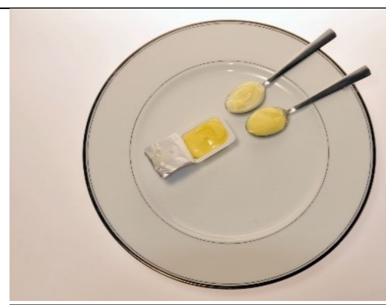
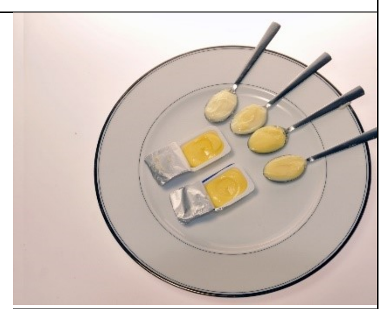
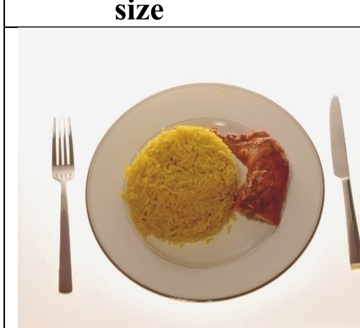
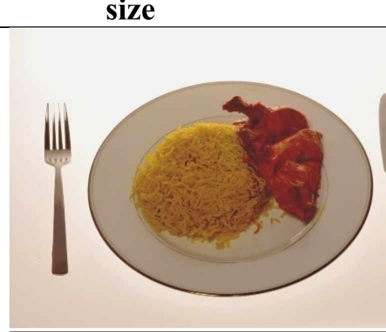
Appendices

Appendix 1: Examples of food images

a. **Cucumber Small portion size**	b. **Cucumber Medium portion size**	c. **Cucumber Large portion size**
		
d. **Butter Small portion size**	e. **Butter Medium portion size**	f. **Butter Large portion size**
		
g. **Chicken in rice mixed dish Small portion size**	h. **Chicken in rice mixed dish Medium portion size**	i. **Chicken in rice mixed dish Large portion size**
		

Appendix 2: Camera setting for photographing food images

Appendix 3: Print AE-FFQ

Print AE-FFQ

AE-FFQ PART I

Over the last 1 month, on average, how often did you eat the following foods?
على مدار الشهر الماضي ، في المتوسط ، كم مرة تناولت الأطعمة التالية؟

بند الطعام بالجرام	**Food line item (in grams)**	**Portion sizes** حجم الحصة			**Range of frequencies** نطاق الترددات
		Small صغير	Medium متوسط	Large كبير	From Never or less than once a month to 3 times per day من أقل من مرة في الشهر إلى 3 مرات في اليوم
منتجات الألبان	**Dairy foods**				
حليب بقر؛ كامل، قليل أو خالي الدسم (مل)	Cow Milk: full-fat, low fat or skimmed (ml)	150	200	240	
روب؛ كامل، قليل أو خالي الدسم	Yoghurt: full-fat, low fat or skimmed	30	85	170	
لبن آب	Laban Up	100	200	400	
لبن؛ كامل، قليل أو خالي الدسم	Buttermilk: Full-fat, low fat or skimmed	90	180	360	
شرائح الجبن للسندويشات أو شرائح جبن الشيدر أو شرائح موزاريلا أو شرائح الجبن رومي	Sandwich cheese sliced or Cheddar cheese or Mozzarella or Roomy Cheese	40	60	80	

جبنة فيتا أو حلومي أو عكاوي أو قشقوان؛ كاملة، قليلة أو خالية الدسم	Feta Cheese or Halloumi or Akkawi cheese; full-fat or low fat	30	50	90	
الأكلات الشعب ية	**Composite dishes** ***"Please do not add the vegetables reported here again in the vegetables section"***				
متبل الباذنجان	Mutabal	60	90	180	
تبولة	Tabouleh	65	130	195	
حمص بطحينة	Hummus	60	120	180	
محشي ورق عنب	Stuffed grape leaves	50	100	150	
محشي كوسا	Stuffed Marrow (Mahshi Koosa)	120	180	360	
محشي ملفوف	Stuffed Cabbage (Mahshi Malfouf)	90	180	270	
هريس، جريش أو) عرسية (لحم أو دجاج	Harees, Jareesh, Arsiya (meat or chicken)	125	250	500	
مرقوقة أو ثريد (لحم أو) دجاج	Margooga, Thareed (meat or chicken) *"Please report the meat consumed with this dish in the Proteins section"*	125	250	500	
صالونة (حدد فقط كمية المرق بالصالونة (اللحم، الدجاج أو السمك	Salona (Meat or Chicken or Fish): Please only indicate the amount of sauce you usually consume *"Please report the meat consumed with this dish in the Proteins section"*	45	90	135	

أرز مطبوخ على شكل برياني أو مجبوس أو كبسة أو مندي؛ باستثناء الأرز الأبيض	Cooked rice as in Biryani, Machbous, Kabsa, Mandi; other than white rice. *"Please report the meat consumed with this dish in the Proteins section"*	150	300	450	
معكرونة بصلصة البشاميل و الدجاج	Macaroni with Bechamel and chicken	200	300	400	
بروتينات؛ بيض? لحم? سمك، فاصوليا واللحوم المصنعة	**Proteins** ***"Please report all meats consumed in this section only"***				
فاصوليا مطبوخة (مثال الفول المدمس)، أو العدس، أو الدانجو(الغير مضاف بالحمص (بطحينة أو بشوربة فاصوليا	Baked beans (as in Fool Medamas) or lentils or broad beans or chickpeas	96	144	223	
بيض مغلي أو مقلي أو مخفوق	Eggs boiled, fried, scrambled	46	92	138	
لحم الضأن، الغنم أو البقر المطبوخ مع العيش أو الصالونة أو المرقوقة أو الثريد	Lamb, mutton, or beef, cooked with rice or salona or margouga	60	120	180	
لحم الضأن، الغنم أو البقر المشوي بالفرن أو على الفحم (المرافق للعيش أو الخبز)؛ مثال الكباب، لحم تكة، شيش طاووق. (باستثناء الهمبورجر أو الشوارما	Lamb, mutton, or beef, grilled or barbecued (with bread or rice), as in kebab, meat Tikka, Shish Tawook	35	70	140	
لحم الإبل مع العيش أو الصالونة أو المرقوقة أو الثريد	Camel meat, cooked with rice or salona or margouga	60	120	180	
دجاج مطبوخ مع العيش أو الصالونة أو المرقوقة أو الثريد	Chicken cooked with rice or	70	120	190	

	Salona or margouga				
دجاج مشوي بالفرن أو على الفحم (المرافق للعيش أو الخبز)؛ مثال الكباب، دجاج تكة، شيش طاووق. (باستثناء (الهمبورجر أو الشوارما	Chicken grilled or barbecued (with bread or rice), as in kebab, chcicken Tikka, Shish Tawook	45	90	130	
دجاج مقلي بالزيت (مثال) دجاج كنتاكي	Fried Chicken e.g. Kentuky chicken	60	120	240	
كبدة، قلب، كلي، طحال	Organ meat e.g. Liver, Kidneys...	90	150	240	
سمك مقلي أو سمك مخبوز أو أصابع سمك؛ المرافق للعيش أو الخبز	Fried fish or paneed fish (with bread or rice)	90	180	360	
سمك أبيض غير مقلي (كسمك الهامور، كنعد، صافي، شعري) المطبوخ مع العيش أو الصالونة	Non fried white fish (e.g., Hamour, king fish, emperor...) cooked with rice or Salona	90	150	240	
سمك أبيض كسمك الهامور، كنعد، صافي، شعري؛ المشوي بالفرن أو على الفحم (المرافق للعيش أو الخبز	Grilled white fish (e.g., Hamour, king fish, emperor...), (with bread or rice)	85	165	330	
سمك دهني (غير أبيض)، طازج أو معلب (كسمك التونة، الماكريل، السلمون، (السردين)؛ (المرافق للعيش أو الخبز	Oily fish, (e.g. Tuna, Salmon, Sardines..), (with bread or rice)	85	120	180	
فواكه البحر كالربيان، الجمبري، أو المحار؛ مشوي أو مقلي أو مطبوخ مع عيش أو صالونة	Sea food e.g. Shrimps	48	96	145	
سمك مالح (كنعد، عوال)	Malleh Fish	45	90	135	
مرتاديلا أو سلامي أو لانشون أو لحم مقدد	Mortadella, Salami, Luncheon meat	30	60	120	
هوت دوج، نقانق	Hot Dog, sausages	34	68	102	
خضروات	**Vegetables "Please report here only the**				

	vegetables you did not report in the composite dishes section”				
جزر طازج؛ بالحبة أو على شكل سلطة أو مطبوخ على شكل صالونة أو مرقوقة أو ثريد	Carrots, raw as in salad, or cooked as in Salona or thareed	24	48	96	
بطاطا مطبوخة؛ مثال بالسلطة أو بالصالونة أو مع العيش (باستثناء البطاطس المقليّة و (رقائق بطاطس الشيبس	Potato cooked, as in a Salad or salona or thareed or rice, (other than french fries or chips)	30	60	130	
بروكلي أو قرنبيط	Broccoli or cauliflower	23	45	91	
ملفوف أو كرنب طازج مثال بسلطة الملفوف أو بالسلطة الخضراء، أو مطبوخ على شكل صالونة (الغير مضاف بمحشي (ملفوف)	Cabbage or kale, raw as in coleslaw salad, or cooked as in Salona, (other than Mahshi malfoof)	56	112	168	
خيار، مع القشر، طازج؛ بالحبة أو على شكل سلطة	Cucumber, with peel, raw (as in green salad or Fattoush)	26	50	105	
بازيلاء	Green Peas	30	60	90	
فاصوليا خضراء	Green Beans	60	125	190	
كوسا، (باستثناء المحشي كوسا)	Marrow, (other than mahshi Koosa)	45	90	180	
خس، (مثال بالسلطة) الخضراء أو الفتوش	Lettuce (as in green salad or Fattoush)	10	20	30	
ورقيات طازجة؛ مثال أوراق الفجل (الرويد)، الجرجير، البربير، البقل	Green leaves (as in radish leaves, watercress, rocca leaves)	7	15	30	
طماطم طازجة بالحبة أو على شكل سلطة	Tomato, raw (as in green salad or Fattoush)	30	60	120	

بصل أخضر أو أبيض، طازج؛ بالحبة أو على شكل سلطة	Onion, or spring onion, raw (as in green salad or Fattoush)	5	10	20	
فلفل حلو طازج؛ بالحبة أو على شكل سلطة أو مطبوخ على شكل صالونة أو مرقوقة أو ثريد	Green pepper, raw as in salad, or cooked as in Salona or thareed	47	95	190	
قرع أو بطاطا حلوة	Pumpkin or Sweet potato	60	120	180	
باذنجان مقلي أو مطبوخ (الغير مضاف (للمتبل	Eggplant, fried or cooked (Other than in Mutabbel)	50	100	150	
بامية	Okra	45	90	160	
حبوب ذرة مطبوخة بالزبدة أو مع السلطة أو بالصالونة	Sweetcorn, in butter or salad, or in Salona	50	110	160	
خضروات مختلطة) طازجة أو مجمدة)	Mixed vegetales (fresh or frozen)	45	90	140	
حبوب، أرز، مكرونة ، بطاطا	**Cereals (pasta and other cereals), rice and starches)**				
حبوب الافطار غير مغلفة بالسكر (مثال (كورنفليكس أو رايس كريسبيس	Non-sugar-coated cereals (e.g. Cornflakes, Rice Crispies)	24	36	48	
حبوب الافطار مغلفة بالسكر (مثال كوكو (بوبس أو فروستيز	Sugar coated cereals (e.g. Sugar Puffs, Cocoa Pops, Frosties)	22	35	70	
حبوب الافطار الكاملة مثال رقائق النخالة أو الميوسلي	Wholegrain cereals such as Bran Flakes or Muesli	25	37	70	
أرز أبيض أو أرز أبيض بالشعرية	White rice, rice with Vermicelli	150	300	450	
معكرونة؛ (باستثناء المعكرونة مع صلصة البشاميل)	Pasta boiled, (other than pasta with Bechamel)	90	180	270	
بطاطس مقليّة	French Fries	30	120	180	
شوفان، مثل شوربة الشوفان	Oats as in Oats soup	10	20	30	

بيتزا (خضار أو لحم أو دجاج	Pizza (vegetables, meat, or chicken)	90	180	360	
السّاندوتشات والمقبلات	**Sandwiches and baked snacks**				
فلافل	Falafel	23	46	69	
سمبوسة (خضار أو لحم أو دجاج	Sambosa (vegetables, meat, or chicken)	20	60	120	
باكورة هندية	Pakora	32	64	128	
عرايس (لحم أو دجاج)	Arayes (meat or chicken)	50	100	150	
فطاير، مناقيش (جبن أو لحم أو زعتر أو (سبانخ	Fatayer, Manaqueesh (cheese, meat, zaatar or spinach)	45	90	180	
شوارما (لحم أو دجاج)	Shawarma (meat or chicken)	100	180	360	
هامبورجر (لحم أو دجاج)	Hamburger (meat or chicken)	108	199	306	
الخبز و البسكويت المالح	**Breads and savory biscuits**				
خبز أبيض (سلايس)	White bread, slice	24	48	72	
خبز اسمر(سلايس)	Brown Bread, Slice	35	70	105	
خبز رقاق (الغير مضاف) بالثريد	Rgag Bread (Other than in Thareed)	30	60	120	
خبز لبناني أسمر أو أبيض	Arabic Bread, white or brown	33	65	130	
خبز جباب	Chebab bread	84	168	252	
خبز سمون، خبز الهوت دوج	Samoon Bread or Hot Dog Bread	32	64	128	
شباتي (بدون زيت)	Chapati (without oil)	60	120	180	
خبز مقلي مثال البراتا أو بوري	Fried bread, e.g. Paratha or Puri	80	160	240	
كراكرز أو بسكويت) مملحة (مثال سالتين	Crackers and Salted biscuits (e.g., Saltine crackers)	6	12	24	

ما يدهن على الخبز أو يضاف على الخضراوات أو على السلطات	**Spreads on breads, on vegetables or on salads. (Excluding use in cooking)**				
لبنة، جبنة قابلة للذهن (بوك، فلادليفيا أو المثلثات أو كيري)، جبنة بيضاء؛ كاملة أو قليلة الدسم	Labneh, or Cheese spread (Philadelphia, Triangle or Kiri) or White cheese; full-fat or low-fat	30	45	60	
سمن	Ghee	7	15	30	
زبدة	Butter	5	10	20	
مايونيز أو كريم للسلطة	Mayonnaise or Salad cream	10	20	40	
مربّى	Jam	7	15	30	
عسل	Honey	21	42	84	
شوكولاتة قابلة للدهن) مثال نوتيلا)	Chocolate spread (e.g., Nutella)	7	15	30	
دبس التمر	Date molasses or dates syrup	10	20	30	
عصير ليمون أصفر أو لومي أخضر	Lemon or lime juice	10	20	40	
كاتشب أو صلصة طماطم	Ketchup or tomato sauce	10	20	40	
صلصة حارة (دقوس أو) شطة	Hot chilli sauce, Daggous	20	30	40	
مخللات أو شاتني أو اجار	Pickles or Chutney	7	15	23	
زيتون	Olives	11	22	44	
الشوربة	**Soups**				
شوربة خضار فقط	soup of vegetables only	125	250	375	
شوربة بلحم أو دجاج	Meat or chicken soup	125	250	375	
شوربة فاصوليا (مثال) شوربة عدس	Soup with legumes (e.g., lentils soup)	125	250	375	
شوربة مجففة فورية	Instant dehydrated soup	7	15	30	
شوربة الاندومي (نودلز) مجففة فورية	Instant noodles soup (e.g., Indomie soup)	38	77	154	

فواكه وفواكه جافة	**Fruits and Dried Fruits**				
تفاح أو كمثرى	Apple or pear	38	75	150	
موز	Banana	75	120	200	
برتقال أو صنطرة (يوسف أفندي) أو جريب فروت	Orange or tangerine or grapefruit	45	85	170	
فراولة أو كرز أو ثمرة العليق أو توت	Strawberries or Cherries or Blackberries or Blueberries	45	80	160	
أناناس	Pineapple	55	110	165	
رمان	Pomegranate	100	200	400	
عنب	Grapes	25 (5 pieces)	45 (9 pieces)	110 (18 pieces)	
كيوي	Kiwi	35	70	140	
برقوق أو خوخ أو مشمش أو تين طازج	Plum or peach or apricot or fig	33	66	135	
مانجو	Mango	120	207	330	
بطيخ أو شمام	Watermelon or melon	76	152	304	
سلطة فواكه	Fruit salad	60	120	240	
تمر أو رطب	Dates	27	36	56	
مشروبات	**Beverages**				
مشروبات غازية محلاة (مثال بيبسي أو كوكا كولا، بما في ذلك مشروب ماونتن ديو)	Soft drinks (Sweetened) (e.g., Pepsi, Coca Cola, including Mountain Dew)	150	355	710	
مشروبات غازية "دايت/لايت" (مثال بيبسي أو كوكا كولا)	Soft drinks (diet, light) (e.g., Pepsi, Coca Cola)	150	355	710	
عصير الفاكهة الطبيعية بنسبة 100% (بدون سكر مضاف	Fruit juice (no added sugar), 100% juice	200	300	600	
عصير الفواكه من المركزات، مثال كوكتيل فواكه (مع سكر مضاف)	Fruit cocktail (with added sugar)	200	300	600	
مشروبات الطاقة، مثال ريد بول	Energy Drinks, e.g. Red Bull	250	355	710	
ميلك شيك أو سموثي؛ (مثال ميلك شيك (الافوكادو	Milk shakes or smoothies, (e.g.,	180	250	350	

	Avocado milk shake)				
شراب بنكهة الفاكهة (مثال التانغ، فيمتو، (كابري سن	Fruit-Flavored drink (e.g., Tang, Vimto, Capri-Sun)	12.5	25	37	
الحلوى والوجبات الخفيفة	**Sweets and other Snacks**				
أم علي	Um Ali	120	240	360	
كنافة بالجبنة أو بالكريمة	Kunafah (cheese or cream)	43	86	172	
بلاليط	Balaleet	60	130	190	
لقيمات	Lgeimat	26	52	78	
قرص، مثال قرص مفروك	Qurs	50	100	200	
حلوى عمانية	Omani Halwa	32	64	128	
رهش، حلوى	Rahash, Halwa	15	45	75	
بقلاوة	Baklava	18	36	54	
معمول التمر	Maamoul date cookies	30	60	120	
كريم كراميل أو كسترد أو مهلبية	Crème Caramel, Custard, Pudding, Farni	50	100	200	
بسكويت أو كوكيز؛ مثال دايجستف)	Biscuits or cookies (e.g., Digestive)	15	30	60	
الكعكة الإسفنجية أو الكب كيك أو البانكيك	Sponge cake or cupcakes, or Pancakes	25	50	75	
دونات	Donuts	35	70	140	
الكرواسون (زعتر أو جبن أو شوكولاته)، أو لفات القرفة أو الجبن، أو التارتولات بالكريمة أو الفواكه	Croissants (e.g., Zaatar, Cheese, chocolate), Cinnamon rolls, Danish Pastries	55	110	220	
كيكة بالكريمة	Cream cake	33	65	130	
أصابع الشوكولاتة (مثال من باتشي، مارس أو سنيكيرز)، أو سكاكر أو حلوى الكراميل	Chocolate bars (Snickers, Mars..) or hard candies or caramel candy	18	51	102	
ايس كريم	Ice Cream	30	90	150	
بطاطس شيبس	Potato Chips	15	25	50	

بذور دوار الشمس المحمص أو بذور القرع المحمص	Salted Sunflower or Pimpkin Seeds	8	15	30	
مكسَّرات مشكَّلة	Mixed Nuts	21	42	84	
فشار	Pop Corn	11	22	33	

AE-FFQ PART 2

على مدار الشهر الماضي في المتوسط ، كم مرة تناولت الأطعمة التالية؟

Over the last 1 month, on average, how often did you eat the following foods?

الأذواق الغذائية	**Food Preferences**	**Never or less than once a month**	**1-3 times /month**	**1-5 times /week**	**Daily**
منتجات الألبان القليلة والمنزوعة الدسم (مثال: حليب، جبن، لبنة	Low fat or skimmed dairy products as in milk, cheese, labneh				
الخضروات (لا تشمل البطاطا او الورقيات)	Vegetables, Not including potato or green leaves.				
خضار ورقية خضراء (خص، جرجير، (...بربير، رويد، سبانخ، بقول	Green leafy vegetables (lettuce, watercress, Radish leaves...)				
الفواكه ومنتجات الفواكه (لا تشمل عصير (الفاكهة	Fruits, not including fruit juices				
الأسماك و منتجات الأسماك	Fish and Fish products				
أطباق أو منتجات اللحوم (بما في ذلك (المرتديلا، النقانـق، اللّحـم المقـدد	Meat, meat dishes and products, (including mortadella, sausages, cured meat)				
أطباق أو منتجات الدجاج أو الديك الرومي	Chicken or turkey, chicken dishes and products, (Including salami, sausages)				
عصائر الفاكهة والمشروبات الغازية المحلاة	Fruit juices and Sugary sweetened beverages				

عادات الأكل الشهرية	Monthly food habits	Never or less than once a month	1-3 times /month	1-5 times /week	Daily
كم مرّة أكلت الوجبات في مطاعم الوجبات السريعة ؟ (مثل الشوارما أو الهمبرجر أو (البيتزا	How often did you eat at a fast food restaurant? (e.g., Shawarma or Hamburger or Pizza)				
كم مرة أكلت الأطعمة المقليَّة (بالبيت أو خارج البيت)؟	How many times did you eat fried foods, inside or outside the house?				
كم مرة استهلكت الشحوم الموجودة على اللحوم أو جلد الدجاج؟	How many times did you eat the fat around meat or chicken?				
كم عدد المرات التي استخدمت فيه مكعبات المرق أثناء، مثال مكعبات ماجي	How many times did you use stock, such as Maggie Stock?				
الدهون المستخدمة في الطبخ	**Fats used in Cooking**	**Never or less than once a month**	**1-3 times /month**	**1-5 times /week**	**Daily**
زيت نباتي (مثال زيت الذرة أو نوار الشمس)	Cooking oil, e.g., Corn or Sunflower oil				
الزّيتون زيت	Olive oil				
سمن	Ghee				
زبدة	Butter				
عادات الأكل: خلال يوم عادي	**Foods consumed daily**	**Small PS**	**Medium PS**	**Large PS**	Never or Less than once a day to 6 times per day
ماء	Water	250	250	250	

سكر (المضاف للشاي كرك، القهوة، الشاي (الأحمر	Added Sugar (Added to Karak tea, Coffee, Red tea)	4.2	8.4	12.6	
حليب مبخر أو مكثف، مثال أبو قوس (المضاف للشاي كرك، القهوة، الشاي (الأحمر	Evaporated milk (Added to Karak Tea, coffee, Red tea)	7	14	28	
ملح (المضاف عند الأكل	Salt added at the table	0.5	1	2	

Dietary Supplements use

المكملات الغذائية	**Vitamins and Supplements**	**Measurement Unit** (Pill / capsule/mg/IU/ µg/teaspoon/ml)	**Dosage quantity**	**Commercial brand**	Never or less than once /month	1-3 times / month	Once /week	2-4 times/ week	5-6 times/ week	1 time /day	2-3 times /day	5-4 times /day
الفيتامينات والمعادن المتعددة	Multivitamins and minerals											
فيتامين د	Vitamin D											
حمض الفوليك	Folic Acid											
مركب فيتامينات ب	Vitamin B complex											
فيتامين "ج	Vitamin C											
الكالسيوم	Calcium											
حديد	Iron											
مكملات زيت السمك، أوميغا ?	Omega 3, fish oil											
خر، يرجى التحديد	Other, please specify											
آخر، : يرجى التحديد	Other, please specify											

Appendix 4: Ethical Approval

AAMD • HREC | AL AIN MEDICAL DISTRICT-HUMAN RESEARCH ETHICS COMMITTEE
HREC ADMINISTRATION: hrec.uaeu@uaeu.ac.ae

13th April, 2017 Ref: SS/fa/17-06

Dr Najoua El Mesmoudi
Nutrition and Health Department
CFA
UAEU

Dear Dr El Mesmoudi

Re: Ethics Application PhD Thesis Najoua ID 201390012 *ERH-2017-5504 17-06*

Thank you for submitting your application to the Ethics Committee. The application has been reviewed by Al Ain Medical District Human Research Ethics Committee (AAMDHREC) and I am pleased to provide you ethical approval of your project.

The AAMDHREC is an approved organization of Federal Wide Assurance (FWA) and compliant with ICH/GCP standards.

The Committee must be informed if there is deviation from the approval protocol or if you have any other concerns.

Annual reports plus a terminal report are necessary and the Committee would appreciate receiving copies of abstracts and publications should they arise.

I wish you success with this important study.

With kind regards,

Yours sincerely,

UAEU SEHA AAMDHREC

Dr. Syed Shah
Chair, Al Ain Medical District Human Research Ethics Committee

جامعة الإمارات العربية المتحدة United Arab Emirates University | UAEU College of Medicine and Health Sciences | SEHA صحة

Appendix 5: Participant information sheet for photographs pre-testing

UAEU
جامعة الإمارات العربية المتحدة
United Arab Emirates University

Participant information sheet

Title of the study: Pre-testing of food photographs for the estimation of food portion sizes for an online Food Frequency Questionnaire for use in the UAE

Dear Participant:

You are being invited to take part in the above-named pre-testing study. Before you decide to take part in the study, it is important that you understand why this research is being conducted and what it will involve. Please take time to read the following information carefully.

Ask us if there is anything that is not clear of if you would like to get more information. Take your time to decide whether or not you wish to take part.

Topic of the research, the investigation and the location:

This study is carried out as part of a research project aiming at developing and validating an online Food Frequency Questionnaire (FFQ) for the Emirati Adult population.

In order to quantify the food items listed in our FFQ, we have developed for each food item a set of 3 pictures depicting small, medium and large portions sizes.

The purpose of this study is to assess the ability of the food images used as aids in the online FFQ in estimating the actual amount of food servings.

The location of the interviews will be outside the restaurant at the College of Medicine, where most faculty and students have their lunch.

The study will be conducted by Najoua El Mesmoudi, PhD. Candidate at the department of Nutrition and Health, College of Food and Agriculture, United Arab Emirates University.

What is expected from you:

- You will be given this information sheet that you will be asked to read and a consent form that you will be asked to sign if you do decide to take part in this study. You will be presented with a total of 20 plates of food servings.
- You will be asked to estimate if, in your opinion, the food on the plate represents a smaller, ideal, or a larger portion size for you.
- You will be asked to compare the food serving presented on the plate with the portions displayed on the laptop.

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- You will be given an answer form where you are kindly asked to record the estimated portion of food in the plate, in your opinion, and as compared to the series of the 3 images of the corresponding food items. There will be a total of 20 plates to assess.

Benefits of the study:

Pre-testing of the food images for use in the online FFQ is an important step for estimating current portions, thus reducing reporting bias in dietary assessment tools and improving the accuracy of dietary surveys.

Risks of the study

There are no known risks associated with this study because it only requires comparing plats of food to food images on the computer.

Confidentiality:

Your responses will be treated anonymously and utmost privacy will be maintained. Any information about you will not have your name on it so that you cannot be recognized from it. Any report that will be prepared form this study will not identify you.

Freedom to withdraw:

You are free to decided not to answer any question at any point of the study or to withdraw at any time without providing any justifications.

For more information and to ask questions:

If you need more information or have questions about this study, please contant the principal investigator, Najoua El Mesmoudi at this number: 050 98 39 174 or by email at 201390012@uaeu.ac.ae.

Thank you for your time

Najoua El Mesmoudi
Department of Nutrition and Health
College of Food and Agriculture
United Arab Emirates University.

Appendix 6: Participant Consent form for photographs pre-testing

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Consent Form

Title of the study: Pre-testing of food photographs for the estimation of food portion sizes for an online Food Frequency Questionnaire for use in the UAE

1. I confirm that I have read and understood the above information sheet and have had the opportunity to ask questions.
2. I understand that my participation is voluntary and that I am free to withdraw.
3. I understand that my data will be kept confidential and if published, the data will not be identified as mine.

I agree to take part of this study.

____________________________________ __________

(Name and signature of the participant) (Date)

____________________________________ __________

(Name and signature of the person taking consent) (Date)

Appendix 7: Demographic questionnaire for photographs pre-testing

المفتاح الشخصـــــي

☐☐☐☐☐☐☐☐☐☐

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D Number#

Date:__________

Demographic Questionnaire

استبيان ديموغرافي

Study Title: Pre-testing of Food photographs for the estimation of food portion sizes for an online Food Frequency Questionnaire for the UAE population

عنوان ابحث التحقق من صور طعام لتقدير حصص الغذاء في استبيان تكرار الطعام لمواطني الإمارات العربية المتحدة

Please answer the following questions by ticking the correct box with an X, thank you.

الرجاء وضع علامة X على الجواب الصحيح، مع الشكر

1. What is your age? كم هو عمرك؟	
18 -25	
26-40	
41-55	
56 or older أكبر من 56	

2. I am a أنا	
Female أنثى	

المفتاح الشخصـــــي

□□□□□□□□□□

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D Number#

Male ذكر	

3. **What is the highest degree or level of school you have completed?** **ما هي أعلى شهادة حصلت عليها؟**	
Less than high school أقل من الثانوية العامة	
High school graduate or diploma الثانوية أو دبلوم	
Some college credit, no degree بعض المرحلة الجامعية	
Undergraduate degree جامعي	
Graduate degree دراسات عليا	

Appendix 8: Answer sheet for photographs pre-testing

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ANSWER FORM

Pre-testing of food photographs for the estimation of food portion sizes in an Online Food Frequency Questionnaire

Participant Code#

Start Here!

TABLE WITH PLATES OF FOOD number:

20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	Plate#
																				My Estimation (S/M/L)
																				Smaller than ideal
																				Ideal/Normal portion
																				Larger than ideal

Appendix 9: Information sheet for the validation study (in Arabic)

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نموذج معلومات المشاركين

عنوان البحث: تطوير استبيان تكرار الطعام لمواطني الإمارات والتحقق من صحته

السلام عليكم ورحمة الله وبركاته...

عزيزي المشارك،

نود منك أن تشاركنا في الدراسة البحثية المذكورة اعلاه. سيطلب منك المشاركة في الدراسة لأنك مواطن أو مواطنة إماراتي(ة) تعيش في مدينة العين، وعمرك يتراوح بين 18 و 70 سنة.

قبل أن تبادر بإعطاء موافقتك التطوعية من المهم أن تعلم ما هي أهداف إجراء البحث وماذا سينطوي عليه.

يرجى أخذ الوقت الكافي لقراءة المعلومات التالية بعناية. ولا تتردد في طلب التوضيح إذا كان هناك أي شيء غير واضح أو إذا كنت ترغب في المزيد من المعلومات.

هدف الدراسة ، الباحث وموقع الدراسة:

إن الهدف من هذا البحث هو تقييم المدخول الغذائي لدى مواطني دولة الإمارات لدراسة العلاقة بين النظام الغذائي الخاص بالمواطنين البالغين والأمراض المزمنة. تحقيقا لهذه الغاية، ستقوم الباحثة بمقابلتك لتتعرف على نظامك الغذائي المعتاد. ويمكنك اختيار المكان المناسب لك لإجراء المقابلات.

وسيشرف على هذه الدراسة نجوى المصمودي، طالبة دكتوراه بقسم التغذية والصحة، جامعة الإمارات العربية المتحدة.

ما يتوجب عليكم القيام به:

إذا قررت أن تشارك فسوف يتم منحك ورقة معلومات المشاركين هذه و نموذج الموافقة للمشاركة في البحث العلمي للاطلاع والتوقيع عليها.

كما سوف يطلب منك إجراء ٤ مقابلات مع الباحثة. ومع ذلك فإنك لا تزال تتمتع بكامل الحرية في حالة اخترت الانسحاب من الدراسة في أي وقت ودون إبداء أي سبب.

عدد المقابلات المطلوبة ومكانها:

إذا قررت المشاركة في الدراسة، فسوف يطلب منك إجراء ٤ مقابلات مع الباحثة، موزعة على شهر واحد كالتالي:

خلال المقابلة الأولى، سوف يطلب منك ملء الاستبيان الديموغرافي للتعرف على سنك وجنسك ومستواك الدراسي. كما ستقوم الباحثة بقياس وزنك وطولك.

في كل من 3 مقابلات، سوف تطلب منك الباحثة ذكر الأطعمة التي تناولتها خلال الأربع والعشرين ساعة السابقة.

بعد هذه المقابلات الثلاث، ستلتقي بك الباحثة لآخر مرة لتطلب منك ملء استبيان الطعام المتكون من لائحة من الأطعمة الأكثر استهلاكا.

إكمال المقابلة الواحدة سوف يستغرق حوالي ٢٠ ـ ٣٠ دقيقة وإكمال المعلومات بالاستبيان سوف يستغرق حوالي ٣٠ دقيقة.

سوف تجرى كل المقابلات في مكان مناسب لك.

التقدير للمشاركة في الدراسة:

لن تحصل على أي مردود مالي مقابل مشاركتك في الدراسة، لكن سيتم منحك شهادة تقديراً لمشاركتك في هذه الدراسة.

فوائد الدراسة:

من خلال مشاركتك في هذه الدراسة سوف تساعد العلوم على فهم العلاقة بين النظام الغذائي الخاص بمواطني دولة الإمارات البالغين والأمراض المزمنة.

التأثيرات السلبية:

ليس هنالك أي تأثيرات سلبية نتيجة لهذه الدراسة، حيث لن تتطلب من المشاركين سوى المشاركة بالمقابلات. و تتمتع بكامل الحرية في حالة اخترت عدم الإجابة أي من الأسئلة.

السرّية:

في حال وافقت على المشاركة في هذه الدراسة، تتعهد الباحثة أن جميع المعلومات التي سوف يتم جمعها عنك خلال هذا البحث سيتم الاحتفاظ بها بسرية تامة. سيتم التعامل مع كافة البيانات المقدمة من قبلك بشكل مجهول وسيتم الحفاظ عليها بخصوصية تامة. بيانات البحث لن تحمل اسمك بحيث لا يمكن التعرف عليك من خلالها.

حق الإنسحاب:

لا يفوتني أن أنوه أنه في أي نقطة معينة في الدراسة يحق لك رفض الإجابة عن أي سؤال معين أو التوقف عن المشاركة تماماً حيث أنه من حقك الانسحاب من البحث في أي وقت ودون إبداء أسباب.

اسئلة واستفسارات:

اذا كنت بحاجة إلى المزيد من المعلومات أو لديك أسئلة حول هذه الدراسة ، يرجى الاتصال بي على هذا الرقم :174 38 98 050 أو عن البريد الإلكتروني:201390012@uaeu.ac.ae

ولكم فائق الشكر والتقدير

نجوى المصمودي
قسم التغذية والصحة
جامعة الإمارت العربية المتحدة

Appendix 10: Consent form for the validation study (in Arabic)

نموذج الموافقة

عنوان البحث: تطوير استبيان تكرار الطعام لمواطني الإمارات والتحقق من صحته

1. أقر بأنني قد قرأت وفهمت ورقة المعلومات هذه والخاصة بالدراسة المذكورة أعلاه، ولقد تمت إتاحة الفرصة لي لطرح الأسئلة
2. وأنا أفهم أن المشاركة في الدراسة طوعية وأنني حر في الإنسحاب منها وقتما أشاء.
3. وأنا أفهم أن البيانات الخاصة بي سيتم الحفاظ على سريتها وفي مكان آمن.

وعليه أوافق على المشاركة في البحث المشار إليه أعلاه:

اسم وتوقيع المشارك	التاريخ

اسم وتوقيع الشخص مستلم الموافقة	التاريخ

Appendix 11: Information sheet for the validation study (in English)

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Participant information sheet

Title of the Study: Development and validation of a Quantitative Food Frequency Questionnaire for the UAE population

Dear Participant:

You are being invited to take part in the above-named research project if you are an Emirati National, living in Al-Ain, and your age is between 18 and 70 years old.
Before you decide to take part of the study, it is important for you to understand why this research is being conducted and what it will involve. Please take time to read the following information carefully.
Ask us if there is anything that is not clear or if you would like to get more information. Take your time to decide whether or not you wish to take part.

Topic of the research, the investigator(s) and the location:

The purpose of the study is to investigate the relationship between diet and chronic diseases specifically for UAE nationals. To this end, participants will be interviewed by the investigator about their usual diet. The location of the interviews will be any chosen location that is convenient to the participant.
The study will be conducted by Najoua El Mesmoudi, PhD candidate at the department of Nutrition and Health, College of Food and Agriculture, United Arab Emirates University.

What is expected from you:

You will be given this Information sheet that you will be asked to read and a consent form that you will be asked to sign if you do decide to take part in this study.
You will also be asked to have 4 different meetings with the investigator. However, you will be still free to withdraw from the study at any time and without giving a reason.

Number of meetings and their location:

If you decide to participate in the study, you will be asked to meet 4 times with the investigator, over a one month period. The meetings will be as follows:

- During the first meeting, the investigator will start by asking you to fill a demographic questionnaire, where you will be asked about your age, gender and your highest level of education. The investigator will also measure your weight and your height.
- In the first meeting and the following 2 meetings (a total of 3 meetings), the investigator will conduct an interview with you, where you will be asked to provide information about the food you consumed during the past 24 hours.

- After these 3 interviews, the investigator will meet with you a 4th and last time and ask you to complete a food questionnaire that asks you to report how often you consumed a list of foods over the last month.
- Each interview will take about 20 to 30 minutes to complete, and the questionnaire will take about 30 minutes to complete.
- All meetings will be held in a place that is convenient to you.

Compensation for the participation in the study:

There is no financial compensation for your participation in this study. However, we will provide you with a certificate of appreciation to thank you for your participation.

Benefits of the study:

The information obtained during this study will help assess the relationship between diet and chronic diseases specifically for UAE nationals and the dietary changes that the country is undergoing.

Risks of the study:

There are no known risks associated with this study as it only requires interviews. If you do not feel comfortable answering some of the questions, you are always free to not answer a question, or to discontinue your participation at any time.

Confidentiality:

Your responses will be treated anonymously and utmost privacy will be maintained. Any information about you will not have your name on it so that you cannot be recognized from it. Any report that will be prepared from this study will not identify you.

Freedom to Withdrawal:

You are free to decide not to answer any question at any point of the study or to withdraw at any time without providing any justifications.

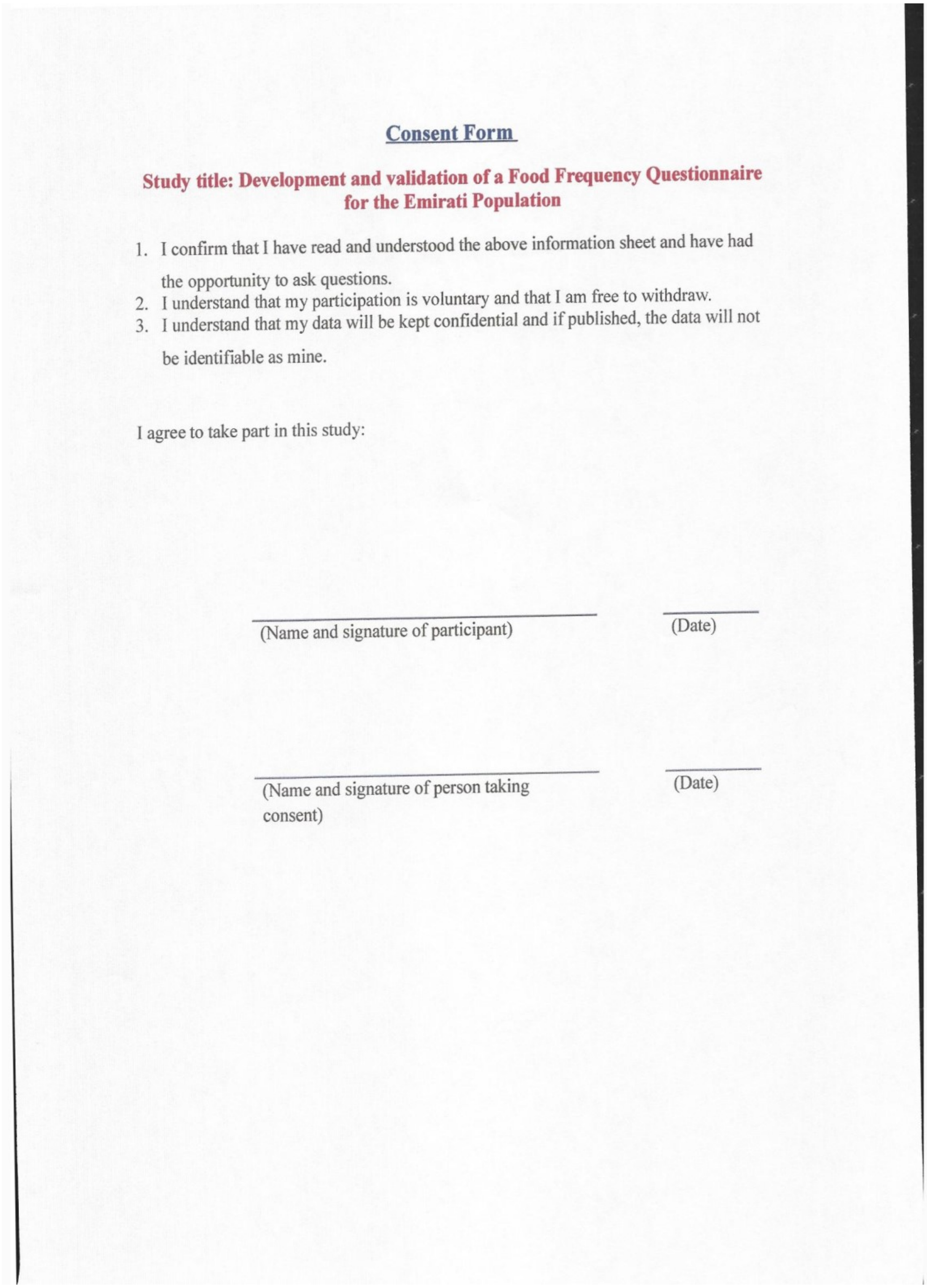
For more information and to ask Questions:

If you need more information or have questions about this study, please contact the principal investigator, Najoua El Mesmoudi at this number: 050 98 38 174 or by email at 201390012@uaeu.ac.ae.

Thank you for your time,

Najoua El Mesmoudi
Department of Nutrition and Health
College of Food and Agriculture
United Arab Emirates University

Appendix 12: Consent form for the validation study (in English)



Consent Form

Study title: Development and validation of a Food Frequency Questionnaire for the Emirati Population

1. I confirm that I have read and understood the above information sheet and have had the opportunity to ask questions.
2. I understand that my participation is voluntary and that I am free to withdraw.
3. I understand that my data will be kept confidential and if published, the data will not be identifiable as mine.

I agree to take part in this study:

(Name and signature of participant) (Date)

(Name and signature of person taking consent) (Date)

Appendix 13: Demographic questionnaire for the validation study (in Arabic and English)

المفتاح الشخصـــــي

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United Arab Emirates University

D Number#

Date:_________

Demographic Questionnaire

استبيان ديموغرافي

Study Title: Development and Validation of a Quantitative Food Frequency Questionnaire for the UAE population

عنوان البحث: تطوير استبيان تكرار الطعام لمواطني الإمارات والتحقق من صحته

Please answer the following questions by ticking the correct box with an X, thank you.

الرجاء وضع علامة X على الجواب الصحيح، مع الشكر

1. What is your age? كم هو عمرك؟	
18 -25	
26-40	
41-55	
56 or older أكبر من 56	

2. I am a أنا	
Female أنثى	
Male ذكر	

المفتاح الشخصـــــي

□□□□□□□□□□

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D Number#

3. What is the highest degree or level of school you have completed? ما هي أعلى شهادة حصلت عليها؟	
Less than high school أقل من الثانوية العامة	
High school graduate or diploma الثانوية أو دبلوم	
Some college credit, no degree بعض المرحلة الجامعية	
Undergraduate degree جامعي	
Graduate degree دراسات عليا	

4. Answer this question only if you are a student. (Please skip this question and go directly to question #5 otherwise). اجب على السؤال التالي فقط إن كنت طالبا. (في حال أنك لست طالبا، الرجاء تخطي هذا السؤال و التوجه للسؤال 5)	
If you are currently a student; During the week, do you live at the hostel or at home? إذا كنت طالبا حالياً، هل تعيش في المنزل أو في سكن الجامعة؟	
At Home بالمنزل	
At the University Campus بالسكن الجامعي	

5. Do you have any condition that made you change your eating habits:	

المفتاح الشخصـــــي

□□□□□□□□□□□

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United Arab Emirates University

D Number#

هل تعاني من أي مرض يجعلك تغيير عاداتك الغذائية؟	
Yes نعم	
No لا	

6. Did your weight change during the last 3 months? هل تغير وزنك خلال الثلاث أشهر الماضية؟	
Yes نعم	
No لا	

Appendix 14: Example of recipe calculation performed on the Excel™ sheet matrix (Ma'amoul cookie)

Food:	Ma'amoul cookie
Method:	Calculation WITH retention factors

Step 1: Make a list of input

Step 2: Fill in amount of

Step 5: Collect data about nutrient content of input ingredients per 100 g from a FCBD (e.g. USDA SR DB)

Step 6: Calculate the value of each nutrient per 100 g cooked food. Nutrient content per 100 g ingredient * Raw weight of ingredient (g) /Total cooked weight (g)

Step 7: Collect data about retention factors for vitamins and minerals, considering the involved cooking procedure. Notice: 1.For this recipe, the cooking procedure is to: "FLOUR/MEAL,BAKE" 2.Retention factors are based USDA Table of Nutrient Retention Factors, Release 6

List of ingredients (Best food match from a FCDB*)	Original weight of ingredients as in recipe	Measurements**	Weight of ingredients	Protein (PROT): PROT in Raw ingredients	PROT in Raw ingredients per 100	PROT in cooked ingredients per 100	Saturated fat (FASAT): FASAT in Raw ingredients	FASAT in Raw ingredients per 100	FATSAT in cooked ingredients per 100	Vitamin A: Vit A (RAE) in Raw ingredients	Vit A (RAE) in Raw ingredients per 100	Vit A (RAE) in cooked ingredients per 100	RF for Vit A (RAE)	Vit A (RAE) in cooked ingredients after RF per 100
			g	g	g	g	g	g	g	mcg	mcg	mcg	-	mcg
Flour, All Purpose Wheat, White, Unenriched	1.50	c.	187.50	19.37	10.33	2.12	0.29	0.16	0.03	0.00	0.00	0.00	0.90	0.00
Butter, Unsalted	1.00	c.	227.20	1.93	0.85	0.21	114.71	50.49	12.58	1554.05	684.00	170.49	1.00	170.49
Sugar, White Granulated	0.50	c.	100.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Baking Powder, Double Acting with	1.00	t.	4.60	0.01	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Dates, Medjool	225.00	g	225.00	4.07	1.81	0.45	0.17	0.08	0.02	15.75	7.00	1.73	0.85	1.47
Butter, Unsalted	1.00	T.	14.20	0.12	0.85	0.01	7.17	50.49	0.79	97.13	684.00	10.66	1.00	10.66
Flour, Semolina	251.00	g	251.00	31.83	12.68	3.49	0.38	0.15	0.04	0.00	0.00	0.00	1.00	0.00
Salt, Table	0.50	t.	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Vanilla Sugar	3.00	g	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Milk, Whole 3.3%	0.50	c.	122.00	3.84	3.15	0.42	2.28	1.86	0.25	56.12	46.00	6.16	1.00	6.16
Cardamon, Ground	0.25	t.	0.50	0.05	10.80	0.01	0.00	0.60	0.00	0.00	0.00	0.00	1.00	0.00
Cinnamon, Ground	0.25	t.	0.58	0.02	4.00	0.00	0.00	0.35	0.00	0.09	14.96	0.01	1.00	0.01
Raw weight (g)			1139.38	61.25	44.58	6.72	125.00	104.17	13.71	1723.13	1435.96	189.04	-	188.78
Raw weight before cooking (g)			1139											
Yield factor			0.80											
Cooked weight (g)			911.5											

* FCDB: Food Composition Database

** Measurements: c. -cup, t. -teaspoon, g.-gram, T.-Tablespoon

Step 3: Determine raw weight. Sum weight of input

Step 4: Determine cooked weight using the appropriate

Step 8: Sum contributions of all ingredients for a selected nutrient in 100 g cooked food.

Step 10: Calculate energy value of cooked food in kcal. kcal (per 100 g): 4*6.719 + 9*22.449 + 4*67.061 = 26.876 + 202.041 + 268.244 = 497.16

Appendix 15: Examples of foods assigned to each of the 31 food groups assessed in the validation study for the AE-FFQ by the three 24HRs

Food group	Examples of foods assigned from the AE-FFQ or the three 24HRs to the 31 food groups.
Dairy drinks	Milk, Buttermilk, Laban up
Cheeses hard and spreadable	Cheddar, Mozzarella, Feta, Halloumi, Akkawi cheese, Labneh, triangle cheese, Kiri™
Yogurts	Plain and fruit yogurts
Rice and rice dishes	White rice, Biryani rice, Mandi rice, Machbous rice, rice from Sushi, Maqluba rice, rice in stuffed vegetables
Pasta and other cereal dishes (Oats)	Pasta dishes, lasagna, pasta with bechamel
White breads	Samoon bread, sliced bread, Rgag, paratha, buns. pizzas
Whole grains breads	Sliced whole grain, brown bread
legumes	Foul, baked beans, Lentils, lentils from Daal, cooked chickpeas, and chickpeas from Hummus
eggs	Egg fried, boiled, and Omelets
Red meat	All meat dishes excluding processed meats and sausages
Meat products	Processed meats; turkey salami or mortadella, sausages, shawarma meat, Beef, or chicken Hot Dog weiner or Frankfurter
Chicken	Chicken from all sources, chicken stewed, braised, with Skin, and without skin, Chicken tikka, roasted, fried, pan-fried, fried with skin, nuggets
Fish and Seafood	Fish and seafood from all sources cooked, baked, or fried, e.g. Red mullet fried, Cod flesh fried in batter, grilled seabass, grilled seabream, grilled Salmon, Mackerel, Tuna, Canned Tuna, Shrimp grilled, cooked or fried
Vegetables total	Vegetables from all sources, including from stews (Salona, Margoga, Thareed), in rice, or pasta dishes, sandwiches, and salads
Green leafy vegetables	Lettuce, Arugula, parsley from salads
Cruciferous vegetables	Cabbage, Broccoli, and cauliflower from mixed dishes
Red or yellow vegetables	Tomatoes, sweet potatoes, carrots cooked, and raw, pumpkin from any dish
Potatoes	From salads and mixed dishes, French fries not included
Other vegetables	All other vegetables not included in the above categories, e.g. Cucumber, eggplant, green beans, okra, peas, mushrooms etc.
Savory snacks	Fatayer, Pies, falafel, samosa, croissants, plain or with different fillings (cheese, thyme, or spinach)
Fruits	All fruits
Dried fruits	Dates and other dried fruits
Soft drinks, Including Energy Drinks	All soft drinks and energy drinks containing added sugar
Diet soft drinks	All soft drinks and energy drinks not containing added sugar
Fruit juices including smoothies	All commercial and fresh juices and smoothies (e.g. avocado smoothie)

sugar, syrups, jams, molasses, honey	Sugar or syrups added to beverages, jams, date molasses, and honey
French fries	French fries only
Sweet snacks	Biscuits (Oreo™, Digestive™, tea biscuit), cakes, muffins, doughnuts (glazed and plain), fruit pies, including Arabic sweets)
Sweets, candies, and chocolates	Candies, milk, and dark chocolates, chocolate bars
Chips	Potato chips and corn chips
Nuts and seeds	Mixed nuts, with, or without added Salt Added and pumpkin seeds

Foods groups in green depict foods evidenced as having protective effects in relation to NCDs. (Afshin et al., 2019).
Foods groups in red depict foods evidenced as having offensive effects in relation to NCDs (Afshin et al., 2019).
24HR = 24-hour dietary recall; AE-FFQ = Adult Emirati food frequency questionnaire.

Appendix 16: Secondary analysis

Comparison of energy and nutrient intakes using the AE-FFQ and three 24HRs based on Spearman correlations (n = 60).

Energy or nutrient	Spearman Correlation (Crude)	P-Value
Energy (kcal)	0.56	0.004
Carbohydrate (g)	0.54	0.002
Protein (g)	0.51	0.002
Fat (g)	0.43	0.015
Cholesterol (g)	0.45	0.004
SFA (g)	0.32	0.094
MUFA (g)	0.41	0.019
PUFA (g)	0.48	0.011
Sodium (mg)	0.50	0.000
Vitamin C (mg)	0.40	0.001
Calcium (mg)	0.43	0.026
Iron (mg)	0.12	0.512
Vitamin D (mcg)	0.20	0.186
Vitamin E (mg)	0.48	0.484
Thiamine (mg)	0.28	0.045
Riboflavin (mg)	0.33	0.228
Pyrodoxin (mg)	0.42	0.002
Folate (mcg)	0.37	0.001
Vitamin B12 (mcg)	0.30	0.175
Dietary Fiber (g)	0.48	0.011
Sugar, Total (g)	0.58	0.008
Vitamin A (mcg)	0.13	0.271
Median	0.43	--

24HR = 24-hour dietary recall; AE-FFQ = Adult Emirati food frequency questionnaire; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; SFA = saturated fatty acids.