Nutrient intakes, compliance with recommendations and key sources in women of child-bearing age (18-50y) in Ireland

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Declaration

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork, Munster Technological University or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork and Munster Technological University concerning plagiarism and intellectual property.

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Personal Contribution to this thesis

This thesis is based on data from the National Adult Nutrition Survey (NANS) which was carried out between October 2008 and April 2010. This survey was carried out by the nutrition units in University College Cork (UCC) and University College Dublin (UCD), which form part of the Irish Universities Nutrition Alliance (IUNA). All of the analyses in this thesis were performed by me. The attached work is entirely my own original work.

Contribution to the research group

During the timeframe of this MSc, I worked with the National Dietary Surveys Research Team in UCC and Munster Technological University (MTU). I was involved in the National Teens' Food Survey II (NTFS II) carried out between March 2019 and March 2020 by the nutrition units in UCC, MTU, UCD and Technological University Dublin.

In my role as a fieldworker on this survey, I collected data from participants in the Cork, Kerry and Waterford area including data related to dietary intake, health & lifestyle, eating behaviour, anthropometric measurements and the collection and processing of spot urine samples. Following data collection, I entered the dietary intake data into Nutritics® and the questionnaire data into DaSurvey®. I was also involved in the quality control of these data.

Abigail O'Mahony

Abstract

Background:

Women's pre-conceptional health (including nutritional status) is important for both the health of the individual themselves and also for the lifelong health of any occurring offspring. However, it has been estimated that up to 50% of pregnancies are unplanned, thus optimal nutritional status is important for all women of child-bearing age (WCBA) not just those with pregnancy intentions. Despite the accumulation of evidence of the importance of nutritional status at this life-stage, nutrient recommendations for WCBA for the most part don't differ from recommendations for other population groups. The notable exception to this is that all WCBA are recommended to take a folic acid supplement to reduce the risk of neural tube defects (NTDs) in an occurring pregnancy.

Objectives:

The overall aim of this thesis was to estimate the nutrient intakes among WCBA in Ireland. The first aim was to estimate the mean daily intake of energy, macronutrients, dietary fibre and salt, to determine compliance with dietary guidelines and to identify the key dietary sources of these nutrients in WCBA. A further aim was to estimate the mean daily intake of micronutrients, the prevalence of inadequate intakes and risk of excessive intakes and to identify the key dietary sources of micronutrient intakes in this population group.

Methods:

The analysis for this research was based on data from the subset of WCBA (18-50 years) (*n* 487) in the Irish National Adult Nutrition Survey (NANS) (2008-2010). Food and beverage intakes were estimated using a 4-day semi-weighed food record. Nutrient intakes were estimated using WISP® which uses data from 'McCance and Widdowson's the Composition of Foods', Sixth Edition (plus all nine supplemental volumes). During the NANS, modifications were made to the food composition database to include recipes of composite dishes, fortified foods, nutritional

supplements, generic Irish foods that were commonly consumed and new foods on the market. The mean daily intake (MDI) of energy and nutrients were estimated by summing the total amount of energy and each nutrient consumed and dividing the total by the number of recording days (four) using SPSS® Version 26. Compliance with dietary guidelines was examined for macronutrients, dietary fibre and salt. The prevalence of inadequate micronutrient intakes (%<estimated average requirement (EAR)) was examined (excluding under-reporters for energy intake (31%)) and the risk of excessive intakes (%> upper levels (UL)) was also determined. The percent contribution of specific food groups to mean daily intakes of energy, macro- and micro-nutrients was calculated by the mean proportion method.

Results:

This study found that that while protein intakes are sufficient among WCBA in Ireland, a large proportion of this population have total fat intakes above recommendations (42%) and carbohydrate intakes below recommendations (59%). This population group also have high intakes of saturated fat (13% of total energy (%TE)), free sugar (9%TE) and salt (5.5g/d from food sources only) and low intakes of dietary fibre (17g/d). Important sources of energy in the diet were 'cereal & cereal products' (including potatoes) 'meat, fish & eggs' and 'dairy & dairy products' which when combined contributed over two-thirds of energy intake on average. However 'top-shelf' foods (i.e. 'sugars, confectionery, preserves & savoury snacks', 'biscuits, cakes & pastries' and 'sugar-sweetened beverages') also contributed a high proportion of energy intake (21%) in addition to contributing significantly to intakes of fat (15%), saturated fat (16%) and free sugars (59%). This population group also have high intakes of saturated fat (13% of total energy (%TE)), free sugar (9%TE) and salt (5.5g/d from food sources only) and low intakes of dietary fibre (17g/d). With regard to micronutrients, significant proportions of WCBA have inadequate intakes of vitamin D (93%), vitamin C (48%), calcium (41%), folate (32%), iodine (26%), riboflavin (25%), vitamin A (18%), magnesium (18%) and iron (10%). There was little risk of excessive intakes of micronutrients among WCBA with negligible proportions (<3%) of this population having intakes of vitamin B6 and iron greater than the UL.

Important sources of vitamins and minerals were milk and milk products, meats, breads and cereals, especially fortified breakfast cereals, and fruits and vegetables.

Conclusions:

In summary, this study has found unfavourable intakes of total and saturated fat, carbohydrate, sugar, salt and dietary fibre together with low intakes of key micronutrients in WCBA in Ireland. The data presented in this study will have important implications for public health guidance for this vulnerable population group. Furthermore, information about the relative contributions of specific foods to nutrient intakes will be useful to both policy makers and the food industry to develop targeted dietary strategies to improve the diets of WCBA in Ireland.

List of Abbreviations

AI	Adequate Intake
BW	Body Weight
BMR	Basal Metabolic Rate
CVD	Cardiovascular Disease
DFE	Dietary Folate Equivalents
DNFCS	Dutch National Food Consumption Survey
DoH	Department of Health
DRV	Dietary Reference Values
EAR	Estimated Average Requirement
EFSA	European Food Safety Authority
FNB	Food and Nutrition Board
FSAI	Food Safety Authority of Ireland
HDL	High-Density Lipoprotein
IOM	Institute of Medicine
IUNA	Irish Universities Nutrition Alliance
LDL	Low-Density Lipoprotein
MDI	Mean Daily Intake
MUFA	Monounsaturated Fatty Acids
NANS	National Adult Nutrition Survey
NNR	Nordic Nutrition Recommendations
PUFA	Polyunsaturated Fatty Acids
RI	Reference Intake
RNI	Reference Nutrient Intake

SACN	Scientific Advisory Committee on Nutrition
TE	Total Energy
UCC	University College Cork
UCD	University College Dublin
UI	Urinary Iodine
UL/TUL	Tolerable Upper Intake Level
URs	Under-reporters
UU	Ulster University
WHO	World Health Organization
WCBA	Women of Child-Bearing Age

Chapter 1

Literature Review

Introduction

It is well established that preconceptional health (including nutritional status) is critically important with regard to favourable maternal and infant outcomes in both the short- and long-term. It has been estimated that up to 50% of pregnancies are unplanned, thus optimal nutritional status is important for all women of child-bearing age (WCBA) not just those with pregnancy intentions (Sedgh et al., 2014). While women can technically become pregnant and bear children at any time through their fertility years (from the start of menstruation to menopause when menstrual periods end), the World Health Organisation (WHO) reports statistics for WCBA as those between 15-49 years of age and most studies that report on WCBA as a sub-group include women from 18-50 years of age (or similar age-range) (World Health Organisation, 2015).

Consuming a varied and balanced diet during these critical years is crucial for the current and future wellbeing of the woman and also for the wellbeing of any children that she may bear. Notwithstanding the negative impact of nutrient imbalances on health outcomes of the individual which are well documented in the literature, micronutrient deficiencies in particular can adversely affect fertility, pregnancy outcomes, and risk of congenital disabilities in an occurring pregnancy (Gómez et al., 2020, Rai et al., 2015).

Despite the accumulation of evidence of the importance of nutritional status at this life-stage, nutrient recommendations for WCBA have not been differentiated by pregnancy intention and for the most part don’t differ from recommendations for other population groups (EFSA Panel on Dietetic Products and Allergies, 2010). It is important to understand the current dietary intake of WCBA to identify if there are gaps with regard to current recommendations and also to have a body of sound scientific evidence if more population specific recommendations are to be made for any nutrient.

Hence, this review aims to investigate the dietary intake and key sources of energy and nutrients in the diets of WCBA in Europe using data from nationally representative nutrition surveys.

Inclusion/exclusion criteria

This review includes dietary intake data from nationally representative food/nutrition surveys which include data on WCBA across Europe. For inclusion in this review, the studies must have been conducted post 2000, dietary intake data collected at an individual level via food records or 24-hour recalls and data must have been published in English. Only studies of adults were included in this review.

Comparison of studies

Data from nationally representative nutrition surveys in 18 European countries are presented in this review. The most up-to-date survey (meeting the inclusion criteria outlined above) with data available for the population group (WCBA) and nutrient of interest was used, for example updated data on energy and salt intakes are available (in English) from the French Individual and National Studies on Food Consumption Survey 3 (INCA3) while other nutrient intake data are reported from INCA2. Across studies, there was a variation in methodologies used (e.g. methods used to collect food intake data, reference cut-off points used to assess nutrient intake/adequacy and age-group cut-offs). Furthermore, for estimation of micronutrient intakes, some countries may underestimate intakes as they do not all account for nutritional supplement use. The literature, studies and reports that were analysed to complete the literature review for this thesis did not contain data in relation to intakes exceeding EFSA ULs, while every effort was made to include a comprehensive set of data, the data looked at as part of this thesis includes all of the data available.

Estimation of nutritional quality of diets

The nutritional quality of the diets of WCBA across Europe was evaluated in this review using the most recent dietary reference values (DRVs) available. Mean nutrient intakes reported in studies were compared to Recommended Intakes (RI), Population Reference Intakes (PRI) or Adequate Intakes (AI) (EFSA Panel on Dietetic Products and Allergies, 2010). The RI is the range of intake for macronutrients (% of energy intake) that is adequate for maintaining health and is associated with a low risk of chronic diseases. The PRI (or Reference Nutrient Intake (RNI)) is the level of (nutrient) intake that is adequate for virtually all people in the population group. The PRI is assumed to meet the requirements of 97.5% of the individuals in the population. The AI is the value estimated when a PRI cannot be established. This is the average observed nutrient intake by a population group of apparently healthy people that is assumed to be adequate. The Estimated Average Requirement (EAR) (the level of nutrient intake estimated to meet the requirements of 50% of individuals) is used to assess the prevalence of inadequate intake in a population group. This review refers to the %<EAR where mentioned within individual studies. For the UK National Diet and Nutrition Survey (NDNS), the Lower Reference Nutrient Intake (LRNI) which is the amount of a nutrient that is enough for only a small proportion of a population who have low requirements (2.5%) was used as a cut off rather than the EAR (Department of Health, 1991)

Table 1 presents a summary of the national nutrition surveys in Europe for which data on intakes and sources of nutrients in WCBA were available (18 countries). Of these, 7 countries collected dietary intake data via a food record (Denmark and France: 7-day, Sweden and the UK: 4-day, Hungary, Italy and Spain: 3-day), 1 country used 3 48hr recalls (Finland), 4 countries used two 24hr recalls (Belgium, Germany, the Netherlands and Portugal) and 6 countries used one 24hr recall (Andorra, Austria, Iceland, Latvia, Lithuania and Turkey). There were some variations in the age-groups for which data were reported, however data were generally presented for women aged 18+ (with variations in the upper cut-off) with the exception of Portugal (which reported dietary intake data for the total population aged 18-64y and not just for women).

Tables 2, 3 and 4 present the mean daily intake (MDI) of energy and nutrients in WCBA from national nutrition surveys across Europe while the key sources of energy and nutrients are presented in **Tables 5, 6 and 7**. It is important to note that micronutrient intakes reported for Belgium and Hungary and the key sources of nutrients from Portugal, Finland and the UK are from food sources only (i.e. exclude nutritional supplements).

Findings are reported below for energy and individual nutrients including intakes, adequacy and sources across countries.

Energy

Energy intakes for WCBA (as with all population groups) should be sufficient to meet macronutrient and micronutrient requirements, while reducing the risk of developing poor nutritional status (Blanco-Rojo et al., 2014). Maintaining energy balance is important in limiting the risk of developing obesity and is associated with co-morbidities such as diabetes and cardiovascular disease (Maggio and Pi-Sunyer, 2003). **Table 2** presents the MDI of energy in WCBA from 18 national nutrition surveys in Europe including Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Portugal, Spain, Sweden, the Netherlands, the UK and Turkey. The MDI of energy ranged from 1605-2151kcal/d among WCBA in these countries (Ax et al., 2016, Bates et al., 2020, Beslenme et al, 2016, Dubuisson et al., 2019, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). The key sources of energy (% contribution of food groups) reported for WCBA were 'cereal & cereal products' which contributed 21-31% of intake, 'meat & meat products' (13-17%) and 'dairy and dairy products' (11-17%) (**Table 5**). Top-shelf foods i.e. those high in fat and sugar such as 'sugar & sweets' contributed 5% of energy intake for WCBA in Finland, 'sugars & confectionery' & ' cakes & sweet biscuits' contributed 14% of energy intake for WCBA in the Netherlands, 'cookies, cakes & sweets' contributed 10% of energy intake for WCBA in Portugal, 'bakery & confectionery' contributed 13% of energy intake for WCBA in Spain and 'sugar & confectionery' contributed 5% of energy intake for WCBA in the UK (Bates et al., 2020, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Total fat and individual fatty acids

While dietary fat is an essential component of cell membranes and a pre-cursor for many signalling molecules, at 9kcal/g, it is the most energy-dense macronutrient. A high consumption of fat, especially saturated fat may increase the risk of chronic diseases including obesity in all population groups including WCBA which may increase the risk of gestational diabetes, preeclampsia and increased time taken to conceive (Clifton and Keogh, 2017, EFSA Panel on Dietetic Products Nutrition and Allergies, 2010b, Poston et al., 2016). The MDI of total fat for WCBA in European countries ranged from 32-35% total energy (%TE) in Iceland, Portugal, Sweden and the Netherlands, which is in line with population recommendations for an average population intake of 35%TE (Department of Health, 1991) (**Table 2**). However, intake of total fat among WCBA in Belgium, Denmark, Finland, France, Hungary, Italy, Lithuania, Spain and the UK exceeded this recommendation (range: 36-42%TE) (Ax et al., 2016, Bates et al., 2014, Dubuisson et al., 2009, Helldán et al., 2013, Leclercq et al., 2009, Lopes et al., 2017, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). The key sources of total fat for WCBA in European countries were ‘fats & oils’ which contributed 10-34% of fat intake, ‘meat & meat products’ which contributed 17-25% of fat intake and ‘dairy & dairy products’ which contributed 14-18% of fat intake. The contribution of ‘top-shelf’ foods to fat intake ranged from 3-12% in Finland, the Netherlands, Portugal, Spain and the UK (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Regarding saturated fat, due to the association of high intake of saturated fat with an increase in LDL-cholesterol concentration and risk of coronary heart disease (CHD), the UK Scientific Committee on Nutrition (SACN) have recommended that the average population intake of saturated fat should be <10%TE and while the European Food Safety Authority (EFSA) have not provided a quantitative guideline they have recommended to keep saturated fat intake as low as possible (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010b, Scientific Advisory Committee On Nutrition, 2015). The MDI of saturated fat for WCBA in European countries including Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Lithuania, Portugal, Sweden, the Netherlands and the UK ranged from 11-15%TE which exceeds the recommendation of <10%TE (**Table 2**) (Ax et al., 2016, Bates et al., 2014, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Leclercq et al., 2009, Lopes et al., 2017, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009) The key sources of saturated fat intake for WCBA in European countries were ‘dairy & dairy products’ which contributed 22-34% of saturated fat intake, ‘meat & meat products’ (16-25%) and ‘top-shelf’ foods (11-20%) (**Table 5**). ‘Fats & oils’ contributed 10-13% of saturated fat intakes in the Netherlands and the UK, while the contribution from ‘fats & oils’ was higher (19-23%) in Finland, Portugal and Spain which may be partly explained by a higher consumption of fat spreads & oils in these countries (approx. 20-25g/d) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Partearroyo et al., 2019, Ruiz et al., 2016, Van Rossum et al., 2020).

While it is recommended to reduce overall intakes of total and saturated fat, it is also important to improve the profile of fatty acid intake i.e. increase the intake of unsaturated fats such as monounsaturated fat (MUFA) and polyunsaturated fat (PUFA) (within recommended limits for total fat) due to their role in lowering the levels of LDL-cholesterol in the blood thereby reducing risk of CHD (Casas et al., 2018, Clifton and Keogh, 2017, Zhu et al., 2019). The MDI of MUFA for WCBA in European countries ranged from 12-17%TE in Austria, Belgium, Denmark, Finland, France, Germany, Iceland, Italy, Portugal, Spain, Sweden and the Netherlands which is in line with the recommendation for a minimum average population intake of 12%TE from the UK Department of Health (DoH) (Department of Health, 1991) (**Table 2**) (Ax et al., 2016, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Leclercq et al., 2009, Lopes et al., 2017, Pedersen, 2015, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). The key sources of MUFA intake for WCBA in European countries were ‘meat & meat products’ which contributed 17-24% of MUFA intake, ‘fats & oils’ (23-44%) and ‘dairy & dairy products (9-12%) (**Table 5**). The contribution of ‘fats & oils’ to MUFA intake was 23 and 25% for WCBA in the Netherlands and Finland, respectively while ‘fats & oils’ contributed 37% of MUFA intake in Portugal and 44% in Spain which may be partly explained by a higher consumption of olive oil in these countries (Helldán et al., 2013, Lopes et al., 2017, Partearroyo et al., 2019, Van Rossum et al., 2020). The contribution of ‘top-shelf’ foods to MUFA intake in WCBA in Finland, Portugal, Spain and the Netherlands ranged from 2-11% (Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

In addition to their role in lowering LDL-cholesterol concentrations, PUFAs have also been shown to have a role in nerve function, blood clotting, brain health and muscle strength (Department of Health, 1991, Shahidi and Ambigaipalan, 2018). The MDI of PUFA among WCBA ranged from 6-7%TE in Austria, Belgium, Denmark, Finland, France, Iceland, Spain, Sweden and the Netherlands which is in line with the recommendation for a minimum average population intake of 6%TE (Department of Health, 1991), while WCBA in Germany, Italy and Portugal had intakes of PUFA below this recommendation (4-5%TE) (**Table 2**) (Ax et al., 2016, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Lopes et al., 2017, Lundblad et al., 2019, Pedersen, 2015, Ruiz E, 2016, Steingrimsdottir et al., 2014, Temme et al., 2010, Van Rossum et al., 2020). 'Fats & oils' were a key source of PUFA intake among WCBA in Finland, Portugal, Spain and the Netherlands (22-35%), which may partly be explained by a high consumption of fats and oils in these countries as previously outlined (**Table 5**). Other key sources of PUFA intake for WCBA in Europe included 'meat & meat products' (10-27%) and 'cereal & cereal products' (16-21%) (**Table 5**) (Helldán et al., 2013, Lopes et al., 2017, Van Rossum et al., 2020).

Protein

The EFSA has set a PRI of 0.83g/kg bodyweight/day for all adults including WCBA based on requirements for tissue growth and maintenance (EFSA Panel on Dietetic Products Nutrition and Allergies, 2012) while the Nordic Nutrition Recommendations (NNR) recommend an intake range of 15-20%TE from protein (Nordic, 2014). Mean intakes of protein among WCBA in Denmark, Finland, France, Iceland, Italy, Lithuania, Portugal, Spain, Sweden, the Netherlands, the UK and Turkey ranged from 15-20%TE which is in line with recommendations from the NNR however, intakes among WCBA in Germany were below these recommendations (14%TE) (**Table 2**) (Ax et al., 2016, Bates et al., 2014, Dubuisson et al., 2009, Helldán et al., 2013, Heuer et al., 2015, Leclercq et al., 2009, Lopes et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020). The key sources of protein for WCBA in Finland, Netherlands, Portugal, Spain and the UK were 'meat & meat products' (27-46%), 'dairy & dairy products' (14-27%), 'cereal &

cereal products' (15-23%) and 'fish' (5-11%) (**Table 5**) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Carbohydrate

The EFSA has recommended an intake range for carbohydrate of 45-60%TE for all adults including WCBA (EFSA Panel on Dietetic Products, 2010). The MDI of carbohydrate for WCBA in Denmark, Finland, France, Lithuania and Spain ranged from 41-44%TE, which is below the recommended range of 45-60%, while higher intakes were reported for WCBA in Andorra, Austria, Belgium, Germany, Hungary, Iceland, Italy, Portugal, Sweden, the Netherlands and the UK (45-49%TE), which met the recommendations (**Table 2**) (Ax et al., 2016, Bates et al., 2014, Elmadfa et al., 2008, Heuer et al., 2015, Leclercq et al., 2009, Lopes et al., 2017, Ministeri de Salut, 2013, Nagy et al., 2017, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). The key sources of carbohydrate for WCBA in Finland, Netherlands, Portugal, Spain and the UK were 'cereal & cereal products' (35-50%), 'top-shelf' foods (7-26%) and 'dairy & dairy products' (6-13%) (**Table 5**) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Free sugars

Whilst it is recommended to consume 45-60%E from carbohydrate to meet energy needs in the context of acceptable intake ranges for fat and protein, it is also recommended to reduce intake of sugars (particularly added or free sugars). Free sugars include all mono- and di-saccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and unsweetened fruit juices (Scientific Advisory Committee On Nutrition, 2015). The UK SACN recommends that the average population intake of free sugars should not exceed 5%TE (based on the effect of free sugars intake on the risk of dental caries and total energy intake). Furthermore, the WHO recommends that free sugars intake should be kept below 10%TE for individuals (based on the effect of free sugar intake on body weight and dental caries) (World Health Organisation, 2015). The MDI of free sugars for WCBA in the Netherlands (11%TE) and the UK (10%TE) were higher then the the

MDI of free sugars for WCBA in Spain (7%TE) but all were above the SACN recommendation of intake of free sugars less than 5%TE (**Table 2**) (Bates et al., 2014, Ruiz et al., 2016, Van Rossum et al., 2020). The key sources of free sugar intake for WCBA in Portugal, Spain and the UK were top-shelf' foods (including sugar-sweetened beverages) which contributed 46-78% of intakes and 'dairy & dairy products' which contributed 6-13% of intakes (**Table 5**) (Bates et al., 2014, Lopes et al., 2017, Ruiz et al., 2016).

Dietary Fibre

The EFSA have set an AI of 25g/d for fibre intake in all adults (including WCBA) due to the association of low fibre intakes with impaired bowel function and constipation. Furthermore, the EFSA have reported that there is evidence of health benefits associated with consumption of dietary fibre intakes greater than 25g/day (e.g. reduced risk of CHD and type 2 diabetes and improved weight maintenance) (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010a). The MDI of dietary fibre for WCBA in Andorra, Austria, Belgium, Denmark, Finland, France, Iceland, Italy, Latvia, Lithuania, Portugal, Spain, Sweden, the Netherlands, the UK and Turkey ranged from 16-21g/d, which was below the AI of 25g/d however the intake of dietary fibre for WCBA in Germany was within recommendations (25g/d) (**Table 2**) (Ax et al., 2016, Bates et al., 2014, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Temme et al., 2010, Van Rossum et al., 2020). The key sources of dietary fibre for WCBA in Finland, Netherlands, Portugal, Spain and the UK were 'cereal & cereal products' (32-52%), 'fruit' (8-19%) and 'vegetables' (13-34%) (**Table 5**) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Salt

Due to the association of high salt intake with the risk of raised blood pressure and cardiovascular diseases, the WHO have set a recommendation for a maximum salt intake from all dietary sources (including discretionary salt) of <5g/d for all individuals (World Health Organisation, 2015). The MDI of salt from food sources only reported for WCBA in Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Iceland, Latvia, Lithuania, Portugal, Spain, Sweden and Turkey ranged from 4.1-7.5g/d. These countries did not include estimates of discretionary salt intake, while the MDI of salt for WCBA in Hungary was 12.5g/d, due to the inclusion of table salt in their estimates of salt intake (**Table 2**) (ANSES, 2017, Ax et al., 2016, Bates et al., 2014, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Temme et al., 2010, Van Rossum et al., 2020). The key sources of salt intake for WCBA in Finland, Netherlands, Portugal, Spain and the UK were ‘cereal & cereal products’ which contributed 21-33% of salt intake, ‘meat & meat products’ which contributed 18-25% of intake and ‘soups/sauces’ which contributed 8-17% of intake (**Table 5**) (Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Vitamin A

The EFSA has set a PRI of 650µg/d for vitamin A for all women over 18 years of age based on the intake required to maintain a liver concentration indicative of an adequate vitamin A status (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015e). The MDI of vitamin A among WCBA in Europe was generally above the PRI (ranging from 755-1100µg/d) in Denmark, Finland, Iceland, Italy, Lithuania, Portugal and the UK, however, the MDI of vitamin A among WCBA in France, Spain and the Netherlands were below this recommendation (range: 628-650µg/d) (**Table 3**) (Bates et al., 2014, Dubuisson et al., 2009, Helldán et al., 2013, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2015, Steingrimsdottir et al., 2014, Van Rossum et al., 2020). The proportion of WCBA with inadequate intakes of vitamin A was 30% in the Netherlands (EAR: 700µg/d) and 23% in Portugal (EAR: 490µg/d) (Lopes et al., 2017, Van Rossum et al., 2020). In the UK, 8% of WCBA had intakes below the LNRI of 250µg/d ((Bates et al., 2020). The key sources of vitamin A for WCBA in European countries were ‘vegetables’ which contributed 20-35% of vitamin A intake, ‘meat & meat products’

(10-21%) and ‘dairy & dairy products’ (14-24%) (**Table 6**) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Vitamin D

The EFSA has recently set an AI for vitamin D of 15 µg/d for all adults over 18 years of age (including WCBA) based on serum 25 (OH)D status deemed to be adequate for bone health for WCBA (EFSA Panel on Dietetic Products Nutrition and Allergies, 2016c). Furthermore, evidence has accumulated regarding the impact of maternal vitamin D levels on the long-term health of offspring and a positive association between high maternal vitamin D status and bone mass of the child at 9 years of age has been observed (Javaid et al., 2006). The MDI of vitamin D among WCBA in Europe was well below the recommendation of 15 µg/d in Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Portugal, Spain, Sweden, the Netherlands, the UK and Turkey (range 0.9-8.7µg/d) (**Table 3**) (Ax et al., 2016, Bates et al., 2014, Beslenme et al, 2016, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). The MDI of 8.7µg/d which was the highest value reported was for WCBA in Finland and can be explained by the recent national policies on vitamin D that include fortification of fluid dairy products and a vitamin D supplementation policy. These policies coupled with a high habitual intake of oil-rich fish, have resulted in an increase in vitamin D intakes in the Finnish adult population including WCBA (Raulio et al., 2017). It is well documented in the literature that there is a high prevalence of inadequate vitamin D intakes for populations of all ages in Europe and further afield (Spiro and Buttriss, 2014). The key sources of vitamin D for WCBA in European countries were ‘meat & meat products’ which contributed 20-67% of vitamin D intake, ‘dairy & dairy products’ (7-33%), ‘fats & oils’ (5-27%) and ‘fish’ (9-26%) (**Table 6**). (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Temme et al., 2010, Van Rossum et al., 2020).

Vitamin E

The EFSA have set an AI for vitamin E of 11mg/d for all adults over 18 years of age (including WCBA) based on observed intakes in healthy populations with no apparent α-tocopherol deficiency (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015f). The MDI of vitamin E among WCBA in Europe was typically above the AI ranging from 11-12mg/d in France, Iceland, Italy, Lithuania, the Netherlands and the UK while intakes in Denmark, Finland and Spain were below these recommendations (6.8-9.7mg/d (**Table 3**) (Dubuisson et al., 2009, Helldán et al., 2013, Leclercq et al., 2009, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020). The key sources of vitamin E for WCBA in European countries were ‘fats & oils’ which contributed 10-46% of vitamin E intake, ‘fruit & vegetables’ (19-20%), ‘cereal & cereal products’ (8-21%) and ‘meat & meat products’ (10-13%) (**Table 6**) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Thiamin

The EFSA recommends a PRI for thiamin of 0.1mg/MJ for all adults over 18 years of age (including WCBA) based on intakes required for carbohydrate and protein metabolism (EFSA Panel on Dietetic Products Nutrition and Allergies, 2016b). Within their recommendation, they note that there is no evidence that the relationship between thiamin requirement and energy requirement differs between men and women, or between younger and older adults. The MDI of thiamin among WCBA in Denmark, Finland, Iceland, Italy, Lithuania, Portugal, the Netherlands and the UK ranged from 0.8-3.4mg/d which (based on crude calculations of mg/MJ from the data presented in **Tables 2 & 3**) is above the PRI set by EFSA (**Table 3**) (Bates et al., 2014, Helldán et al., 2013, Leclercq et al., 2009, Lopes et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Steingrimsdottir et al., 2014, Van Rossum et al., 2020). The key sources of thiamin for WCBA in European countries were ‘meat & meat products’ which contributed 20-26% of thiamin intake, ‘cereal & cereal products’ (18-35%) and ‘dairy & dairy products’ (7-12%) (**Table 6**) (Helldán et al., 2013, Lopes et al., 2017, Temme et al., 2010, Van Rossum et al., 2020).

Riboflavin

The EFSA recommends a PRI for riboflavin of 1.6mg/d for all adults over 18 years of age (including WCBA) based on body saturation measured through urinary riboflavin excretion (EFSA Panel on Dietetic Products Nutrition and Allergies, 2017). The MDI of riboflavin among WCBA in Italy, Lithuania, Portugal and the Netherlands were below the PRI (ranging from 1.2-1.5mg/d) while the MDI among WCBA in Denmark, Finland, Iceland and the UK were in line with or above the PRI (ranging from 1.6-3.3mg/d) (**Table 3**) (Bates et al., 2014, Helldán et al., 2013, Leclercq et al., 2009, Lopes et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Van Rossum et al., 2020). The proportion of WCBA with inadequate intakes of riboflavin was 39% in Portugal (EAR: 1.4mg/d) and 13% of WCBA in the UK had intakes below the LNRI of 0.8mg/d (Bates et al., 2014, Lopes et al., 2017). The key sources of riboflavin for WCBA in European countries were 'dairy & dairy products' which contributed 30-46% of riboflavin intake, 'meat & meat products' (11-24%) and 'cereal & cereal products' (8-22%) (**Table 6**) (Helldán et al., 2013, Lopes et al., 2017, Temme et al., 2010, Van Rossum et al., 2020).

Niacin

The EFSA recommends a PRI for niacin of 1.6mg/MJ (6.6mg/1000kcal) based on the relationship between niacin requirements and energy requirements (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014d). The MDI of niacin among WCBA in European countries ranged from 13-39mg/d which (based on crude calculations of mg/1000kcal from the data presented in **Tables 2 & 3**) are above the PRI set by EFSA (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Pedersen, 2015, Pomerleau et al., 2001). The key sources of niacin for WCBA in European countries were 'meat & meat products' which contributed 30-42% of niacin intake, 'cereal & cereal products' (15-26%) and 'dairy & dairy products' (11-17%) (**Table 6**) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Van Rossum et al., 2020).

Vitamin B6

The EFSA recommends a PRI for vitamin B6 of 1.6mg/d for all women over 18 years of age based on intakes required to maintain a concentration of plasma PLP indicative of an adequate vitamin B6 status (EFSA Panel on Dietetic Products Nutrition and Allergies, 2016d). The MDI of vitamin B6 was typically above the PRI among WCBA in France, Iceland, Italy, Portugal, the Netherlands and the UK (ranging from 1.6-4.8mg/d) with the exception of WCBA in Denmark and Lithuania where intakes were below the PRI (1.4mg/d) (**Table 3**). (Bates et al., 2014, Dubuisson et al., 2009, Leclercq et al., 2009, Lopes et al., 2017, Pedersen, 2015, Pomerleau et al., 2001). The proportion of WCBA with inadequate intakes of vitamin B6 was 14% in the Netherlands (EAR: 1.1mg/d) and 26% in Portugal (EAR: 1.4mg/d)(Lopes et al., 2017, Van Rossum et al., 2020). The key sources of vitamin B6 for WCBA in European countries were 'meat & meat products' which contributed 22-26% of vitamin B6 intake, 'cereal & cereal products' (10-29%) and 'dairy & dairy products' (8% for each country where data were available) (**Table 6**) (Bates et al., 2014, Lopes et al., 2017, Van Rossum et al., 2020).

Vitamin B12

The EFSA recommends an AI for vitamin B12 of 4µg/d for all adults over 18 years of age based on the evidence that an intake of 4µg/day and greater is associated with serum concentrations of holoTC and cobalamin within the reference ranges derived from healthy subjects, together with MMA and the concentrations below the cut-off values for adults, indicating an adequate cobalamin status (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015b). The MDI of vitamin B12 among WCBA in Austria, Denmark, Finland, France, Germany, Iceland, Italy, Portugal, Spain, Sweden and the UK was above the AI ranging from 4-8µg/d, while the MDI of vitamin B12 in Andorra, Belgium, Hungary, Latvia, Lithuania, the Netherlands and Turkey was below the AI ranging from 0.9-3.8µg/d (**Table 3**) (Ax et al., 2016, Bates et al., 2014, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). The proportion of WCBA with inadequate intakes of vitamin B12 was 8% in the Netherlands (EAR 2µg/d) and 2% of WCBA in the UK had intakes below the LNRI of 1µg/d (Bates et al., 2014, Van Rossum et al., 2020). The key sources of vitamin B12 for WCBA in European countries were ‘meat & meat products’ which contributed 26-66% of vitamin B12 intake, ‘dairy & dairy products’ (20-38%) and ‘fish’ (10-23%) (**Table 6**) (Helldán et al., 2013, Lopes et al., 2017, Temme et al., 2010, Van Rossum et al., 2020).

Folate

The EFSA recommends a PRI for folate of 330µg/d for all adults over 18 years of age based on the folate intake required to maintain folate adequacy characterised by serum and red blood cell folate concentrations of ≥10 and 340nmol/L, respectively (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014b). It is well established that folic acid (the synthetic form of folate) when taken prior to conception and during the first few weeks of pregnancy can prevent a significant proportion of neural tube defects (NTD)-affected pregnancies (Prevention of neural tube defects, 1991). Subsequently, many countries worldwide recommend that WCBA take a folic acid supplement of 400µg/d regardless of pregnancy intention (Gomes et al., 2016). The MDI of folate among WCBA in Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Latvia, Lithuania, Portugal, Spain, Sweden, the Netherlands and the UK was below the PRI ranging from 190-329µg/d, however WCBA in Iceland and Turkey had a MDI of folate above the PRI (range: 334-339µg/d) (**Table 3**) (Ax et al., 2016, Bates et al., 2014, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). The proportion of WCBA with inadequate intakes of folate was 66% in Portugal (EAR 250µg/d) and 28% in the Netherlands (EAR 260µg/d) and 7% of WCBA in the UK had a MDI of folate below the LNRI of 100µg/d (Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020). The key sources of folate for WCBA in European countries were ‘cereal & cereal products’ which contributed 18-34% of folate intake, ‘vegetables’ (13-28%) and ‘meat & meat products’ (7-11%) (**Table 6**) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Van Rossum et al., 2020, Vandevijvere et al., 2009).

Vitamin C

The EFSA recommends a PRI for vitamin C of 95mg/d for all adults over 18 years of age (including WCBA) based on the quantity of vitamin C that balances metabolic vitamin C losses and allows the maintenance of an adequate body pool characterised by fasting plasma ascorbate concentrations (EFSA Panel on Dietetic Products Nutrition and Allergies, 2013). The MDI of vitamin C among WCBA in France, Lithuania, Spain and the Netherlands ranged from 66-94mg/d which is below the PRI while the MDI of vitamin C among WCBA in Denmark, Finland, Iceland, Italy, Portugal and the UK ranged from 107-141mg/d which is above the PRI (**Table 3**) (Bates et al., 2014, Dubuisson et al., 2009, Helldán et al., 2013, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020). The proportion of WCBA with inadequate intakes of vitamin C was 38% in Portugal (EAR: 80mg/d) and 21% in the Netherlands (EAR: 86mg/d) (Lopes et al., 2017, Van Rossum et al., 2020). The key sources of vitamin C for WCBA in European countries were ‘vegetables’ which contributed 22-51% of vitamin C intake, ‘fruit’ (20-54%) and ‘potatoes & potato products’ (10-17%) (**Table 6**) (Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Calcium

The EFSA recommends a PRI for calcium of 1000mg for adults aged 18-24 years and 950mg/d for adults aged over 25 years (including WCBA) based on calcium balance studies (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015a). The MDI of calcium among WCBA in Andorra, Austria, Belgium, France, Hungary, Iceland, Italy, Latvia, Lithuania, Portugal, Spain, Sweden, the Netherlands, the UK and Turkey was below the PRI ranging from 457-953mg/d with the exception of intakes in Denmark, Finland, Germany and the Netherlands which ranged from 1038-1074mg/d which is above the PRI set by EFSA (**Table 4**). (Ax et al., 2016, Bates et al., 2014, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). The proportion of WCBA with inadequate intakes of calcium was 61% in Portugal (EAR 860mg/d) and the proportion of WCBA in the UK with intakes of calcium below the LRNI of 400mg was 9% (Bates et al., 2014, Lopes et al., 2017). The key sources of calcium for WCBA in European countries were 'dairy & dairy products' which contributed 38-61% of calcium intake, 'cereal & cereal products' (11-30%) and 'vegetables' (5-10%) (**Table 7**) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Van Rossum et al., 2020, Vandevijvere et al., 2009).

Iron

The EFSA recommends a PRI for iron of 16mg/d for all premenopausal females over 18 years of age based on requirements to replace whole-body losses (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015c). The MDI of iron among WCBA in Europe ranged from 8.6-13mg/d which was below the PRI recommended by EFSA for all countries (**Table 4**) (Ax et al., 2016, Bates et al., 2014, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). The proportion of WCBA in Portugal with inadequate intakes of iron was 17% (EAR: 7mg/d) and in the UK, the proportion of WCBA with intakes of iron below the LRNI of 8mg was 25% (Bates et al., 2014, Lopes et al., 2017). The key sources of iron for WCBA in European countries were 'cereal & cereal products' which contributed 18-43% of iron intake, 'meat & meat products' (15-21%) and 'vegetables' (9-17%) (**Table 7**) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020)

Magnesium

The EFSA recommended an AI for magnesium of 300mg/d for all females over 18 years of age (including WCBA) based on the observed intakes in healthy populations in the European Union (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015d). The MDI of magnesium among WCBA was below the AI in France, Iceland, Italy, Lithuania, Portugal, Spain, the Netherlands and the UK ranging from 211-295mg/d, with the exception of intakes in Denmark and Finland where the mean intakes were 342 and 344mg/d, respectively (**Table 4**) (Bates et al., 2014, Dubuisson et al., 2009, Helldán et al., 2013, Leclercq et al., 2009, Lopes et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Van Rossum et al., 2020). The proportion of WCBA with inadequate intakes of magnesium was 27% in the Netherlands (EAR: 285mg/d) and in the UK, 11% of WCBA had intakes of magnesium below the LRNI of 150mg/d (Bates et al., 2014, Van Rossum et al., 2020). The key sources of magnesium for WCBA in European countries were 'cereal & cereal products' which contributed 23-29% of magnesium intake, 'dairy & dairy products' (10-16%) and 'meat & meat products' (8-18%) (**Table 7**) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Potassium

The EFSA recommends an AI for potassium of 3500mg/d for all adults over 18 years of age on the basis of the relationships between potassium intake and blood pressure and stroke (EFSA Panel on Dietetic Products Nutrition and Allergies, 2016a). The MDI of potassium among WCBA in Europe was below the AI for all countries (ranging from 2250-3400mg/d) (**Table 4**) (Ax et al., 2016, Bates et al., 2014, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). The proportion of WCBA in the UK with intakes of potassium below the LRNI of 2000mg was 24% (Bates et al., 2014). The key sources of potassium for WCBA in European countries were 'dairy & dairy products' which contributed 12-19% of potassium intake, 'cereal & cereal products' (14-19%) and 'vegetables' (12-25%) (**Table 7**) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Van Rossum et al., 2020).

Iodine

The EFSA recommends an AI for iodine of 150µg/d for all adults over 18 years of age (including WCBA) which has been extrapolated for adults based on a large epidemiological study in European school-aged children showing that goitre prevalence is lowest for a urinary iodine concentration above around 100µg/L (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014c). The MDI of iodine among WCBA in Andorra, Belgium, France, Latvia, Lithuania, Spain, the UK and Turkey was below the AI (ranging from 48-149µg/d), while intakes in Denmark, Finland and Germany ranged from 190-227µg/d (**Table 4**) (Bates et al., 2014, Dubuisson et al., 2009, Helldán et al., 2013, Heuer et al., 2015, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Pedersen, 2015, Pomerleau et al., 2001, Van Rossum et al., 2020, Vandevijvere et al., 2009). The proportion of WCBA in the UK with intakes of iodine below the LRNI of 70µg/d was 12% (Bates et al., 2014). The key sources of iodine for WCBA in European countries were 'dairy & dairy products' which contributed 35-37% of iodine intake, 'cereal & cereal products' (11-22%) and 'meat & meat products' (9-11%) (**Table 7**) (Bates et al., 2014, Helldán et al., 2013).

The risk of excessive intake of micronutrients can be evaluated using the tolerable upper intake level (UL) as a reference value. The UL is defined as the maximum level of total chronic daily intake of a nutrient (from all sources) judged to be unlikely to pose a risk of adverse health effects to humans (EFSA Panel on Dietetic Products, 2006). While there was limited data on the proportion of WCBA with micronutrient intakes above the UL across Europe, where available the data indicated that the risk of excessive micronutrient intakes among WCBA was negligible with <=1% of WCBA in the Netherlands having intakes of vitamin B6, folic acid, magnesium and zinc above the UL

Conclusion

Preconceptional health (including nutritional status) is critically important with regard to favourable maternal and infant outcomes in both the short- and long-term.

Interestingly, nutrient recommendations for WCBA are not differentiated by pregnancy intention and for the most part recommendations are no different than for other adult population groups (EFSA Panel on Dietetic Products and Allergies, 2010).

This review has found that while protein intakes are sufficient in this population group, a large proportion of WCBA in Europe have total fat intakes above recommendations and carbohydrate intakes below recommendations. Furthermore, WCBA in European countries have high intakes of saturated fat, free sugar and salt and low intakes of dietary fibre compared to generally accepted recommendations. This study has also found that WCBA across Europe have low intakes of key micronutrients including vitamin D, folate, riboflavin, vitamin C, calcium, iron, magnesium, potassium and iodine. This review has also identified the key sources of nutrients among this population group across Europe which may be useful to both policy makers and the food industry to develop targeted dietary strategies to improve the diets of WCBA.

It is important to note however, that there were variations in the dietary assessment methods used between the national dietary surveys included in this review (e.g. methods used to collect food intake data, reference cut-off points to assess nutrient intakes/adequacy etc.). Therefore, there is a need to harmonise the dietary assessment methods used to collect food consumption data across Europe in order to accurately compare between countries. EFSA have produced the EU Menu Methodology guidance document to facilitate the collection of more harmonised food consumption data from all European Union Member States (European Food Safety Authority, 2014a). Furthermore, the use of nutritional status biomarkers as objective measures of nutrient intake could also strengthen the ability to compare and contrast between studies/countries, however, the collection of nutritional biomarkers can be challenging within studies for various reasons including cost, feasibility and personnel requirements.

Table 1. Summary of national nutrition surveys in Europe which provide data on intakes and sources of nutrients in WCBA

Country	Study name	Study year(s)	Age (years)	Dietary assessment method	Reference
Andorra	Evaluation of the Nutritional Status of the Andorran Population	2004- 2005	18-64	1 x 24hr recall	(Ministeri De Salut et al., 2013)
Austria	Austrian Nutrition Report	2008	18-64	1 x 24hr recall	(Elmadfa et al., 2009)
Belgium	Belgium National Food Consumption Survey	2014-2015	18-64	2 x 24hr recall	(Vandevijvere et al., 2009)
Denmark	Danish National Survey of Diet and Physical Activity (DANSDA)	2011- 2013	18-75	7-day food record	(Pedersen et al., 2010)
Finland	The National FINDIET 2012 survey	2012	25-64	3 x 48hr recall	(Helldan et al., 2013)
France	Individual and National Food Consumption Surveys (INCA2 & INCA3)	2006- 2007 2014-2015	18-74	7-day food record	(ANSES, 2014, Dubuisson et al., 2009, Dubuisson et al., 2019)
Germany	German National Nutrition Survey II	2005-2007	18-50	2 x 24hr recall	(Heuer et al., 2015)
Hungary	Hungarian Diet and Nutritional Status Survey	2014	18-60	3-day food record	(Nagy et al., 2017)
Iceland	The Diet of Icelanders – A National Dietary Survey	2010-2011	18-60	1 x 24hr recall	(Steingrimsdottir et al., 2014)
Italy	The third Italian National Food Consumption Survey	2005-2006	18-64	3-day food record	(Leclercq et al., 2009)
Latvia	Latvian National Diet Survey	2007- 2009	18-63	1 x 24hr recall	(Institute of Food Safety et al., 2017)
Lithuania	Study of Actual Nutrition and Nutrition Habits of Lithuanian Adult Population	2013-2014	19–75	1 x 24hr recall	(Pomerleau et al., 2001)
Portugal	National Food and Physical Activity Survey (IAN-AF)	2015-2016	18-64*	2 x 24hr recall	(Lopes et al., 2016)
Spain	ANIBES Study	2013	18-75	3-day food record	(Ruiz et al., 2016)
Sweden	Riksmaten Swedish Adults Dietary Survey	2010 - 2011	18-64	4-day food record	(Ax et al., 2016)
The Netherlands	Dutch National Food Consumption Survey	2012-2016	19-79	2 x 24hr recall	(Van Rossum et al., 2020)
The U.K	The National Diet and Nutrition Survey (NDNS)	2008/09-2011/12 2014/15-2015/16 2016/17-2018/19	19-64	4-day food record	(Bates et al., 2014, Bates et al., 2020, Roberts et al., 2018,)
Turkey	Turkey Nutrition and Health Survey (TNHS)	2010	18-60	1 x 24hr recall	(Beslenme et al., 2014)

*Portugal reports data for the total population aged 18-64y (i.e. sub-group data for women only are not available).

Note: All studies include under-reporters in their report of nutrient intake

Table 2. Mean daily intake of energy, macronutrients, dietary fibre and salt in WCBA from national nutrition surveys in Europe

Country	Energy kcal	Total fat %E	Saturated fat %E	MUFA %E	PUFA %E	Protein %E	Carbohydrate %E	Total sugar %E	Free sugar %E	Dietary Fibre g	Salt* g
Andorra	1854	-	-	-	-	-	46.0	11.5	-	17.0	7.3
Austria	1650	-	15.0	12.0	6.1	-	45.6	-	-	17.0	6.2
Belgium	1826	36.4	14.5	13.8	6.9	-	46.9	-	-	18.0	5.2
Denmark	2008	36.0	14.0	13.0	6.0	16.0	43.0	-	-	21.0	7.5
Finland	1840	35.5	14.9	12.6	6.3	17.2	43.9	10.0	-	21.0	6.5
France	1860	39.6	14.9	14.0	6.0	16.7	43.8	18.0	-	16.0	7.0
Germany	1996	-	15.0	12.1	5.1	14.0	49.0	24.0	-	25.0	6.3
Hungary	2151	36.2	10.8	-	-	-	46.8	8.6	-	-	12.5
Iceland	1742	35.0	13.0	12.0	6.0	18.0	46.0	17.0	-	17.3	5.7
Italy	1939	36.8	11.3	17.0	4.0	15.9	45.5	14.0	-	17.7	-
Latvia	1613	-	-	-	-	-	-	-	-	15.8	5.6
Lithuania	1561	41.9	12.9	-	-	16.7	42.9	14.0	-	15.6	7.1
Portugal	1747	31.8	10.7	12.0	5.0	20.2	45.7	7.5	-	18.1	6.4
Spain	1676	39.0	-	17.0	6.0	17.0	41.0	17.0	7.3	18.9	5.8
Sweden	1819	34.5	13.3	12.0	6.0	16.7	46.2	-	-	18.5	6.9
The Netherlands	1863	35.3	12.9	12.2	6.8	15.9	44.1	20.5	11.0	18.3	-
The U.K	1605	35.7	12.4	-	-	17.1	45.1	19.0	9.9	18.1	-
Turkey	1638	-	-	-	-	-	-	-	-	20.3	4.1

%E: Percent energy, *Salt intake from food sources only (except for Hungary)
- Data not available

Table 3. Mean daily intake of vitamins in WCBA from National Nutrition Surveys in Europe

Country	Vit A µg	Vit D µg	Vit E mg	Vit B1 mg	Vit B2 mg	Niacin mg	Vit B6 mg	Vit B12 µg	Folate µg	Vit C mg
Andorra	-	2.4	-	-	-	-	-	3.8	223	-
Austria	-	2.6	-	-	-	-	-	5.4	241	-
Belgium*	-	3.5	-	-	-	-	-	3.6	190	-
Denmark	1110	4.3	8.8	1.2	1.6	30.0	1.4	5.6	329	115
Finland	755	8.7	9.7	1.1	1.7	29.0	-	5.0	234	118
France	628	2.4	11.1	-	-	-	1.6	5.1	268	94.3
Germany	-	2.4	-	-	-	-	-	4.2	311	-
Hungary*	-	2.0	-	-	-	-	-	3.0	133	-
Iceland	1028	3.9	12.0	3.4	3.3	38.0	4.2	8.0	339	141
Italy	818	2.3	11.0	0.9	1.3	-	1.8	5.5	-	123
Latvia	-	1.6	-	-	-	-	-	3.6	213	-
Lithuania	1020	3.9	12.0	1.0	1.2	13.0	1.4	0.9	238	66.0
Portugal	775	7.4	-	1.2	1.5	31.0	1.8	4.0	216	107
Spain	650	4.4	6.8	-	-	-	-	5.8	265	84.0
Sweden	-	5.2	-	-	-	-	-	4.8	247	-
The Netherlands	807	5.3	16.0	3.1	3.3	21.3	2.9	12.1	338	159
The U.K	1046	3.4	11.6	1.8	1.8	33.8	2.6	5.0	272	112
Turkey	-	0.9	-	-	-	-	-	2.7	334	-

- Data not available, DFE is recorded for folate in the Netherlands
* Intakes are reported from food sources only (i.e., excluding nutritional supplements)

Table 4. Mean daily intake of minerals in WCBA from National Nutrition Surveys in Europe

Country	Calcium mg	Iron mg	Magnesium mg	Potassium mg	Iodine µg
Andorra	776	11.0	-	2597	146
Austria	790	10.0	-	2867	-
Belgium*	720	8.6	-	-	123
Denmark	1038	10.0	342	3200	227
Finland	1074	10.3	344	3400	190
France	850	11.0	261	2681	117
Germany	1061	11.0	-	3260	192
Hungary*	691	9.8	-	2600	-
Iceland	824	13.0	255	2690	-
Italy	730	10.0	257	2861	-
Latvia	457	9.1	-	2250	53.0
Lithuania	562	9.9	263	2550	48.0
Portugal	729	10.0	249	2694	-
Spain	668	13.0	211	2838	87.0
Sweden	806	9.7	-	2865	-
The Netherlands	980	10.7	328	2915	173
The U.K	748	11.2	233	2533	149
Turkey	605	10.0	-	2311	59.0

- Data not available

* Intakes are reported from food sources only (i.e., excluding nutritional supplements)

Table 5. Key sources of energy, macronutrients, dietary fibre and salt (% contribution of food groups) for WCBA from National Nutrition Surveys in Europe

	Finland [a] **(Women 25-64y)**	**Netherlands** [b] **(Women 19-79y)**	**Portugal** [c] **(Total population 18-64y)**	**Spain** [d, e] **(Women 18-64y)**	**UK** [f, g] **(Women 19-64y)**
Energy	Cereals 31% Milk & dairy products 17% Meat dishes 13% Fats & oils, gravies 8% Fruit, berries & dishes 7% Sugar & sweets 5%	Cereals & cereal products 23% Dairy products & substitutes 16% Meat products & substitutes 11% Fruit, nuts & seeds, olives 8% Cakes & sweet biscuits 8% Fats & oils 6% Sugars & confectionery 6%	Cereals & cereal products 29% Meat, fish & eggs 17% Dairy products 11% Cookies, cakes & sweets 10% Fruit & vegetables 8% Fats & oils 8%	Cereals & cereal products 21% Olive oil & other oils 14% Meat & other meat products 14% Bakery & confectionary 13% Milk & other dairy 12% Fruits & vegetables 12%	Cereals & cereal products 31% Meat & meat products 16% Vegetables & potatoes 11% Milk & milk products 10% Sugar & confectionery 5% Alcoholic beverages 5%, Non-alcoholic beverages 4%
Total fat	Fats & oils, gravies 22%, Milk & dairy products 18% Meat dishes 18% Cereals 18%	Dairy products & substitutes 20% Fats & oils 18% Meat products & substitutes 17% Cereals & cereal products 9% Sauces & seasonings 8% Cakes and sweet biscuits 8%	Fats & oils 27% Meat, fish & eggs 25% Dairy products 14% Cookies, cakes & sweets 12% Cereals & cereal products 7%	Olive oil & other oils 34% Meat & meat products 24% Dairy products 15%, Bakery & pastry 9% Fish & shellfish 5%	Meat & meat products 22% Cereals & cereal products 20% Milk & milk products 14% Vegetables & potatoes 10% Fat spreads 10%
Saturated fat	Milk & dairy products 31% Fats & oils, gravies 19% Cereals 17% Meat dishes 16%	Dairy products & substitutes 34% Meat products & substitutes 18% Fats & oils 13% Cakes & sweet biscuits 9% Cereals & cereal products 6% Sugar & confectionery 5%	Meat, fish & eggs 25% Dairy products 22% Fats & oils 20% Cookies, cakes & sweets 16% Cereals & cereal products 5% Salty snacks & pizzas 4%	Dairy & dairy products 24% Meat & meat products 24% Olive oil & other oils 23% Bakery & confectionary 11%	Milk & milk products 23% Meat & meat products 22% Cereals & cereal products 20% Fat spreads 10% Vegetables & potatoes 6%
MUFA	Fats & oils, gravies 25% Meat dishes 22% Cereals 17% Milk & dairy products 12%	Fats & oils 23% Meat products & substitutes 17% Sauces & seasonings 11% Cereals & cereal products 11% Dairy products & substitutes 10% Fruit, nuts & seeds, olives 8%	Fats & oils 37% Meat, fish & eggs 24% Dairy products 10% Cookies, cakes & sweets 9% Soups 9% Salty snacks & pizzas 4%	Olive oil & other oils 44% Meat & meat products 20% Dairy & dairy products 9% Bakery & confectionary 7%	-
PUFA	Fats & oils, gravies 28%	Fats & oils 27%	Meat, fish & eggs 27%	Olive oil & other oils 35%	-

	Cereals 21% Meat dishes 17% Miscellaneous 11% Vegetables & veg dishes 6% Fish dishes 6%	Cereals & cereal products 16% Sauces & seasonings 14% Meat products & substitutes 10% Fruit, nuts & seeds, olives 9% Cakes & sweet biscuits 6%	Fats & oils 22% Cereals & cereal products 16% Fruit & vegetables 9% Cookies, cakes & sweets 9% Salty snacks & pizzas 5%	Meat & meat products 19% Fish & shellfish 9% Bakery & confectionary 9%	
Protein	Milk & dairy products 27% Meat dishes 27% Cereals 23% Fish dishes 7%	Meat products & substitutes 27% Dairy & substitutes 25% Cereals & cereal products 22% Fish & shellfish 5%	Meat, fish & eggs 46% Cereals & cereal products 20% Dairy products 16% Fruit & vegetables 5% Cookies, cakes & sweets 5% Soups 3%	Meat & meat products 31% Dairy & dairy products 19% Cereals & cereal products 15% Fish & shellfish 11% Eggs 4%	Meat & meat products 36% Cereal & cereal products 23% Milk & milk products 14% Vegetables & potatoes 9% Fish & fish dishes 8%
Carbohydrate	Cereals 43% Fruit, berries & dishes 15% Milk & dairy products 13% Sugar & sweets 7% Beverages 5%	Cereals & cereal products 35% Dairy & substitutes 10% Fruit, nuts & seeds 10% Cakes & sweet biscuits 10% Non-alcoholic beverages 9% Sugar & confectionery 7%	Cereals & cereal products 50% Cookies, cakes & sweets 13% Fruit & vegetables 12% Dairy products 8% Non-alcoholic beverages 6% Soups 4%	Cereals & cereal products 39% Fruits & vegetables 23% Bakery & confectionary 21%	Cereals & cereal products 45% Vegetables & potatoes 14% Non-alcoholic beverages 7% Fruit 7% Sugar, preserves & confectionery 7% Milk & milk products 6%
Free sugar	-	-	Cookies, cakes & sweets 36% Table sugar 21% Non-alcoholic beverages 19% Dairy products 12% Cereals & cereal products 7%	Bakery & confectionary 78% Dairy & dairy products 13% Cereals & cereal products 3% Fruit, Juices & nectars 2%	†Sugar, preserves & confectionery 25% Cereals & cereal products 24% Non-alcoholic beverages 21% Alcoholic beverages 9% Miscellaneous 6% Milk & milk products 6%
Dietary fibre	Cereals 52% Fruit, berries & dishes 19% Vegetables & veg dishes 13% Miscellaneous 5%	Cereals & cereal products 41% Vegetables 16% Fruit, nuts & seeds, olives 15% Potatoes & other tubers 8% Cakes & sweet biscuits 5%	Cereals & cereal products 46% Fruit & vegetables 33% Soups 10% Cookies, cakes & sweets 7% Salty snacks & pizza 3%	Vegetables & fruit 52% Cereals & cereal products 32% Bakery & confectionary 9%	Cereals & cereal products 38% Vegetables & potatoes 30% Meat & meat products 12% Fruit 8%

Salt	Cereals 33%	Cereals & cereal products 25%	Salt 29%		Cereals & cereal products 31%
	Meat dishes 24%	Meat products & substitutes 18%	Cereals & cereal products 21%		Meat & meat products 25%
	Milk & dairy products 13%	Dairy & substitutes 18%	Meat, fish & eggs 18%	-	Miscellaneous 11%
	Vegetables & veg dishes 6%	Sauces & seasonings 10%	Dairy products 9%		Milk & milk products 9%
		Soups & stocks 7%	Soups 8%		Vegetables & potatoes 9%

- Data not available

MUFA: Monounsaturated fat, PUFA: Polyunsaturated fat

[†] Sources of free sugar and dietary fibre in the UK provided for the total population 19-64y

[a] (Helldán et al., 2013), [b] (Van Rossum et al., 2020), [c] (Lopes C, 2016), [d] (Ruiz et al., 2016), [e] (Ruiz and Varela-Moreiras, 2017), [f] (Bates B., 2014),[g] (Roberts et al., 2018)

Table 6. Key sources of vitamins (% contribution of food groups) for WCBA from National Nutrition Surveys in Europe

	*Finland [a] (Women 25-64y)	Netherlands [b] (Women 19-79y)	*Portugal [c] (Total population 18-64y)	Spain [d, e, f] (Total Population 9-75y)	*UK [g] (Women 19-64y)
Vitamin A	Vegetables & vegetable dishes 28% Meat dishes 21% Fats & oils & gravies 18% Milk & dairy products 14% Cereals 7%	Dairy products & substitutes 24% Vegetables 20% Fats & oils 16% Meat products & substitutes 11% Dietary supplements 10%	Fruit & vegetables 29%, Soups 23% Dairy products 18% Meat, fish & eggs 10% Cookies, sweets & cakes 7%	Vegetables & fruit 40% Dairy & dairy products 22% Eggs 11% Ready to eat meals 5% Fats & oils 6%	Vegetables & potatoes 35% Meat & meat products 16% Milk & milk products 13% Fat spreads 11%
Vitamin D	Milk & dairy products 33% Fats & oils & gravies 27% Fish dishes 23% Cereals 6%	Fats & oils 25% Meat products & substitutes 20% Dietary supplements 18% Fish & shellfish 9% Dairy products & substitutes 7%	Meat, fish & eggs 67% Dairy products 10% Cookies, sweets & cakes 8% Fats & oils 5%	Fish & shellfish 26% Eggs 25% Milk & dairy products 23% Cereals & grains 15%	Meat & meat products 27% Fat spreads 19% Fish 18% Egg & egg dishes 14% Cereals & cereal products 13%
Vitamin E	Fat & oils & gravies 23% Cereals 21% Vegetables & vegetable dishes 10% Meat dishes 10% Miscellaneous 10% Fruit, berries & dishes 9%	Fats & oils 19% Sauces & seasonings 12% Dietary supplements 12% Vegetables 9% Fruit, nuts & seeds, olives 8% Cereals & cereal products 8%	Fats & oils 32% Fruit & vegetables19% Meat, fish & eggs 13% Soups 9% Cereals & cereal products 8%	Olive oil & other oils 46% Vegetables & fruit 20% Fish & shellfish 10% Ready to eat meals 4%	Vegetables & potatoes 20% Cereals & cereal products 19% Meat & meat products 12% Fat spreads 10%
Vitamin B1	Meat dishes 26% Cereals 24% Milk & dairy products 12% Fruit, berries & dishes 10% Vegetables & vegetable dishes 9% Potatoes & potato dishes 6%	Meat products & substitutes 21% Cereals & cereal products 18% Dietary supplements 14% Dairy products & substitutes 9% Non-alcoholic beverages 8%	Cereals & cereal products 29% Meat, fish & eggs 23% Fruit & vegetables 16% Dairy products 10%	-	Cereals & cereal products 35% Vegetables & potatoes 22% Meat & meat products 20% Milk & milk products 7%
Vitamin B2	Milk & dairy products 46% Cereals 15% Meat dishes 13% Vegetables & vegetables dishes 8% Fruit, berries & dishes 5%	Dairy products & substitutes 38% Dietary supplements 13% Meat products & substitutes 11% Cereals & cereal products 8% Vegetables 6%	Dairy products 31% Meat, fish & eggs 24% Cereals & cereal products 19% Fruit & vegetables 8% Cookies, cakes & sweets 8%	-	Milk & milk products 30% Cereals & cereal products 22% Meat & meat products 16% Vegetables & potatoes 7%

Niacin	Meat dishes 30% Cereals 18% Milk & dairy products 17% Miscellaneous 11% Vegetables & vegetables dishes 6% Fruit, berries & dishes 4%	Meat products & substitutes 31% Cereals & cereal products 15% Non-alcoholic beverages 13% Dietary supplements 12% Fruit, nuts & seeds, olives 6%	Meat, fish & eggs 42% Cereals & cereal products 23% Dairy products 11% Fruit & vegetables 7%	-	Meat & meat products 35% Cereals & cereal products 26% Vegetables & potatoes 9% Fish & fish dishes 8%
Vitamin B6	-	Meat products & substitutes 22% Dietary supplements 13% Non-alcoholic beverages 10% Cereals & cereal products 10% Potatoes & other tubers 9% Dairy products & substitutes 8%	Cereals & cereal products 29% Meat, fish & eggs 26% Fruit & vegetables 17% Soups 10% Dairy products 8%	-	Meat & meat products 23% Vegetables & potatoes 22% Cereals & cereal products 18% Milk & milk products 8%
Vitamin B12	Milk & dairy products 36% Meat dishes 26% Fish dishes 21% Cereals 8%	Dairy products & substitutes 38% Meat products & substitutes 27% Dietary supplements 12% Fish & shellfish 10%	Meat, fish & eggs 66% Dairy products 20% Cookies, sweets & cakes 4%	[†]Meat & meat products 28% Milk & dairy products 25% Fish & shellfish 23% Eggs 17%	Milk & milk products 34% Meat & meat products 27% Fish & fish dishes 17% Cereal & cereal products 8%
Folate	Cereals 29% Vegetables & vegetable dishes 18% Fruit, berries & dishes 15% Milk & dairy products 13% Meat dishes 10%	Cereals & cereal products 20% Vegetables 17% Dietary supplements 14% Dairy products & substitutes 12% Non-alcoholic beverages 9%	Cereals & cereal products 34% Fruit & vegetables 25% Meat, fish & eggs 11% Soups 10% Dairy products 6%	[†]Vegetables & fruit 31% Cereals & grains 18% Milk & dairy products 11% Eggs 8% Meat & meat products 7%	Vegetables & potatoes 28% Cereals & cereal products 27% Meat & meat products 10% Milk & milk products 8%
Vitamin C	Fruit, berries & dishes 54% Vegetables & vegetable dishes 25% Beverages 5% Meat dishes 4%	Vegetables 22% Fruit, nuts & seeds, olives 20% Non-alcoholic beverages 16% Dietary supplements 15% Potatoes & other tubers 10%	Fruit & vegetables 49% Cereals & cereal products 17% Soups 14% Non-alcoholic beverages 11%	Vegetables & fruit 80% Milk & dairy products 9% Ready to eat meals 5% Sauces & condiments 3%	Vegetables & potatoes 38% Non-alcoholic beverage 21% Fruit 20% Meat & meat products 8%

[*] Sources of nutrients (Portugal, Finland & UK) from food sources only (excluding nutritional supplements)

[†] Sources of vitamin B12 and folate in Spain provided for women 18-64y

[a] (Helldán et al., 2013), [b] (Van Rossum et al., 2020), [c] (Lopes C, 2016), [d] (Ruiz et al., 2016), [e] (Partearroyo et al., 2017), [f] (Olza et al., 2017a), [g] (Bates B., 2014)

Table 7. Sources of minerals for WCBA from National Nutrition Surveys in Europe

	[*]Finland [a] (Women 25-64y)	**Netherlands [b] (Women 19-79y)**	**[*]Portugal [c] (Total population 18-64y)**	**Spain [d, e, f] (Total Population 9-75y)**	**[*]UK [e] (Women 19-64y)**
Calcium	Milk & dairy products 61% Cereals 11% Vegetables & vegetable dishes 5% Fruit, berries & dishes 5% Beverages 5%	Dairy products & substitutes 56% Non-alcoholic beverages 13% Vegetables 6% Cereals & cereal products 7%	Dairy products 45% Non-alcoholic beverages 11% Cereals & cereal products 11% Fruit & vegetables 10%	Milk & dairy products 53% Vegetables & fruit 12% Cereals & grains 11% Ready to eat meals 5% Fish & shellfish 4%	Milk & milk products 38% Cereals & cereal products 30% Meat & meat products 8% Vegetables & potatoes 8%
Iron	Cereals 41% Meat dishes 20% Vegetables & vegetable dishes 9% Fruit, berries & dishes 6%	Cereals & cereal products 24% Meat, products substitute 15% Vegetables 10% Non-alcoholic beverages 10% Dietary supplements 8%	Cereals & cereal products 29% Meat, fish & eggs 21% Fruit & vegetables 15% Cookies, sweets & cakes 7%	[†]Vegetables & fruit 25% Meat & meat products 20% Cereals & grains 18% Fish & shellfish 7%	Cereals & cereal products 38% Meat & meat products 19% Vegetables & potatoes 17%
Magnesium	Cereals 29% Milk & dairy products 15% Beverages 15% Meat dishes 9% Vegetables & vegetable dishes 8% Fruit, berries & dishes 8%	Cereals & cereal products 23% Non-alcoholic beverages 15% Dairy products & substitutes 15% Fruits, nuts & seeds, olives 9% Meat products & substitutes 8%	Cereals & cereal products 24% Meat, fish & eggs 18% Fruit & vegetables 15% Dairy products 12% Non-alcoholic beverages 9%	Cereals & grains 23% Vegetables & fruit 20% Milk & dairy products 16% Meat & meat products 13% Fish & shellfish 6%	Cereals & cereal products 28% Vegetables & potatoes 17% Meat & meat products 14% Milk & milk products 10% Non-alcoholic beverages 7% Fruit 6%
Potassium	Milk & dairy products 19% Cereals 16% Vegetables & vegetable dishes 14% Beverages 14% Meat dishes 12% Fruit, berries & nuts 11%	Non-alcoholic beverages 16% Dairy products & substitutes 16% Meat products & substitutes 12% Vegetables 12% Fruits, nuts & seeds & olives 10% Potatoes & other tubers 9%	Fruit & vegetables 20% Cereals & cereal products 19% Meat, fish & eggs 19% Dairy products 15% Soups 9%	-	Vegetable & potatoes 25% Meat & meat products 16% Cereals & cereal products 14% Milk & milk products 12% Non-alcoholic beverages 9%
Iodine	Milk & dairy products 37% Cereals 22% Meat dishes 11% Fish & dishes 9% Vegetable & vegetable dishes 7%	-	-	-	Milk & milk products 35% Cereals & cereal products 11% Fish & fish dishes 11% Meat & meat products 9% Eggs & egg dishes 6%

[*] Sources of nutrients (Portugal, Finland & UK) from food sources only (excluding nutritional supplements)

[†] Sources of iron in Spain provided for women 18-64y

[a] (Helldán et al., 2013), [b] (Van Rossum et al., 2020), [c] (Lopes C, 2016), [d] (Ruiz et al., 2016), [e] (Samaniego-Vaesken et al., 2017), [f] (Olza et al., 2017b), [g] (Bates B., 2014)

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Aims and objectives

The overall aim of this research was to investigate the intake of macronutrients and micronutrients, compliance with dietary guidelines and the key sources of nutrients in women of child-bearing age in Ireland. This investigation used data from the National Adult Nutrition Survey (NANS) (2008-2010), which was the most recent nationally representative survey to investigate dietary intake, anthropometry and health and lifestyle characteristics of women of child-bearing age (WCBA) aged 18–50 years, living in the Republic of Ireland (*n* 487).

Objectives:

1. To estimate the mean daily intake of energy, macronutrients, dietary fibre and salt, to determine compliance with dietary guidelines and to identify the key dietary sources.

2. To estimate the mean daily intake of micronutrients, the prevalence of inadequate intakes and risk of excessive intakes and to identify the key dietary sources.

Chapter 2

National Adult Nutrition Survey: Methodology

Methodology

Analyses for the present thesis were based on data from the Irish National Adult Nutrition Survey (NANS), which was a cross-sectional survey conducted in the Republic of Ireland from 2008-2010 by the Irish Universities Nutrition Alliance (IUNA) units at University College Cork and University College Dublin to establish a database of habitual food and beverage consumption in a representative sample of 1500 adults aged between 18 and 90 years.

A detailed outline of the survey methodology and the methods relevant to this study are provided below. Further information and methods relating to additional data collected in the NANS such as questionnaires, (health & lifestyle, physical activity & food choice) anthropometric and blood pressure measurements is available at www.iuna.net. For the purposes of this thesis, data from the subgroup of women of child-bearing age (WCBA) aged 18-50 years (n 487) were used.

Ethical approval

The NANS was conducted according to the guidelines laid down in the Declaration of Helsinki and ethical approval was obtained from the Clinical Research Ethics Committee of the Cork Teaching Hospitals, University College Cork and the Human Ethics Research Committee of University College Dublin.

Sampling and recruitment methodology

The fieldwork phase was carried out between October 2008 and April 2010. Eligible participants in the NANS were adults aged 18 years and over who were free living and who were not pregnant or breastfeeding. A sample of adults were randomly selected from a database of names and addresses held by Data Ireland (An Post) and an introductory letter and information leaflet were posted to each person selected from the database. A second level of recruitment was used in which names and addresses were compiled through referrals from respondents and participation was invited for those that were contactable. A researcher called to potential respondents' homes to introduce the survey and invite participation. If the individual agreed to participate, a consent form was signed and the survey commenced. If the person was not at home, the researcher called on three more occasions on different days and at different times, before deeming them ineligible. The final response rate for the survey was 60%. Demographic analysis of the NANS sample has shown it to be nationally representative of Irish adults with respect to age, gender, social class and geographical location when compared to Irish Census 2006 data.

Food consumption data and quantification

Food and beverage intake data were collected using a 4-day semi-weighed food record. For all participants, the study period included at least one weekend day. The researcher made three visits to the participant during the 4-day recording period: an initial training visit to demonstrate how to complete the food diary and use a portable food scales that was provided, a second visit 24-36 hours into the recording period to review the diary, check for completeness and clarify details regarding specific food descriptors and quantities, and a final visit 1 or 2 days after the recording period to check the recordings from the final days and to collect the diary. Participants were asked to record detailed information regarding the amount, type and brand of all food, beverages and food supplements consumed over the four-day period and where applicable the cooking methods used, the packaging size and type and details of recipes and any leftovers. Participants were also encouraged to keep the packaging of foods consumed to provide further information on ingredient and nutritional information for the foods and beverages and also the packaging type used.

A quantification protocol that had been established by the IUNA for the North/South Ireland Food Consumption Survey (NSIFCS) (Harrington et al., 2001) was adapted for the NANS. Further details can be found on www.iuna.net however, it is summarised as follows:

1) Weighed (by respondent/manufacturer weights) - A portable food scales (Tanita KD-400, Japan) was given to each participant. The researcher gave detailed instructions (including a demonstration) as to how to use the food scales during the training session. This method was used to quantify 46% of foods and drinks consumed. A further 10% of weights were derived from

manufacturer's weights. To facilitate collection of such data, researchers asked participants to collect all packaging of food and beverages consumed.

2) Food Atlas – A photographic food atlas (Nelson et al., 1997) was used to quantify 16% of foods and beverages consumed.
3) Food Portion Sizes - "Food Portion Sizes" (Food Standards Agency, 2002a) was used to quantify 11% of foods and beverages consumed.
4) Household Measures - Measures such as teaspoon, tablespoon, fluid ounces, pint etc. were used to quantify 11% of foods and beverages consumed.
5) IUNA Weights - Average portion weights that had been ascertained for certain foods by the IUNA survey team were used. This method was used to quantify 4% of foods and beverages consumed.
6) Estimated - Food quantities were defined as estimated if the researcher made an estimate of the amount likely to have been consumed based on their knowledge of the participant's general eating habits as observed during the recording period. This method was used to quantify 2% of foods and beverages consumed.

Nutrient composition of foods

Food and beverage intake data were analysed using WISP© (Tinuviel Software, Anglesey, UK), which estimates nutrient intakes using data from McCance and Widdowson's The Composition of Foods, sixth (Food Standards Agency, 2002b) and fifth (Holland et al., 1995) editions plus all nine supplemental volumes (Holland et al., 1988; Holland et al., 1989; Holland et al., 1991; Holland et al., 1992a; Holland et al., 1993; Chan et al., 1994; Chan et al., 1995; Holland et al., 1996).

During the NANS, modifications were made to this food composition database to include recipes of composite dishes, nutritional supplements, fortified foods, generic Irish foods that were commonly consumed and new foods on the market (Black et al., 2011). Additionally, the food composition database was updated with values for total fat, saturated fat, mono-unsaturated fat, polyunsaturated fat, free sugars, sodium, vitamin D, iodine and folic acid, the details of which have been outlined in detail elsewhere (Giltinan, 2012; Black et al., 2015; (Kehoe et al., 2020); Li et al., 2016; McNulty et al., 2017; Walton et al., 2017).

Defining under-reporters of food (energy) intake

As under-reporting of food consumption can result in an overestimate of the prevalence of inadequacy in a population group (Carriquiry, 1999), under-reporters (URs) were identified and excluded from analysis when assessing adequacy of nutrient intakes. Basal metabolic rate (BMR) was predicted for each participant from standard equations using body weight and height and minimum energy intake cut-off points (1.10) calculated as multiples of BMR, were used to identify URs (28% of total sample) (Goldberg et al., 1991).

Anthropometry

Anthropometric measurements were taken by the researcher in the respondents' homes. Weight, height, waist and hip circumference and measures of body composition were recorded with full details provided at www.iuna.net (as outlined previously). With reference to the data included in this thesis, the estimated average requirement (EAR) for protein is derived based on kilogram of body weight (g/kg/d), and body weight was measured in duplicate using a Tanita body composition analyzer BC-420MA (Tanita Ltd, GB) to the nearest 0.1kg. Respondents were weighed after having voided, wearing light clothing and without shoes.

Quality Control

A number of quality control procedures were put in place in an attempt to minimise error and ensure consistency throughout the collection and utilisation of all data collected. Detailed SOPs were followed for each stage of data collection and data entry including training documents and coding manuals. Researchers received training that included role-play workshops prior to commencing fieldwork, where they were trained to take a natural and friendly approach to fieldwork and to avoid prompting foods. This was carried out in an attempt to make respondents feel at ease and so that the most reliable data possible could be obtained. It was stressed to respondents that they should not try to change or 'improve' their diet during the recording period. At the end of the recording period, respondents were asked whether their food intake had been the same as usual, less than usual or more than usual during the recording period and to explain why this might have been. Respondents were also asked whether they had been on a weight reducing or weight gain diet whilst taking part in the survey and if there were any items consumed during the recording period which had not yet been written down. Details were then recorded by the researcher in the food diary.

Each researcher was primarily responsible for the collection, quantification, coding and data entry of their own food diaries in an attempt to maintain consistency and were provided with detailed guidelines regarding each task. WISP-DES© (the food data-entry system) was set up to incorporate over-range checks for portion sizes, by generating a warning if a food weight was entered as five times a typical 'large' portion size. Researchers were also asked to rate each respondents' food diary as 'accurate and complete', 'inaccurate and complete', 'accurate and incomplete' and 'inaccurate and incomplete' so that data quality could be considered during certain analyses. A coding manual was developed for the questionnaires and all questionnaires were dual entered using customised questionnaire software (Q-Builder, Tinuviel Software, Anglesey, UK) which uses a rules-based validation process permitting answers from the coding manual only.

Classification of food groups

Each of the 2552 food codes (including 233 supplements) consumed during the survey were assigned to one of 68 food groups (Appendix I) in the database and also further aggregated into 19 food groups to facilitate investigation of food group intakes and contribution of food groups to nutrient intakes (Appendix II). Data cleaning and analyses were conducted using SPSS© Version 26.0 for Windows™ (SPSS Inc. Chicago, IL, US

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Chapter 3

Macronutrient intakes, compliance with recommendations and key sources in women of child-bearing age in Ireland

Introduction

It is well established that preconceptional health (including nutritional status) is critically important with regards to favourable maternal and infant outcomes in both the short- and long-term. It is estimated that up to 50% of pregnancies are unplanned thus optimal nutritional status is important for all women of child-bearing age (WCBA) and not just those with pregnancy intentions (Sedgh et al., 2014).

Data on intakes of energy, macronutrients, dietary fibre and salt in WCBA are available from national nutrition surveys in 19 European countries. These studies have identified that while intakes of protein and carbohydrate are generally sufficient in these population groups, intakes of total fat are above recommendations. Furthermore, this population group have high intakes of saturated fat, free sugar and salt and low intakes of dietary fibre (ANSES, 2014, Ax et al., 2016, Bates et al., 2020, Beslenme et al, 2016, Dubuisson et al., 2009 Dubuisson et al., 2019, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Temme et al., 2010, Van Rossum et al., 2020).

The Irish National Adult Nutrition Survey (NANS) (2008-2010) is the most recent nationally representative survey of adults in the Republic of Ireland (including WCBA 18-50 years). This chapter aims to use these data to estimate the mean daily intake (MDI) of energy, macronutrients, dietary fibre and salt, to determine compliance with dietary recommendations and to identify the key sources of these nutrients in WCBA in Ireland.

Methodology

The analyses for this chapter on women of child-bearing age (WCBA) (18-50 years) (*n* 487) are based on data from the National Adult Nutrition Survey (NANS) (2008-2010). A detailed survey methodology for the NANS including sampling, selection, recruitment, data collection, food quantification and nutrient composition is described in Chapter 2.

Estimation of nutrient intakes

The mean daily intake (MDI) of energy, macronutrients, dietary fibre and salt were estimated by summing the total amount of energy and each nutrient consumed and dividing the total by the number of recording days (four). The mean, standard deviation, median and interquartile range of energy, macronutrients, dietary fibre and salt intakes are presented for the total population of WCBA.

Compliance with energy and macronutrient recommendations

Nutrient intakes were compared with the most recent dietary reference values (DRVs) available from the European Food Safety Authority (EFSA) or the UK Scientific Advisory Committee on Nutrition (SACN). The Department of Health (DoH) UK (1991) DRVs were used if they were not superseded by updated DRVs. MDIs of carbohydrate and fat were compared to reference intake ranges recommended by EFSA for carbohydrate (45-60% total energy (%TE)) and for total fat (20-35%TE) (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010a, EFSA Panel on Dietetic Products Nutrition and Allergies, 2010b). The MDI of saturated fat was compared with the recommendation from the UK DoH for a population mean <10%TE (Department of Health, 1991). Monounsaturated fat (MUFA) and polyunsaturated fat (PUFA) intakes were compared with the minimum average population intake recommendations from the UK DoH of 12%TE for MUFA and 6%TE for PUFA (Department of Health, 1991). The MDI of protein was compared to the average requirement (0.66g/kg bodyweight (bw)) derived by EFSA excluding under-reporters (URs) (identified as outlined in Chapter 2) (EFSA Panel on Dietetic Products Nutrition and Allergies, 2012). The MDI of free sugar was compared to the recommended maximum average population intake of <5%TE from the UK SACN (Scientific Advisory Committee On Nutrition, 2015). The proportion (%) of WCBA with free sugar intakes below the World Health Organisation (WHO) guideline for individuals of <10%TE and the conditional guideline of <5%TE was also examined (World Health Organisation, 2015). For dietary fibre, the MDI was compared to the adequate intake (AI) of 25g/d as recommended by EFSA (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010a). Dietary salt was measured as sodium equivalents from food sources only (i.e. excluding discretionary salt: added in cooking or at the table).

Contribution of food groups to intakes of energy, macronutrients, dietary fibre and salt

All foods and drinks consumed in the NANS were allocated into one of nineteen food groups and then further subdivided into sixty-eight food groups (**Appendix I and II**). The percent contribution of each food group to mean daily intakes of energy, macronutrients and dietary fibre were calculated by the mean proportion method (Krebs-Smith et al., 1989) and the key contributors to each nutrient were determined in order of importance for the total population. The mean proportion method provides information about the sources that are contributing to the energy or nutrient intake 'per person'. The mean proportion method is the preferred method when determining important food sources of a nutrient for individuals in the population group as opposed to investigating the sources of a nutrient within the food supply. All analyses in this chapter were conducted using SPSS© Version 26 (SPSS, Inc., IBM, Chicago, IL, USA).

Results

The MDI of energy, macronutrients, dietary fibre and salt in WCBA aged 18-50 years in Ireland are presented in **Table 1**. The contribution (%) of food groups to the MDI of energy and these nutrients are presented in **Table 2**.

Energy

The MDI of energy in WCBA was 1742kcal/d (**Table 1**). The key sources of energy were ‘meat & meat products’, ‘breads & rolls’ and ‘sugars, confectionery, preserves & savoury snacks’ providing 38% of intakes (16, 14 and 8%, respectively). ‘Potatoes & potato products’, ‘milk & yogurt’ and ‘beverages’ each provided a further 7% of energy intake (of which alcoholic beverages provided 2%) and ‘grains, rice, pasta & savouries’ provided 6% (**Table 2**).

Total fat & fatty acids

The MDI of total fat among WCBA was 67g/d providing on average of 35%TE (**Table 1**). Fifty-seven percent of WCBA had a MDI of fat within the recommended intake range of 20-35% and 42% of WCBA had intakes exceeding 35%TE and <1% had intakes below 20%TE. The key sources of total fat in the diet were ‘meat & meat products’ (20%), ‘butter, spreading fats & oils’ (10%), ‘milk & yogurt’ (8%), ‘sugars, confectionery, preserves & savoury snacks’ (8%), ‘potatoes & potato products’ (7%) and ‘biscuits, cakes & pastries’ (7%) (**Table 2**). The MDI of saturated fat was 26g/d (13%TE), which exceeds the recommendation of <10%TE from the UK DoH (**Table 1**). The key sources of saturated fat were ‘meat & meat products’, ‘milk & yogurt’ and ‘butter, spreading fats & oils’ providing 19, 12 and 12% of intakes, respectively, while ‘cheeses’, ‘beverages’ and ‘biscuits, cakes & pastries’ each provided 8% of intakes (**Table 2**). MUFA provided 12%TE, in line with the UK DoH recommendation that MUFA should provide a minimum average population intake of 12%TE. The key sources of MUFA were ‘meat & meat products’ (24%), ‘butter, spreading fats & oils’ (10%), ‘sugars, confectionery, preserves & savoury snacks’ (8%), ‘potatoes & potato products’ (7%), ‘biscuits, cakes & pastries’ (7%) and ‘soups, sauces & miscellaneous foods' (6%) (**Table 2**). PUFA provided 6%TE, in line with the UK DoH recommendation that PUFA should provide a minimum average population intake of 6%TE. The key sources of PUFA in the diet were 'meat & meat products', 'potatoes & potato products' and 'vegetable & vegetable dishes' providing 18, 11 and 11% of intakes, respectively, while 'beverages' and 'butter, spreading fats & oils' each provided 9% of intakes (**Table 2**).

Protein

The MDI of protein was 69g/d providing 16%TE in WCBA (**Table 1**). The MDI of protein expressed per kg bodyweight was 1.0g/kg bw per day with 4% of WCBA having a MDI of protein below the EAR of 0.66g/kg bw from EFSA. The key sources of protein were 'meat & meat products' (38%), 'breads & rolls' (12%) 'milk & yogurt' (10%) and 'fish & fish dishes' (6%) (**Table 2**).

Carbohydrate

The MDI of carbohydrate was 201g/d with carbohydrate providing 44%TE **(Table 1**). Fifty-nine percent of WCBA had intakes of carbohydrate below the reference intake range of 45%TE while no individual had intakes greater than 60%TE. The key sources of carbohydrate were 'bread & rolls' (23%), 'potatoes & potato products' (10%), 'sugars, confectionery, preserves & savoury snacks' (10%), 'breakfast cereals' (9%) and 'grains, rice, pasta & savouries' (8%) (**Table 2**).

Total and free sugar

The MDIs of total and free sugar were 81g/d (17%TE) and 45g/d (9%TE), respectively (**Table 1**). The MDI of free sugar (9%TE) exceeds the UK SACN recommendation for a maximum average population intake of <5%TE. Thirty eight percent of WCBA had a MDI of free sugar greater than the SACN guideline of <10%TE and 82% had intakes greater than the WHO conditional guideline of <5%TE. The key sources of free sugar were 'sugars, confectionery, preserves & savouries' (17%), 'biscuits, cakes

& pastries' (17%), 'beverages' (15%) (primarily sugar sweetened carbonated beverages and squashes, 12%) and 'fruit & fruit juices' (9%) **(Table 2**).

Dietary fibre

The MDI of dietary fibre was 17g/d, which is below the AI of 25g/d proposed by the EFSA (**Table 1**). The key sources of dietary fibre were 'bread & rolls' (25%) (primarily wholemeal/brown bread & rolls 14%), 'vegetable & vegetable dishes' (18%), 'potatoes & potato products' (12%) and 'fruit & fruit juices' (10%) (**Table 2**).

Salt

The MDI of salt from food sources only (excluding discretionary salt added at table and in cooking) was 5.5g/d (**Table 1**). The key sources of salt were 'meat & meat products' (25%) (primarily processed meats 16%) 'bread & rolls' (21%), 'soups, sauces & miscellaneous foods' (10%) and 'vegetable & vegetable dishes' (5%) (**Table 2**).

Table 1. Mean daily intakes of energy, macronutrients, dietary fibre and salt in women of child-bearing age (18-50 years) (n 487) in Ireland

	Dietary Reference Value	Mean	SD	Median	P25	P75
Energy (kJ)		7305	2087	7190	5873	8521
Energy (kcal)		1741	499	1712	1395	2026
Total fat (g)		67.1	23.3	64.7	50.4	81.3
Total fat (%TE)	RI: 20 - 35%TE [a]	34.5	6.4	33.9	30.4	38.4
Saturated fat (g)		25.9	10.2	24.9	18.4	32.2
Saturated fat (%TE)	<10% TE [b]	13.3	3.6	13.1	10.9	15.2
Monounsaturated fat (g)		24.6	9.2	23.3	18.1	30.3
Monounsaturated fat (%TE)	12% TE [b]	12.7	4.8	12.0	9.6	15.7
Polyunsaturated fat (g)		12.5	5.5	11.7	8.6	15.0
Polyunsaturated fat (%TE)	6% TE [b]	6.6	2.8	6.1	4.4	7.8
Protein (g)		69.5	20.3	68.3	55.2	81.2
Protein (%TE)		16.4	3.7	15.9	14.0	18.1
Protein (g/kg bw)	EAR: 0.66g/kg bw [c]	1.0	1.0	0.3	0.8	1.2
Carbohydrate (g)		201	60.5	195	163	234
Carbohydrate (%TE)	RI: 45 - 60%TE [d]	43.6	6.4	43.3	39.3	47.7
Total sugar (g)		80.6	34.9	75.5	55.5	102
Total sugar (%TE)		17.3	5.5	17.1	13.5	20.8
Free sugar (g)		44.6	29.8	37.4	24.1	58.4
Free sugar (%TE)	5% [e], 10% [f]	9.4	5.1	8.8	5.8	12.0
Dietary fibre (g)	25g/d [d]	16.7	6.5	16.0	12.5	20.1
Salt (g)		5.5	5.3	1.8	4.3	6.5

TE= Total Energy, RI= Reference Intake, BW= Body Weight, EAR= Estimated Average Requirement.

[a] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010b), [b] (Department of Health, 1991), [c] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2012), [d] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010a), [e] (World Health Organisation, 2015), [f] (Scientific Advisory Committee On Nutrition, 2015)

Table 2. Contribution of food groups (%) to mean daily intakes of energy, macronutrients, dietary fibre and salt in women of child-bearing age (18-50 years) (n 487) in Ireland

	Energy	Total fat	Saturated fat	MUFA	PUFA	Protein	Carbohydrate	Total sugar	Free sugar	Dietary fibre	Salt
	%	%	%	%	%	%	%	%	%	%	%
Meat & meat products	15.7	20.4	19.4	24.0	17.6	38.2	4.3	2.9	3.0	5.3	25.1
Bread & rolls	13.8	5.5	5.2	3.8	5.8	12.2	22.5	5.2	0.8	24.5	21.1
Sugars, confectionery, preserves & savoury snacks	7.5	8.0	8.1	8.4	8.9	2.2	10.1	17.3	28.8	5.7	2.9
Beverages	7.3	0.4	0.7	0.1	0.0	1.3	5.6	12.1	15.1	0.1	1.2
Potatoes & potato products	7.3	7.0	4.8	7.3	10.8	3.4	10.4	1.3	0.0	11.8	2.5
Milk & yogurt	7.1	8.0	12.4	6.0	2.7	10.3	6.3	15.7	7.6	0.5	5.0
Grains, rice, pasta & savouries	6.0	4.3	4.1	4.2	4.7	5.0	8.3	1.5	0.7	6.4	4.8
Biscuits, cakes & pastries	5.7	6.7	8.0	7.0	4.9	2.2	7.0	8.1	15.1	4.0	3.8
Breakfast cereals	5.3	1.9	1.6	1.6	2.5	3.9	8.9	5.0	6.9	8.5	3.7
Vegetables & vegetable dishes	4.1	5.3	2.6	5.0	10.8	3.7	3.9	5.6	1.5	17.9	5.6
Butter, spreading fats & oils	3.7	10.3	12.1	10.0	8.7	0.1	0.1	0.1	0.0	0.0	2.8
Fruit & fruit juices	3.7	0.4	0.2	0.2	0.5	1.2	7.5	17.2	9.3	10.3	0.5
Soups, sauces & miscellaneous foods	3.1	5.3	3.1	6.5	8.0	1.3	2.0	3.1	4.1	2.1	9.9
Cheese	2.5	5.1	8.2	4.0	1.4	4.0	0.1	0.2	0.0	0.0	4.1
Fish & fish dishes	2.5	3.3	1.8	3.6	5.0	6.2	0.7	0.2	0.2	0.5	4.3
Creams, ice-creams & chilled desserts	2.2	2.7	4.1	2.2	1.1	1.0	2.2	4.1	6.8	0.6	0.7
Eggs & egg dishes	1.6	3.1	2.7	3.6	2.3	2.6	0.0	0.1	0.1	0.1	1.6
Nuts, seeds, herbs & spices	0.9	2.0	1.0	2.2	3.6	0.9	0.2	0.2	0.0	1.4	0.3
Nutritional supplements	0.1	0.2	0.0	0.1	0.8	0.3	0.0	0.0	0.0	0.3	0.0

MUFA= Monounsaturated fatty acid, PUFA= Polyunsaturated fatty acid. Note: Food groups are listed in order of contribution to energy intakes (decreasing order)

Discussion

This study provides information on the intakes of energy, macronutrients, dietary fibre and salt, compliance with recommendations and key sources in a nationally representative sample of WCBA in Ireland. As there are no DRVs for nutrient intakes specific to WCBA, intakes were compared with recommendations for women of all ages as appropriate. In summary, this study has shown that while protein intakes are sufficient in this population group, a large proportion of WCBA have total fat intakes above recommendations and carbohydrate intakes below recommendations. Furthermore, this population group have high intakes of saturated fat, free sugar and salt and low intakes of dietary fibre.

The above findings are discussed below in context with the literature and the implications of the findings for each nutrient. It is important to acknowledge that within the literature there are variations between studies in terms of age groups examined (e.g. 18-50 vs 18-75y). Furthermore, data available for sources of nutrients in Portugal are for the total population of men and women rather than women alone. As the categorisation of food groups varies between countries, some food groups are discussed as larger groups (e.g. dairy & dairy products) for a clearer comparison across the literature.

Energy

The MDI of energy in WCBA in Ireland was 1742kcal/d, which comprised of 35% fat, 44% carbohydrate and 16% protein. The MDI of energy observed in our study was similar to that reported for WCBA in other European countries including Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Norway, Portugal, Spain, Sweden, the Netherlands, the UK and Turkey (1613-2151kcal/d) (Ax et al., 2016, Bates et al., 2020, Beslenme et al, 2016, Dubuisson et al., 2019, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Temme et al., 2010, Van Rossum et al., 2020). For WCBA in Ireland 'cereal & cereal products' including potatoes contributed 33% of energy intake, 'meat, fish & eggs' contributed 20% of energy intake and 'dairy & dairy products' (i.e. 'milk & yogurt', 'cheese' and 'creams, ice-creams & chilled desserts') contributed 12% of energy intake. 'Top-shelf' foods (i.e. 'sugars, confectionery, preserves & savoury snacks', 'biscuits, cakes & pastries' and 'sugar-sweetened beverages') contributed 21% of energy intake. Despite the variations of classification of food groups across countries, the key contributors to energy intake for WCBA in other European countries were similar where 'cereal & cereal products' contributed 21-33%, 'meat & meat products' contributed 13-17% and 'dairy and dairy products' contributed 10-17% and 'top-shelf' foods (where comparable) contributed 8-20% (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Total fat and individual fatty acids

While dietary fat is an essential component of cell membranes and a pre-cursor for many signalling molecules, at 9kcal/g, it is the most energy-dense macronutrient. A high consumption of fat, especially saturated fat may increase the risk of chronic diseases including obesity in all population groups including WCBA which may increase the risk of gestational diabetes, preeclampsia and increased time taken to conceive (Clifton and Keogh, 2017, EFSA Panel on Dietetic Products Nutrition and Allergies, 2010b, Poston et al., 2016). The MDI of total fat for WCBA in Ireland was 35%TE which is in line with population recommendations for an average population intake of 35%TE (Department of Health, 1991), however, 42% of WCBA had intakes above the upper threshold of the recommended intake range of 35%TE (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010b). Consistent with our findings, intakes of total fat ranged from 32-35%TE in Iceland, Norway, Portugal, Sweden, the Netherlands and the UK, however, intake of total fat was higher for WCBA in Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Italy, Latvia, Lithuania, Spain, and Turkey (36-42%TE) (Ax et al., 2016, Bates et al., 2020, Beslenme et al, 2016, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Temme et al., 2010, Van Rossum et al., 2020). The key sources of total fat in the diet of WCBA in Ireland were ‘meat & meat products’ (20%), ‘dairy & dairy products’ (16%), ‘top-shelf’ foods (15%), ‘butter, spreading fats & oils’ (10%) and ‘potatoes & potato products’ (7%) (primarily, chipped, fried & roasted potatoes (5%)). The key contributors to total fat intake for WCBA in other European countries were similar where ‘meat & meat products’ contributed 18-25% and ‘dairy & dairy products’ contributed 14-20% of intakes. The contribution of ‘top-shelf’ foods to fat intake was slightly lower in other European countries compared to Ireland with a range of 9-12% in Portugal, Spain and the Netherlands, which can be explained by the variations in food group classifications (e.g. some biscuits/cakes are included in ‘cereal’ categories in these countries). The contribution of ‘fats & oils’ to fat intake was similar to our findings in the UK (10%), but higher for WCBA in other countries such as Finland, Portugal, Spain and the Netherlands (20-34%) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Due to the association of high saturated fat intake with an increase in LDL-cholesterol concentration and risk of coronary heart disease (CHD), the UK SACN have recommended that the average population intake should be <10%TE and while EFSA have not provided a quantitative guideline it is recommended to keep saturated fat intake as low as possible (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010b, Scientific Advisory Committee On Nutrition, 2015). The MDI of saturated fat for WCBA in Ireland was 13%TE which exceeds the recommendation of <10%TE from SACN (Scientific Advisory Committee On Nutrition, 2015). The MDI of saturated fat for WCBA in other European countries including Andorra, Austria, Denmark, Finland, France, Germany, Iceland, Italy, Lithuania, Norway, Sweden, the Netherlands and the UK ranged from 11-15%TE which are also above the recommendation of <10%TE (Ax et al., 2016, Bates et al., 2020, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Leclercq et al., 2009, Lundblad et al., 2019, Ministeri de Salut, 2013, Pedersen, 2015, Pomerleau et al., 2001, Steingrimsdottir et al., 2014, Van Rossum et al., 2020). The key sources of saturated fat for WCBA in Ireland were ‘dairy & dairy products’ (20%) ‘meat & meat products’ (19%), ‘top-shelf’ foods (16%), and ‘butter, spreading fats & oils’ (12%). Despite the variations in classification of food groups across countries, the key contributors to saturated fat intake for WCBA in other European countries were generally similar. 'Dairy & dairy products' contributed 22-34% of saturated fat intakes in Finland, Portugal, Spain, the Netherlands and the UK while 'meat & meat products' contributed 16-24% and 'top-shelf' foods contributed 11-20%. 'Fats & oils' contributed 10-13% of saturated fat intakes in the Netherlands and the UK, while the contribution from 'fats & oils' was higher (19-23%) in Finland, Portugal and Spain which may be partly explained by a higher consumption of fat spreads & oils in these countries (approx. 20-25g/d compared to 11g/d in WCBA in Ireland) (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Partearroyo et al., 2019, Ruiz et al., 2016, Van Rossum et al., 2020).

While it is recommended to reduce overall intakes of total fat, it is also important to improve the profile of fatty acid intake i.e. increase MUFA and PUFA intake (within recommended limits) due to their role in lowering the levels of LDL-cholesterol in the blood thereby reducing CHD risk (Casas et al., 2018, Clifton and Keogh, 2017, Zhu et al., 2019). The MDI of MUFA for WCBA in Ireland was 12%TE, which was in line with the recommendation for a minimum average population intake of 12%TE (Department of Health, 1991). The MDIs of MUFA in WCBA in other European countries ranged from 12-17%TE in Austria, Belgium, Denmark, Finland, France, Germany, Iceland, Italy, Norway, Portugal, Spain, Sweden and the UK which is above the recommendation of 12%TE with the exception of intakes for WCBA in the Netherlands (11%TE) (Ax et al., 2016, Bates et al., 2020, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Pedersen, 2015, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Temme et al., 2010, Van Rossum et al., 2020). The key sources of MUFA for WCBA in Ireland were 'meat & meat products' (24%), 'top-shelf' foods (15%) 'butter, spreading fats & oils' (10%), 'dairy & dairy products' (10%) and 'potatoes & potato products' (7%). The key contributors to MUFA intake for WCBA in other European countries were similar to that in Ireland with 'meat & meat products' contributing 17-24% of MUFA intake. The contribution of 'fats & oils' to MUFA intake was 23 and 25%, respectively in the Netherlands and Finland (Helldán et al., 2013, Van Rossum et al., 2020), while 'fats & oils' contributed 37% of MUFA intake in Portugal and 44% in Spain which may be partly explained by a higher consumption of olive oil in these countries (Lopes et al., 2017, Partearroyo et al., 2019). The contribution of 'dairy & dairy products' to MUFA intake in other European countries was similar to that for Ireland with a range of 9-12% in Finland, Portugal, Spain and the Netherlands. The contribution of 'top-shelf' foods to MUFA intake in WCBA in Portugal and Spain ranged from 7-9% (Ruiz et al., 2016, Temme et al., 2010). While overall intakes of MUFA in WCBA in Ireland were in line with recommendations, it is important to note that 'top-shelf' foods were a key contributor to intakes (15%), hence, in keeping with dietary guidelines it is important to obtain MUFA from higher quality dietary sources.

In addition to their role in lowering LDL-cholesterol concentrations, PUFAs have also been shown to have a role in nerve function, blood clotting, brain health and muscle strength (Department of Health, 1991, Shahidi and Ambigaipalan, 2018). The MDI of PUFA in WCBA in Ireland was 6%TE which was in line with the recommendation for a minimum average population intake of 6%TE (Department of Health, 1991). These findings were similar to that reported among WCBA across Europe where mean intakes of PUFA ranged from 5-7%TE in Austria, Belgium, Denmark, Finland, France, Iceland, Norway, Spain, Sweden and the Netherlands, while WCBA in Germany and Portugal had a MDI of PUFA of 4-5%TE which is below the recommended intake of 6%TE (Ax et al., 2016, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Lopes et al., 2017, Lundblad et al., 2019, Pedersen, 2015, Ruiz E, 2016, Steingrimsdottir et al., 2014, Temme et al., 2010, Van Rossum et al., 2020). The key sources of PUFA in WCBA in Ireland were 'meat & meat products' (18%), 'potatoes & potato products' (11%) and 'vegetable & vegetable dishes' (11%), while 'top-shelf' foods and 'butter, spreading fats & oils' each provided 9% of intakes. The contribution of 'fats & oils' to PUFA intake was higher in WCBA in Finland, Portugal, Spain and the Netherlands (22-35%) compared to Ireland which may partly be explained by a higher consumption of fats and oils in these countries as previously outlined. The contribution of 'meat & meat products' to PUFA intake for WCBA in Finland, Portugal, Spain and the Netherlands was similar to Ireland (10-27%). 'Cereal & cereal products' contributed 16-21% of PUFA intake in WCBA in Finland, Portugal and the Netherlands (Helldán et al., 2013, Lopes et al., 2017, Van Rossum et al., 2020).

Carbohydrate

The MDI of carbohydrate in WCBA in Ireland was 44%TE with 59% of WCBA having intakes below the recommended intake range of 45-60%TE (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010a). The MDI of carbohydrate for WCBA in Denmark, Finland, France, Lithuania, Norway and Spain ranged from 41-44% while higher intakes were reported for WCBA in Andorra, Belgium, Germany, Hungary, Iceland, Italy, Portugal, Sweden, the Netherlands and the UK (45-49%TE) (Ministeri de Salut, 2013, Elmadfa et al., 2009, Heuer et al., 2015, Nagy et al., 2017b, Steingrimsdottir et al., 2014, Leclercq et al., 2009, Lopes C, 2016, Ruiz et al., 2016, Ax et al., 2016, Van Rossum etal., 2020, Bates et al., 2014). The key sources of carbohydrate for WCBA in Ireland were 'bread & rolls' (23%), 'top-shelf' foods (22%), 'potatoes & potato products' (10%), 'breakfast cereals' (9%) and 'dairy & dairy products' (6%). The key sources of carbohydrate for WCBA in other European countries were 'cereal & cereal products' (39-50%), 'top-shelf' foods (7-26%) and 'dairy & dairy products' (6-13%) which are similar to our findings for WCBA in Ireland (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Whilst it is recommended to consume 45-60%E from carbohydrate to meet energy needs in the context of acceptable intake ranges for fat and protein, it is also recommended to reduce intake of sugars (particularly added or free sugars). The UK SACN recommends that the average population intake of free sugars should not exceed 5%TE (based on the effect of free sugar intake on the risk of dental caries and total energy intake) (Scientific Advisory Committee On Nutrition, 2015). Furthermore, the WHO recommended that free sugar intake should be kept below 10%TE for individuals (based on the effect of free sugar intake on body weight and dental caries) (World Health Organisation, 2015). Free sugar comprises of all monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and unsweetened fruit juices. The MDI of free sugar in WCBA in Ireland (9%TE) exceeded the SACN recommendation for an average population intake of <5%TE with 38% of WCBA having a MDI of free sugar greater than the WHO guideline of <10%TE. The intake of free sugar for WCBA in Ireland is slightly lower than that reported for WCBA in the Netherlands (11%TE) and the UK (11%TE) while the MDI of free sugar for WCBA in Spain was 7%TE (Bates et al., 2020, Ruiz et al., 2016, Van Rossum et al., 2020). The key sources of free sugar in WCBA in Ireland were ‘top-shelf’ foods (59%), ‘fruit’ (9%) and ‘dairy & dairy products’ (8%). The key sources of free sugar intake for WCBA in Portugal, Spain and the UK were similar to our findings for WCBA in Ireland where top-shelf’ foods (including sugar-sweetened beverages) contributed 46-78% of intakes and ‘dairy & dairy products’ contributed 6-13% of intakes (Lopes et al., 2017, Roberts et al., 2018, Ruiz et al., 2016).

EFSA have set an AI of 25g/d for fibre intakes in all adults (including WCBA) due to the association of low fibre intakes with impaired bowel function and constipation. Furthermore, the EFSA has reported that there is evidence of benefit to health associated with consumption of dietary fibre intakes greater than 25g/day (e.g. reduced risk of CHD and type 2 diabetes and improved weight maintenance) (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010a). The MDI of dietary fibre for WCBA in Ireland (17g/d) was below the AI of 25g/d (EFSA Panel on Dietetic Products Nutrition and Allergies, 2010a). The MDI of dietary fibre observed in our study of WCBA in Ireland was similar to that for WCBA in Andorra, Austria, Belgium, Denmark, Finland, France, Italy, Iceland, Latvia, Lithuania, Portugal, Spain, Sweden, Turkey, the Netherlands and the UK (16-21g/d), while the intake of dietary fibre for WCBA in Norway and Germany was higher (25-27g/d) (Ax et al., 2016, Bates et al., 2020, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Temme et al., 2010, Van Rossum et al., 2020). The key sources of dietary fibre in WCBA in Ireland were ‘bread & rolls’ (25%), ‘vegetable & vegetable dishes’ (18%), ‘potatoes & potato products’ (12%) and ‘fruit & fruit juices’ (10%). The key sources of dietary fibre for WCBA in other European countries were ‘cereal & cereal products’ (32-52%), ‘fruit’ (8-19%) and ‘vegetables’ (13-34%) which was similar to our findings for WCBA in Ireland (Robert et al., 2018, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Protein

EFSA has set an EAR of 0.66g/kg bodyweight/day for all adults including WCBA based on requirements for tissue growth and maintenance (EFSA Panel on Dietetic Products Nutrition and Allergies, 2012). The MDI of protein for WCBA in Ireland was 1.0g/kg bw with just 4% of WCBA having intakes below the EAR. The MDI of protein (%TE) for WCBA in Ireland was 16%TE which is similar to the intakes reported for WCBA in Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Norway, Portugal, Spain, Sweden, Turkey, the Netherlands and the UK (14-20%TE) (Ax et al., 2016, Bates et al., 2020, Beslenme et al, 2016, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Temme et al., 2010, Van Rossum et al., 2020). The key sources of protein for WCBA in Ireland were ‘meat & meat products’ (38%), ‘dairy & dairy products’ (14%), ‘breads & rolls’ (12%) and ‘fish & fish dishes’ (6%). The key sources of protein for WCBA in other European countries were ‘meat & meat products’ (27-46%), ‘dairy & dairy products’ (14-27%), ‘cereal & cereal products’ (15-23%) and ‘fish’ (5-11%) which was similar to our findings for WCBA in Ireland (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Salt

Due to the association of high salt intake with the risk of raised blood pressure and cardiovascular diseases, the FSAI have set an achievable target for a maximum population intake of <6g/d of salt from all dietary sources (including discretionary salt) (Food Safety Authority of Ireland, 2016). The MDI for WCBA in Ireland of salt from food sources only (excluding discretionary salt) was 5.5g/d. As it is estimated that 25–30% of salt intake in Irish adults (similar to other countries) is from discretionary sources (Giltinan et al., 2020) , urinary salt is a more accurate reflection of total intake. Urinary salt intakes have previously been determined for this population group and it was found that mean urinary salt excretion exceeded the maximum population target of <6g/d for WCBA in Ireland (9.8g/d) (Giltinan et al., 2020). The MDI of salt from food sources only observed in our study for WCBA (5.5g/d) in Ireland was similar to that for WCBA in Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Iceland, Latvia, Lithuania, Norway, Portugal, Spain, Sweden, Turkey and the U.K (4.1-7.6g/d), as these countries did not include estimates of discretionary salt intake, while WCBA in Hungary had the highest intake of 12g/d, due to the inclusion of table salt in their estimates of salt intake (ANSES, 2014, Ax et al., 2016, Bates et al., 2020, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Temme et al., 2010, Van Rossum et al., 2020). The key sources of salt in the diet for WCBA in Ireland were ‘meat & meat products’ (25%) (primarily processed meats 16%), ‘bread & rolls’ (21%), ‘soups, sauces & miscellaneous foods’ (10%) and ‘vegetable & vegetable dishes’ (5%). Despite the variations of classification of food groups across countries, the key contributors of salt intake for WCBA in other European countries were similar where ‘cereal & cereal products’ contributed 21-33%, ‘meat & meat products’ contributed 18-25% and ‘soups/sauces’ contributed 8-17% (Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Strengths and limitations

The key strengths of this study are the nationally representative sample included in the NANS and the detailed dietary intake data collected. It is well acknowledged that misreporting or under reporting of energy intake is a limitation with all dietary assessment; however, this issue was minimised by a high-level of researcher–participant interaction (three-visits over the 4-day period) by trained nutritionists. Additionally, where appropriate, intakes were expressed as a percentage of energy intake which partially corrects this bias.

Conclusion

In summary, this study has reported on the intakes of energy, macronutrients, dietary fibre and salt, compliance with recommendations and key sources in a nationally representative sample of WCBA in Ireland. Overall, this study has found that while protein intakes are sufficient in this population group, a large proportion of WCBA in Ireland have total fat intakes above recommendations and carbohydrate intakes below recommendations. Furthermore, this population group have high intakes of saturated fat, free sugar and salt and low intakes of dietary fibre compared to generally accepted recommendations. These findings are similar to that found in other European countries for WCBA and will have important implications for public health guidance for this vulnerable population group. Furthermore, information about the relative contributions of specific foods to nutrient intakes will be useful to both policy makers and the food industry to develop targeted dietary strategies to improve the diets of WCBA in Ireland.

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Chapter 4

Micronutrient intakes, adequacy and excess and key sources in women of child-bearing age in Ireland

Introduction

It is well established that women's pre-conceptual health (including nutritional status) is not only important for the health of the individual themselves but also sets the foundation for a successful pregnancy and the subsequent health of occurring offspring. Micronutrient deficiencies, in particular, can adversely affect fertility, pregnancy outcomes, and risk of congenital disabilities in an occurring pregnancy (Gómez et al., 2020, Rai et al., 2015). However as mentioned in previous chapters, up to 50% of pregnancies are unplanned, thus optimal nutritional status is important for all women of child-bearing age (WCBA) not just those with pregnancy intentions (Sedgh et al., 2014).

With one notable exception, micronutrient recommendations for WCBA have not been differentiated by pregnancy intention and are similar to recommendations for other population groups (EFSA Panel on Dietetic Products and Allergies, 2010). The exception to this is the recommendation of a folic acid supplement of 400µg for all women who are sexually active regardless of pregnancy intention (Gomes et al., 2016). This recommendation results from the strong evidence that folic acid (the synthetic form of folate) when taken prior to conception and during the first few weeks of pregnancy can reduce the risk of neural tube defects (NTD) in an occurring pregnancy (Prevention of neural tube defects, 1991). In Ireland, it has previously been reported that just 6% of WCBA complied with the recommendation to take a 400µg folic acid supplement daily (Walton et al., 2019). There are no other specific micronutrient recommendations for WCBA.

A review of the literature has shown that data on micronutrient intakes in WCBA are available from national nutrition surveys in 19 countries. These studies have identified that WCBA across Europe have low intakes and a high prevalence of inadequate intakes for vitamin D, folate, riboflavin, vitamin C, calcium, iron, magnesium, potassium and iodine (Ministeri de Salut, 2013, Elmadfa et al., 2009, Vandevijvere et al., 2009, Pedersen, 2015, Helldán et al., 2013, Dubuisson et al., 2009, Heuer et al., 2015, Nagy et al., 2017b, Steingrimsdottir et al., 2014, Leclercq et al., 2009, Institute of Food Safety et al., 2017, Pomerleau et al., 2001, Lopes et al., 2016, Ruiz et al., 2016, Ax et al., 2016, Van Rossum et al., 2020, Bates et al., 2014, Beslenme et al, 2016).

The Irish National Adult Nutrition Survey (NANS) (2008-2010) is the most recent nationally representative survey of adults in the Republic of Ireland (including WCBA 18-50 years). This chapter aims to use these data to estimate the mean daily intake and sources of micronutrients in WCBA in Ireland. Furthermore, the prevalence of inadequate intakes and the risk of excessive intakes for micronutrients will be determined.

Methodology

The analyses for this chapter for women of child-bearing age (WCBA) (18-50 years) (*n* 487) are based on data from the National Adult Nutrition Survey (NANS) (2008-2010). A detailed survey methodology for the NANS including sampling, selection, recruitment, data collection, food quantification and nutrient composition is described in Chapter 2.

Estimation of nutrient intakes

Dietary intake data (including contribution from nutritional supplements) were analysed using WISP© (Tinuviel Software, Anglesey, UK), which estimates nutrient intakes using data from McCance and Widdowson's The Composition of Foods, sixth (Food Standards Agency, 2002b) and fifth (Holland et al., 1995) editions plus all nine supplemental volumes (with further detail outlined in Chapter 2) (Holland et al., 1988; Holland et al., 1989; Holland et al., 1991; Holland et al., 1992a; Holland et al., 1993; Chan et al., 1994; Chan et al., 1995; Holland et al., 1996). Dietary folate equivalents (DFE) were estimated as 1µg DFE = 1µg food folate + (1.7Xfolic acid) (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014a).

For each micronutrient, the mean daily intake (MDI) was estimated by summing the total amount of each nutrient consumed and dividing by the number of recording days (four). The mean, standard deviation, median and interquartile range of micronutrients intakes are presented for the total population of WCBA.

Adequacy of micronutrient intakes

The prevalence of inadequate intakes of micronutrients was estimated using estimated average requirements (EARs) as cut off points. This method has been shown to be effective in obtaining a realistic estimate of the prevalence of dietary inadequacy (de Lauzon et al., 2004). EARs published by the European Food Safety Authority (EFSA) were used for vitamin A, riboflavin, total niacin equivalents, vitamin B6, dietary folate equivalents (DFE), vitamin C, calcium, iron and zinc (EFSA Panel on Dietetic Products Nutrition and Allergies, 2013, EFSA Panel on Dietetic Products Nutrition and Allergies, 2014a, EFSA Panel on Dietetic Products Nutrition and Allergies, 2014d, EFSA Panel on Dietetic Products Nutrition and Allergies, 2015a, EFSA Panel on Dietetic Products Nutrition and Allergies, 2015b, EFSA Panel on Dietetic Products Nutrition and Allergies, 2015c, EFSA Panel on Dietetic Products Nutrition and Allergies, 2015e, EFSA Panel on Dietetic Products Nutrition and Allergies, 2016d, EFSA Panel on Dietetic Products Nutrition and Allergies, 2017). EARs established by the UK Department of Health (DoH) were used for vitamin B12 and magnesium (Department of Health, 1991). The US Institute of Medicine (IOM) and Food and Nutrition Board (FNB) EARs were used for vitamin D and iodine, respectively (Food and Nutrition Board, 2001, Institute of Medicine, 2011).

As under-reporting of food consumption can result in an overestimate of the prevalence of inadequacy in a population group (Carriquiry, 1999), under-reporters (URs) were identified and excluded from analyses when assessing adequacy. Basal metabolic rate (BMR) was predicted for each participant from standard equations using body weight and height and minimum energy intake cut-off points calculated as multiples of BMR were used to identify URs (31% of sample).

For micronutrients such as vitamin E and potassium, no EAR has been established by the EFSA, the UK DoH or the US IOM, therefore, MDIs were compared to the adequate intake (AI) (the average observed daily intake level that is assumed to be adequate) as proposed by EFSA (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015f, EFSA Panel on Dietetic Products Nutrition and Allergies, 2016a).

Risk of excessive intakes of micronutrients

The risk of excessive intakes of micronutrients was evaluated using the tolerable upper intake level (UL) as a reference value. The UL is defined as the maximum level of total chronic daily intake of a nutrient judged to be unlikely to pose a risk of adverse health effects to humans. For nutrients with established ULs, the proportion of the population with MDIs exceeding the UL was calculated. ULs have been derived by EFSA/EU Scientific Committee for Food for vitamin A (retinol), vitamin D, vitamin E, pre-formed niacin, vitamin B6, folic acid, calcium and iodine (EFSA Panel on Dietetic Products Nutrition and Allergies, 2006, EFSA Panel on Dietetic Products

Nutrition and Allergies, 2015a, EFSA Panel on Dietetic Products Nutrition and Allergies, 2016c). The UL from the US FNB was used for vitamin C (Food and Nutrition Board & Institute of Medicine, 2000).

Contribution of food groups to intakes of micronutrient intakes

All foods and beverages consumed in the NANS were allocated into one of nineteen food groups and then further subdivided into sixty-eight food groups (**Appendix I and II**). The percent contribution of each food group to the MDI of micronutrients was calculated by the mean proportion method (Krebs-Smith et al., 1989) and the key contributors to each micronutrient were determined in order of importance for the total population. The mean proportion method provides information about the sources that are contributing to the nutrient intake 'per person'. The mean proportion method is the preferred method when determining important food sources of a nutrient for individuals in the population group as opposed to investigating the sources of a nutrient within the food supply. All analyses in this chapter were conducted using SPSS© Version 26 (SPSS, Inc., IBM, Chicago, IL, USA).

Results

The MDI of micronutrients in WCBA aged 18-50 years in Ireland are presented in **Table 1**. The proportion of WCBA with micronutrient intakes below the EAR (excluding URs) are presented in **Table 2**. The proportion of WCBA with micronutrient intakes above the UL are presented in **Table 3**. The contribution (%) of food groups to the MDI of vitamins and minerals in WCBA are presented in **Table 4** and **Table 5** respectively.

Vitamin A

The MDI of vitamin A in WCBA was 948µg/d (**Table 1**). The proportion of WCBA with intakes of vitamin A below the EAR was 18% (**Table 2**). The proportion of this population with retinol intakes above the UL was 0.6% (**Table 3**). The key sources of vitamin A were 'vegetable & vegetable dishes' (37%), 'milk & yogurt' (10%), 'meat & meat products' (9%), 'soup, sauces & miscellaneous foods' (8%) and 'butter, spreading fats & oils' (8%) (**Table 4**).

Vitamin D

The MDI of vitamin D in WCBA was 3.8µg/d (**Table 1**). The proportion of WCBA with intakes of vitamin D below the EAR was 93% (**Table 2**). No individual in the population had intakes of vitamin D above the UL (**Table 3**). The key sources of vitamin D were 'meat & meat products' (25%), 'fish & fish dishes' (16%), 'milk & yogurt' (12%), 'breakfast cereals' (9%), 'egg & egg dishes' (8%) 'butter, spreading fats & oils' (8%) and 'nutritional supplements' (7%) (**Table 4**).

Vitamin E

The MDI of vitamin E in WCBA was 12.2mg/d (**Table 1**). As there has been no EAR set for vitamin E, it was not possible to assess adequacy in this population group, however, the MDI was above the AI proposed by EFSA of 11mg/d. The proportion of this population with intakes of vitamin E above the UL was 0.4% (**Table 3**). The key sources of vitamin E were 'vegetables & vegetable dishes' (13%), 'butter, spreading fats & oils' (9%), 'soup, sauces & miscellaneous foods' (9%), 'sugar, confectionery, preserves & savoury snacks' (8%), 'meat & meat products' (8%), 'potatoes & potato products' (8%), 'nutritional supplements' (7%) and 'biscuits, cakes & pastries' (6%) (**Table 4**).

Vitamin C

The MDI of vitamin C in WCBA was 125mg/d (**Table 1**). The proportion of WCBA with intakes of vitamin C below the EAR was 48% (**Table 2**). The proportion of this population with intakes of vitamin C above the UL was 0.4% (**Table 3**). The key sources of vitamin C were 'fruit & fruit juices' (28%) (with equal contributions from 'fruit' and 'fruit juices'; 14% each), 'vegetable & vegetable dishes' (24%), 'potatoes & potato products' (14%) and 'nutritional supplements' (10%) (**Table 4**).

Thiamin

The MDI of thiamin in WCBA was 3.3mg/d (**Table 1**). The proportion of WCBA with thiamin intakes below the EAR was 0% (**Table 2**). As an upper level for thiamin has not been set by EFSA or the FNB, it was not possible to assess the proportion of WCBA with intakes above the UL. The key sources of thiamin were 'meat & meat products' (18%), 'bread & rolls' (16%), 'breakfast cereals' (14%), 'potatoes & potato products' (10%), 'nutritional supplements' (9%) and 'vegetables & vegetable dishes' (8%) (**Table 4**).

Riboflavin

The MDI of riboflavin in WCBA was 3.0mg/d (**Table 1**). The proportion of WCBA with intakes below the EAR was 25% (**Table 2**). As no UL has been set for riboflavin by EFSA or the FNB, it was not possible to examine the risk of excessive intakes of riboflavin in this population. The key sources of riboflavin were 'milk & yogurt' (24%), 'meat & meat products' (14%), 'breakfast cereals' (14%), 'nutritional supplements' (9%), 'beverages' (8%) and 'bread & rolls' (5%) (**Table 4**).

Total Niacin Equivalents

Total niacin intake is estimated from preformed niacin and potential niacin (from tryptophan). The MDI of total niacin in WCBA was 24.5mg/d (**Table 1**). The proportion of WCBA with intakes of niacin below the EAR was 1.8% (**Table 2**). No individual in the population had intakes of preformed niacin above the UL (**Table 3**). The key sources of niacin were 'meat & meat products' (38%), 'breakfast cereals' (13%), 'bread & rolls' (11%) and 'nutritional supplements' (7%) (**Table 4**).

Vitamin B6

The MDI of vitamin B6 in WCBA was 3.9mg/d (**Table 1**). The proportion of WCBA with intakes of vitamin B6 below the EAR was 5.1% (**Table 2**). The proportion of this population with intakes of vitamin B6 above the UL was 2.3% (**Table 3**). The key sources of vitamin B6 were 'meat & meat products' (22%), 'potatoes & potato products' (14%), 'breakfast cereals' (12%), 'nutritional supplements' (9%), 'vegetables & vegetable dishes' (6%), 'fruit & fruit juices' (6%) and 'milk & yogurt' (5%) (**Table 4**).

Vitamin B12

The MDI of vitamin B12 was 7.7µg/d (**Table 1**). The proportion of the population with intakes below the EAR was 5.4% (**Tables 2**). As no UL has been derived for vitamin B12 by EFSA or the FNB, it was not possible to examine the prevalence of excessive intakes of vitamin B12 in this population. The key sources of vitamin B12 were 'meat & meat products' (27%), 'milk & yogurt' (22%), 'fish & fish dishes' (15%), 'nutritional supplements' (7%) and 'breakfast cereals' (6%) (**Table 4**).

Dietary Folate Equivalents (DFE)

The MDI of DFE in WCBA was 399µg/d (**Table 1**). The proportion of WCBA with intakes below the EAR was 32% (**Table 2**). The proportion of this population with intakes of folic acid above the UL was 0.4% (**Table 3**). The key sources of DFE were ‘breakfast cereals’ (16%), ‘bread & rolls’ (13%), ‘vegetables & vegetable dishes’ (10%), ‘milk & yogurt’ (9%), ‘potatoes & potato products’ (8%) and ‘beverages’ (7%) (**Table 4).**

Calcium

The MDI of calcium in WCBA was 807mg/d (**Table 1**). The proportion of WCBA with intakes of calcium below the EAR was 41% (**Table 2**). The proportion of this population with intakes of calcium above the UL was 0.2% (**Table 3**). The key sources of calcium were ‘milk & yogurt’ (30%), ‘bread & rolls’ (19%), ‘cheeses’ (9%), ‘meat & meat products’ (5%) and ‘grains, rice, pasta & savouries’ (5%) (**Table 5**).

Iron

The MDI of iron in WCBA was 14.0mg/d (**Table 1**). The proportion of WCBA with intakes of iron below the EAR was 10% (**Table 2**). The proportion of the population with intakes of iron above the UL was 2.5% (**Table 3**), mainly attributable to the use of nutritional supplements and the conservative UL (45mg/d) based on gastrointestinal side effects. The key sources of iron were ‘breakfast cereals’ (18%), ‘bread & rolls’ (18%), ‘meat & meat products’ (15%), ‘vegetable & vegetable dishes’ (8%), ‘beverages’ (6%) and ‘nutritional supplements’ (6%) (**Table 5**).

Magnesium

The MDI of magnesium in WCBA was 250mg/d (**Table 1**). The proportion of the population with intakes below the EAR was 18% (**Table 2**). A UL of 250mg/d has been set by EFSA for magnesium from supplements or added to foods or beverages. No individual in this population had magnesium intakes from supplements above this UL. The key sources of magnesium were ‘bread & rolls’ (14%), ‘meat & meat products’ (14%), ‘beverages’ (11%), ‘milk & yogurt’ (10%), ‘potatoes & potato products’ (8%) and ‘breakfast cereals’ (7%) (**Table 5**).

Zinc

The MDI of zinc in WCBA was 8.9mg/d (**Table 1**). As the EAR for zinc is set based on intakes of phytate and there are no estimates of phytate intakes in this population it was not possible to estimate the prevalence of inadequate zinc intakes in WCBA in Ireland. The proportion of the population with intakes of zinc above the UL was 0.6% (**Table 3**). The key sources of zinc were ‘meat & meat products’ (31%), ‘bread & rolls’ (13%), ‘milk & yogurt’ (11%), ‘breakfast cereals’ (6%) and ‘grains, rice, pasta & savouries’ (6%) (**Table 5**).

Iodine

The MDI of iodine in WCBA was 132µg/d (**Table 1**). The proportion of WCBA with intakes of iodine below the EAR was 26% (**Table 2**). The proportion of the population with intakes of iodine above the UL was 0% (**Table 3**). The key sources of iodine were ‘milk & yogurt’ (50%), ‘fish and fish dishes’ (6%), ‘beverages’ (6%) and ‘egg & egg dishes’ (5%) (**Table 5**).

Potassium

The MDI of potassium in WCBA was 2637mg/d (**Table 1**). As no EAR has been set for potassium, intakes were compared to the AI proposed by EFSA of 3500mg/d. As the MDI was below the AI, the adequacy of intakes of potassium in this population group cannot be determined. As no UL has been defined by EFSA or the FNB for potassium, it was not possible to examine the proportion of this population at risk of excessive intakes of potassium. The key sources of potassium were ‘meat & meat products’ (17%), ‘potatoes & potato products’ (15%), ‘milk & yogurt’ (13%), ‘beverages’ (11%) and ‘vegetable & vegetable dishes’ (9%) (**Table 5**).

Table 1. Mean daily intake of micronutrients in women of child-bearing age (18-50 years) *(n* 487*)* in Ireland

	Mean	**SD**	**Median**	**P25**	**P75**
Vitamin A (µg)	948	769	763	504	1208
Vitamin D (µg)	3.8	3.4	2.7	1.7	4.6
Vitamin E (mg)	12.2	30.6	8.4	6.2	12.1
Vitamin C (mg)	125	288	76.3	42.2	121
Thiamin (mg)	3.3	10.6	1.4	1.1	1.9
Riboflavin (mg)	3.0	8.2	1.6	1.2	2.4
Total niacin equivalents (mg)	24.5	19.1	20.4	15.8	28.4
Vitamin B6 (mg)	3.9	9.0	2.1	1.6	2.9
Vitamin B12 (µg)	7.7	51.6	3.5	2.4	4.9
Dietary folate equivalents (DFE) (µg)	399	592	285	202	439
Folic acid (µg)	120	345	47.0	11.1	126
Calcium (mg)	807	355	749	590	983
Iron (mg)	14.0	19.7	10.4	7.8	13.7
Magnesium (mg)	250	92.7	237	191	297
Zinc (mg)	8.9	5.3	7.7	6.0	9.8
Iodine (µg)	132	74.5	119	81.1	168
Potassium (mg)	2637	958	2534	2096	3131

Table 2. Proportion of women of child-bearing age (18-50 years) in Ireland with micronutrient intakes below the Estimated Average Requirement (EAR) (excluding under-reporters) (*n* 335)

	EAR	**% below EAR**
Vitamin A	490µg/d [a]	17.9
Vitamin D	10µg/d [b]	93.4
Vitamin C	80mg/d [c]	47.8
Thiamin	0.072mg/MJ [d]	0.0
Riboflavin	1.3mg/d [e]	25.1
Total niacin equivalents	1.3mg/MJ [f]	1.8
Vitamin B6	1.3mg/d [g]	5.1
Vitamin B12	1.25µg/d [h]	5.4
Dietary folate equivalents (DFE)	250µg/d [i]	31.9
Calcium	18-24y: 860mg/d 25-50y: 750mg/d [j]	41.2
Iron	7mg/d [k]	9.6
Magnesium	18y: 250mg/d 19-50y: 200mg/d [l]	17.6
Iodine	95µg/d [m]	25.7

[a] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015e), [b] (Institute of Medicine, 2011), [c] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2013) , [d] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2016b), [e] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2017), [f] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014c), [j] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2016d), [h] (Department of Health, 1991), [i] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014a), [j] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015a), [k] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015c), [l] (Department of Health, 1991), [m] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014b).

Table 3. Proportion of women of child-bearing age (18-50 years) in Ireland with micronutrient intakes above the Tolerable Upper Intake Level (UL) (*n* 487)

	UL	**% above UL**
Retinol	3000µg/d [a]	0.6
Vitamin D	100µg/d [b]	0.0
Vitamin E	300mg/d [a]	0.4
Vitamin C	2000µg/d [a]	0.4
Preformed niacin	900mg/d [a]	0.0
Vitamin B6	25mg/d [a]	2.3
Folic acid	1000µg/d [a]	0.4
Calcium	2500mg/d [c]	0.2
Iron	45mg/d [a]	2.5
Zinc	25mg/d [a]	0.6
Iodine	600µg/d [a]	0.0

[a] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2006), [b] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2016c), [c] (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015a)

Table 4. Contribution of food groups (%) to the mean daily intake of vitamins in women of child-bearing age (18-50 years) (*n* 487) in Ireland

	Vit A	Vit D	Vit E	Vit C	Thiamin	Riboflavin	Niacin	Vit B6	Vit B12	DFE
	%	%	%	%	%	%	%	%	%	%
Meat & meat products	9.3	24.9	7.7	4.8	17.7	14.4	38.1	22.3	26.9	5.6
Bread & rolls	1.3	1.5	4.7	0.1	16.0	4.9	11.0	5.2	0.4	13.4
Sugars, confectionery, preserves & savoury snacks	0.9	0.2	7.8	2.6	2.5	3.6	2.0	2.7	1.6	1.9
Beverages	2.0	0.1	0.3	3.0	0.3	7.6	5.7	4.4	1.5	7.3
Potatoes & potato products	0.7	1.3	7.7	13.5	10.1	1.3	3.5	13.7	0.3	8.4
Milk & yogurt	10.2	12.4	4.1	5.9	5.3	24.4	1.8	5.3	21.6	8.7
Grains, rice, pasta & savouries	2.4	2.4	4.4	0.9	3.4	2.2	2.8	1.8	2.8	2.2
Biscuits, cakes & pastries	1.4	3.6	6.4	0.3	2.2	1.5	1.1	0.8	1.0	1.1
Breakfast cereals	0.4	9.3	4.2	4.6	14.4	14.2	12.8	11.8	6.2	16.1
Vegetables & vegetable dishes	37.1	0.6	12.7	23.8	7.9	2.8	3.6	6.3	0.5	10.3
Butter, spreading fats & oils	7.5	7.9	9.3	0.0	0.1	0.2	0.1	3.7	2.6	4.7
Fruit & fruit juices	1.4	0.0	4.6	27.7	4.3	2.4	2.1	5.7	0.2	5.1
Soups, sauces & miscellaneous foods	7.7	0.8	8.7	2.3	3.0	1.8	0.9	1.4	1.5	1.6
Cheeses	6.1	1.3	0.8	0.0	0.3	3.0	0.1	0.5	4.3	1.1
Fish & fish dishes	0.5	16.4	3.7	0.3	1.7	1.8	5.9	3.7	14.6	1.0
Creams, ice-creams & chilled desserts	2.4	2.1	1.6	0.4	0.7	1.8	0.2	0.3	1.5	0.4
Eggs & egg dishes	4.1	8.2	2.6	0.2	0.7	3.1	0.1	0.8	5.9	1.8
Nuts, seeds, herbs & spices	0.2	0.0	1.5	0.1	0.7	0.2	0.8	0.5	0.0	0.4

DFE = Dietary folate equivalents

Note: Food groups are listed in order of contribution to energy intakes (decreasing order)

Table 5. Contribution of food groups (%) to the mean daily intake of minerals in women of child-bearing age (18-50 years) (*n* 487) in Ireland

	Calcium %	Iron %	Magnesium %	Zinc %	Iodine %	Potassium %
Meat & meat products	5.3	15.2	13.8	30.9	3.3	17.1
Bread & rolls	18.9	17.5	14.3	13.3	1.1	6.7
Sugars, confectionery, preserves & savoury snacks	3.6	3.8	4.7	2.8	4.6	4.0
Beverages	3.1	5.8	11.0	0.5	5.8	10.8
Potatoes & potato products	1.4	5.4	8.0	4.6	1.2	14.7
Milk & yogurt	29.7	1.0	10.1	10.5	50.2	12.8
Grains, rice, pasta & savouries	5.1	4.5	4.4	6.0	3.4	2.5
Biscuits, cakes & pastries	2.6	3.9	2.8	2.4	2.5	1.7
Breakfast cereals	4.6	17.7	6.9	6.2	3.2	3.3
Vegetables & vegetable dishes	4.6	7.6	5.7	4.4	0.2	8.8
Butter, spreading fats & oils	0.1	0.0	0.0	0.0	1.0	0.0
Fruit & fruit juices	2.1	2.6	5.6	1.3	1.5	8.4
Soups, sauces & miscellaneous foods	2.0	2.9	2.0	1.8	1.7	2.9
Cheeses	8.9	0.4	1.2	3.2	2.5	0.5
Fish & fish dishes	1.6	1.9	2.6	2.4	5.9	2.8
Creams, ice-creams & chilled desserts	2.0	0.6	1.0	0.9	3.2	1.0
Eggs & egg dishes	1.4	2.5	0.8	2.3	5.4	0.8
Nuts, seeds, herbs & spices	0.4	1.0	2.1	1.3	0.1	0.8
Nutritional supplements	2.5	5.7	3.0	5.3	2.2	0.4

Note: Food groups are listed in order of contribution to energy intakes (decreasing order)

Discussion

This study provides information on the intakes of micronutrients, the prevalence of inadequate intakes, the risk of excess intakes and key sources in a nationally representative sample of WCBA in Ireland. As there are no DRVs for nutrient intakes specific to WCBA, intakes were compared with recommendations for women of all ages as appropriate. In summary this study has found that significant proportions of WCBA have inadequate intakes of vitamin D (93%), vitamin C (48%), calcium (41%), folate (32%), iodine (26%), riboflavin (25%), vitamin A (18%), magnesium (18%) and iron (10%). Furthermore, this study found there was little risk of excessive intakes of micronutrients among WCBA with negligible proportions (<3%) of this population having intakes of vitamin B6 and iron greater than the UL.

The micronutrients for which low intakes were identified among WCBA in Ireland are discussed in more detail below in context with the literature and potential health implications. When comparing micronutrient intakes in WCBA in Ireland to other studies, it is important to note that some studies may underestimate micronutrient intakes if they do not account for nutritional supplement use or collect detailed information on the consumption of fortified foods. Furthermore, some studies used different cut points to assess adequacy than used in this study and hence may not be directly comparable (where different cut points are used, they are noted in the text).

Vitamin A

Vitamin A is an essential nutrient with important roles in the visual cycle and in the systemic maintenance of growth and integrity of cells in body tissues. The EFSA has set an EAR for vitamin A of 490µg/d and a PRI of 650µg/d for all women over 18 years of age based on the intake required to maintain a liver concentration indicative of an adequate vitamin A status (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015e). The MDI of vitamin A for WCBA in Ireland was 948µg/d and the proportion of WCBA with intakes of vitamin A below the EAR was 18% (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015e). The MDI of vitamin A for WCBA in Denmark, Finland, France, Iceland, Italy, Lithuania, Portugal, Spain, the Netherlands and the UK ranged from 628-1020µg/d (Bates et al., 2014, Dubuisson et al., 2009, Helldán et al., 2013, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2015, Steingrimsdottir et al., 2014, Van Rossum et al., 2020). Using EARs of 700μg/d and 490μg/d respectively, the proportion of WCBA with inadequate intakes of vitamin A was 30% in the Netherlands and 23% in Portugal (Lopes et al., 2017, Van Rossum et al., 2020). In the UK, 8% of WCBA had intakes below the LNRI of 250μg/d (Bates et al., 2020). The LRNI is generally used as a cut-off in the UK rather than the EAR and is the amount of a nutrient that is enough for only a small proportion of a population who have low requirements (2.5%) indicating that those below this cut-off will almost certainly be deficient (Department of Health, 1991). The key sources of vitamin A for WCBA in Ireland were 'vegetable & vegetable dishes' (37%), 'dairy & dairy products' (16%), 'meat & meat dishes' (9%) and 'butter, spreading fats & oils' (7%). Despite the variations of classification of food groups across countries, the key contributors to vitamin A intake for WCBA in other European countries were similar where 'vegetables' contributed 28-35% of intakes, 'meat & meat products' contributed 10-21% and 'dairy and dairy products' contributed 13-33% (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Vitamin D

It is well established that adequate vitamin D status is necessary for optimal bone health at all ages and that foetal and neonatal vitamin D status is dependent on maternal vitamin D status. The importance of adequate vitamin D status in WCBA is heightened due to the role of vitamin D in foetal skeletal development in an occurring pregnancy (Kiely et al., 2017). The EFSA has recently set an AI for vitamin D of 15μg/d for all adults over 18 years of age (including WCBA) and the US IOM have set an EAR for vitamin D of 10μg/d both of which are based on serum 25 (OH)D status deemed to be adequate for bone health (EFSA Panel on Dietetic Products Nutrition and Allergies, 2016c, Institute of Medicine, 2011). The MDI of vitamin D for WCBA in Ireland was 3.8μg/d and the proportion of WCBA with intakes below the EAR was 93% (Institute of Medicine, 2011). The MDI of vitamin D for WCBA in Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Portugal, Spain, Sweden, the Netherlands, the UK and Turkey ranged from 0.9-8.7μg/d which is below the AI of 15 μg/d and is consistent with global literature reporting a high prevalence of inadequate vitamin D intakes for populations of all ages (Ax et al., 2016, Bates et al., 2014, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Spiro and Buttriss, 2014, Steingrimsdottir et al., 2014, Temme et al., 2010, Van Rossum et al., 2020). The key sources of vitamin D in WCBA in Ireland were 'meat & meat products' (25%), 'fish & fish dishes' (16%), 'milk & yogurt' (12%), 'breakfast cereals' (9%), 'eggs & egg dishes' (8%), 'butter, spreading fats & oils' (8%) and 'nutritional supplements' (7%). The key sources of vitamin D intake for WCBA in other European countries were similar where 'meat & meat products' contributed 20-33% of vitamin D intake, 'dairy & dairy products' contributed 7-33%, 'fats & oils' contributed 5-27% and 'fish' contributed 9-26% (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Temme et al., 2010, Van Rossum et al., 2020).

Vitamin C

Vitamin C is an essential nutrient for humans and is involved in a number of biochemical and physiological functions in the body, primarily through its role as an antioxidant. The EFSA has set an EAR for vitamin C of 80mg/d and a PRI of 95mg/d for all adults over 18 years of age (including WCBA) based on the quantity of vitamin C that balances metabolic vitamin C losses and allows the maintenance of an adequate body pool characterised by fasting plasma ascorbate concentrations (EFSA Panel on Dietetic Products Nutrition and Allergies, 2013). The MDI of vitamin C for WCBA in Ireland was 125mg/d (median 76mg/d) with almost half of WCBA (48%) having intakes below the EAR. The MDI of vitamin C for WCBA in other European countries ranged from 66-141mg/d (Bates et al., 2014, Dubuisson et al., 2009, Helldán et al., 2013, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020). The proportion of WCBA in Portugal with intakes of vitamin C below the EAR of 80mg/d was 38% and 21% of WCBA in the Netherlands had intakes below the EAR of 86mg/d (Lopes et al., 2017, Van Rossum et al., 2020). The key sources of vitamin C for WCBA in Ireland were 'fruit & fruit juices' (28%), 'vegetable &

vegetable dishes' (24%), 'potatoes & potato products' (14%) and 'nutritional supplements' (10%). The key sources of vitamin C for WCBA in other European countries were similar where 'fruit' contributed 20-54%, 'vegetables' contributed 22-51% and 'potatoes & potato products' contributed 10-17% (Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020).

Riboflavin

In the absence of sufficient evidence to set a DRV based on studies of riboflavin intake and health outcomes, the EFSA has set an EAR for riboflavin of 1.3mg/d and a PRI of 1.6mg/d for all adults over 18 years of age (including WCBA) based on body saturation measured through urinary riboflavin excretion (EFSA Panel on Dietetic Products Nutrition and Allergies, 2017). The MDI of riboflavin for WCBA in Ireland was 3.0mg/d, while the proportion of WCBA with intakes below the EAR was 25% (EFSA Panel on Dietetic Products Nutrition and Allergies, 2017). The MDI of riboflavin for WCBA in Denmark, Finland, Iceland, Italy, Lithuania, Portugal, the Netherlands and the UK ranged from 1.2-3.3mg/d (Bates et al., 2014, Helldán et al., 2013, Leclercq et al., 2009, Lopes et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Van Rossum et al., 2020). The proportion of WCBA in Portugal with inadequate intakes of vitamin C below the EAR of 1.4mg/d was 39% and 13% of WCBA in the UK had intakes below the LRNI of 0.8mg/d (Bates et al., 2020, Lopes et al., 2017). The key sources of riboflavin for WCBA in Ireland were 'milk & yogurt' (24%), 'meat & meat products' (14%), 'breakfast cereals' (14%), 'nutritional supplements' (9%), 'beverages' (8%) and 'bread & rolls' (5%). The key sources of riboflavin for WCBA in other European countries were similar where 'dairy & dairy products' contributed 30-46%, 'meat & meat products' contributed 11-24% and 'cereal & cereal products' contributed 8-22% (Helldán et al., 2013, Lopes et al., 2017, Temme et al., 2010, Van Rossum et al., 2020).

Folate

The EFSA has set an EAR for DFE of 250µg/d and a PRI of 330µg/d for all adults over 18 years of age based on the folate intake required to maintain folate adequacy characterised by serum and red blood cell folate concentrations of ≥10 and 340nmol/L, respectively (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014a). The MDI of DFE for WCBA in Ireland was 399μg/d and the proportion of WCBA with intakes below the EAR was 32% (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014a). It has previously been reported that just 6% of WCBA in this population complied with the recommendation to take a 400μg folic acid supplement daily (Walton et al., 2019). The MDI of folate for WCBA in Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Iceland, Latvia, Lithuania, Portugal, Spain, Sweden, the Netherlands, the UK and Turkey ranged from 253-334μg/d (Ax et al., 2016, Bates et al., 2014, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). Similar to this study of WCBA in Ireland and using a relatively similar EAR (260μg/d), the proportion of WCBA with inadequate intakes of folate in the Netherlands was 28%. In contrast, over two thirds of WCBA in Portugal had intakes of folate below the EAR of 250μg/d. Seven percent of WCBA in the UK had a MDI of folate below the LNRI of 100μg/d (Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020). The key sources of folate (measured as DFE) for WCBA in Ireland were ‘breakfast cereals’ (16%), ‘bread & rolls’ (13%), ‘vegetables & vegetable dishes’ (10%), ‘milk & yogurt’ (9%), ‘potatoes & potato products’ (8%) and ‘beverages’ (7%). The key sources for WCBA in other countries in other European countries were ‘cereal & cereal products’ which contributed 18-34% of folate intakes, ‘vegetables’ contributing13-28% and ‘meat & meat products’ contributing 7-11% (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Van Rossum et al., 2020, Vandevijvere et al., 2009). Some of the differences in the key sources of folate in WCBA in other countries compared to Ireland may be due to the different methods for estimating folate intake with this study estimating folate as DFE which gives a higher weighting to folic acid compared to natural folate due to its higher bioavailability.

Calcium

The EFSA has set an EAR for calcium of 860mg/d (18-24y) and 960mg/d (25y+) and a PRI of 1000mg/d (18-24y) and 950mg/d (25y+) for both men and women over 18 years based on calcium balance studies (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015a). The MDI of calcium for WCBA in Ireland was 807mg/d and the proportion of WCBA with intakes below the EAR was 41% (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015a). The MDI of calcium among WCBA in Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Portugal, Spain, Sweden, the Netherlands, the UK and Turkey ranged from 457-1074mg/d (Ax et al., 2016, Bates et al., 2014, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). Using the same EAR as in this study, the proportion of WCBA with inadequate intakes of calcium in Portugal was higher (61%) than that of WCBA in Ireland (41%) and the proportion of WCBA in the UK with intakes of calcium below the LRNI of 400mg was 9% (Bates et al., 2020, Lopes et al., 2017). The key sources of calcium for WCBA in Ireland were ‘milk & yogurt’ (30%), ‘bread & rolls’ (19%), ‘cheeses’ (9%), ‘meat & meat products’ (5%) and ‘grains, rice, pasta & savouries’ (5%). The key sources of calcium for WCBA in other European countries were similar where ‘dairy & dairy products’ contributed 38-61%, ‘cereal & cereal products’ contributed 11-30% and ‘vegetables’ contributed 5-10% (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Van Rossum et al., 2020, Vandevijvere et al., 2009).

Iron

Anaemia is one of the most common public health problems globally (Mettananda et al., 2018). Although iron deficiency anaemia (IDA) can occur at any age, WCBA are particularly vulnerable to develop IDA due to menstrual losses and also due to increased nutritional demand during pregnancy (if one were to occur). The EFSA has set an EAR for iron of 7mg/d and a PRI of 16mg/d for all premenopausal females over 18 years of age based on requirements to replace whole-body losses (EFSA Panel on

Dietetic Products Nutrition and Allergies, 2015c). The MDI of iron for WCBA in Ireland was 14mg/d and the proportion of WCBA with intakes below the EAR was 10% (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015c). The MDI of iron for WCBA in Andorra, Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Portugal, Spain, Sweden, the Netherlands, the UK and Turkey ranged from 8.6-13mg/d (Ax et al., 2016, Bates et al., 2014, Dubuisson et al., 2009, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). While these data indicate that intakes of iron are highest in WCBA in Ireland, these data should be interpreted with caution and may be due to methodological differences between studies. The proportion of WCBA with inadequate intakes of iron in Portugal was higher than for WCBA in Ireland at 17% (using the same EAR value) (Lopes et al., 2017). In the UK, the proportion of WCBA with intakes of iron below the LRNI of 8mg was 25% indicating a high prevalence of deficiency. It is of note however, that the LRNI from the UK (8mg/d) is higher than the more recent EAR set by EFSA for iron for women of the same age (7mg/d) which is intended to meet the needs of 50% of the population (Bates et al., 2020, Lopes et al., 2017). The key sources of iron for WCBA in Ireland were 'breakfast cereals' (18%), 'bread & rolls' (18%), 'meat & meat products' (15%), 'vegetable & vegetable dishes' (8%), 'beverages' (6%) and 'nutritional supplements' (6%). The key sources of iron intake for WCBA in other European countries were similar where 'cereal & cereal products' contributed 18-43%, 'meat & meat products' contributed 15-25% and 'vegetables' contributed 9-17% (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Ruiz et al., 2016, Van Rossum et al., 2020, Vandevijvere et al., 2009).

Magnesium

The EFSA has set an EAR for magnesium of 250mg/d and a PRI of 300mg/d for all females over 18 years of age (including WCBA) based on the observed intakes in healthy populations in the European Union (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015d). The MDI of magnesium for WCBA in Ireland was

250mg/d and the proportion of WCBA with intakes below the EAR was 18%. The MDI of magnesium among WCBA in Denmark, Finland, France, Iceland, Italy, Lithuania, Portugal, Spain, the Netherlands and the UK ranged from 211-344mg/d (Bates et al., 2014, Dubuisson et al., 2009, Helldán et al., 2013, Leclercq et al., 2009, Lopes et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Van Rossum et al., 2020). The proportion of WCBA in the Netherlands with magnesium intakes below the EAR of 285mg/d was 27% and in the UK, 11% of WCBA had intakes of magnesium below the LRNI of 150mg/d (Bates et al., 2014, Van Rossum et al., 2020). The key sources of magnesium for WCBA in Ireland were ‘bread & rolls’ (14%), ‘meat & meat products’ (14%), ‘beverages’ (11%), ‘milk & yogurt’ (10%), ‘potatoes & potato products’ (8%) and ‘breakfast cereals’ (7%). The key sources of magnesium for WCBA in other European countries were similar where ‘cereal & cereal products’ contributed 23-29%, ‘dairy & dairy products’ contributed 10-16% and ‘meat & meat products’ contributed 8-18% (Bates et al., 2014, Helldán et al., 2013, Lopes et al., 2017, Van Rossum et al., 2020).

Iodine

Sufficient iodine intake is particularly important for WBCA given the important role of thyroid hormones in brain development in utero and early life of any occurring offspring (Zimmermann, 2011). It is well known that severe iodine deficiency during pregnancy may lead to impaired brain development in the child, with effects on cognitive and motor function, hearing and speech and recent evidence suggests that even mild-to-moderate iodine deficiency during pregnancy may be associated with subtle impairments in cognition and school performance (Bath, 2019). The EFSA has concluded that it is not possible to derive an EAR or PRI for iodine based on the available evidence and so has set an AI for iodine of 150µg/d for all adults over 18 years of age (including WCBA) (EFSA Panel on Dietetic Products Nutrition and Allergies, 2014b), however, the US IOM have previously set an EAR for iodine of 95µg/d based on iodine turnover studies (EFSA Panel on Dietetic Products Nutrition and Allergies, 2015d). The MDI of iodine for WCBA in Ireland was 132µg/d and the proportion of WCBA with intakes below the EAR was 26%. The MDI of iodine among WCBA in Andorra, Belgium, Denmark, Finland, France, Germany, Latvia, Lithuania, Spain, the UK and Turkey ranged from 48-227µg/d (Bates et al., 2014, Dubuisson et al., 2009, Helldán et al., 2013, Heuer et al., 2015, Leclercq et al., 2009, Lopes et al., 2017, Lundblad et al., 2019, Ministeri de Salut, 2013, Pedersen, 2015, Pomerleau et al., 2001, Van Rossum et al., 2020, Vandevijvere et al., 2009). The key sources of iodine for WCBA in Ireland were ‘milk & yogurt’ (50%), ‘fish and fish dishes’ (6%), ‘beverages’ (6%) and ‘egg & egg dishes’ (5%). The key sources of iodine for WCBA in other European countries were similar where ‘dairy & dairy products’ contributed 35-37%, ‘cereal & cereal products’ contributed 11-22% and ‘meat & meat products’ contributed 9-11% of iodine intakes (Bates et al., 2014, Vandevijvere et al., 2009).

While intakes of other micronutirents examined in this study were sufficient with respect to the appropriate DRVs it is still important to continue to monitor intakes of all nutrients among this vulnerable population group (as for other populations) in light of changing food consumption patterns and evolving food supply.

Strengths and limitations

The key strengths of this study are the nationally representative sample included in the NANS and the detailed dietary intake data. It is well acknowledged that misreporting or under reporting of energy intake is a limitation with all dietary assessment; however, this issue was minimised by a high-level of researcher–participant interaction (three-visits over the 4-day period) by trained nutritionists. This issue was also accounted for by identifying under-reporters of energy intake (31%) on the basis of the ratio of energy intake to basal metabolic rate and excluding them from the analysis on adequacy of micronutrient intake.

Conclusion

This study has found that significant proportions of WCBA have inadequate intakes of vitamin D (93%), vitamin C (48%), calcium (41%), folate (32%), iodine (26%), riboflavin (25%), vitamin A (18%), magnesium (18%) and iron (10%). Furthermore, this study has found there was little risk of excessive intakes of micronutrients among WCBA and has examined the key dietary sources of micronutrients in this population group. The findings of this study are similar to that found in other European countries for WCBA and will have important implications for public health guidance for this vulnerable population group. Furthermore, information about the relative contributions of specific foods to nutrient intakes will be useful to both policy makers and the food industry to develop targeted dietary strategies to improve the diets of WCBA in Ireland.

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Chapter 5

General Discussion

It is well established that pre-conceptional health (including nutritional status) is critically important with regard to favourable maternal and infant outcomes in both the short- and long-term. It has been estimated that up to 50% of pregnancies are unplanned, thus optimal nutritional status is important for all women of child-bearing age (WCBA) not just those with pregnancy intentions (Sedgh et al., 2014). While women can technically become pregnant and bear children at any time through their fertility years (from the start of menstruation to menopause when menstrual periods end), the World Health Organisation (WHO) reports statistics for WCBA as those between 15-49 years of age and most studies that report on WCBA as a sub-group include women from 18-50 years of age (or similar age-range) (World Health Organisation, 2015). Consuming a varied and balanced diet during these years is important not only for the current and future wellbeing of the woman but also for the wellbeing of any children that she may bear. Notwithstanding the negative impact of nutrient imbalances on health outcomes of the individual which are well documented in the literature, micronutrient deficiencies in particular can adversely affect fertility, pregnancy outcomes, and risk of congenital disabilities in an occurring pregnancy (Gómez et al., 2020, Rai et al., 2015).

Despite the accumulation of evidence of the importance of nutritional status at this life-stage, nutrient recommendations for WCBA for the most part don't differ from recommendations for other population groups (EFSA Panel on Dietetic Products and Allergies, 2010). The notable exception to this is that all WCBA are recommended to take a folic acid supplement to reduce the risk of neural tube defects (NTDs) in an occurring pregnancy. With regard to overall nutritional status, it is important to understand the current dietary intake of WCBA to identify if there are gaps with regard to current recommendations and also to have a body of sound scientific evidence if more population specific recommendations are to be made for any nutrient.

The objective of this thesis was to use data from the National Adult Nutrition Survey (NANS) (2008-2010) to estimate nutrient intakes in WCBA (n 487) in Ireland and to determine compliance with established dietary recommendations. The key sources of energy and nutrients in this population group were also determined.

This first aim of this thesis was to estimate the mean daily intake (MDI) of energy, macronutrients, dietary fibre and salt, to determine compliance of these nutrient intakes with recommendations and to identify the key sources of these nutrients in WCBA in Ireland. This study found that while protein intakes are sufficient in this population group, a large proportion of WCBA in Ireland have total fat intakes above recommendations and carbohydrate intakes below recommendations. Furthermore, this population group have high intakes of saturated fat, free sugar and salt and low intakes of dietary fibre compared to generally accepted recommendations. Important sources of energy in the diet were 'cereal & cereal products' (including potatoes) 'meat, fish & eggs' and 'dairy & dairy products' which when combined contributed over two-thirds of energy intake on average. However, 'top-shelf' foods (i.e. 'sugars, confectionery, preserves & savoury snacks', 'biscuits, cakes & pastries' and 'sugar-sweetened beverages') also contributed a high proportion of energy intake in addition to contributing significantly to intakes of fat, saturated fat and free sugars.

Despite some variations in the methods of data collection and age-groups for which data are reported, similar findings have been reported in studies of WCBA across Europe where suboptimal distributions of macronutrient intakes have been identified with total fat intakes above recommendations and carbohydrate intakes below recommendations (Ax et al., 2016, Bates et al., 2020, Beslenme et al, 2016, Dubuisson et al., 2020, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009). These studies have also identified that WCBA in European countries have high intakes of saturated fat, free sugar and salt and low intakes of dietary fibre compared to generally accepted recommendations (Ax et al., 2016, Bates et al., 2020, Beslenme et al, 2016, Dubuisson et al., 2020, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009).

This second aim of this thesis was to estimate the MDI of micronutrients and to determine the prevalence of inadequate intakes the risk of excessive intakes and the key sources of micronutrients in WCBA in Ireland. This study found that significant proportions of WCBA have inadequate intakes of vitamin D (93%), vitamin C (48%), calcium (41%), folate (32%), iodine (26%), riboflavin (25%), vitamin A (18%), magnesium (18%) and iron (10%). Furthermore, it has previously been reported that just 6% of WCBA in this population complied with the recommendation to take a 400µg folic acid supplement daily (Walton et al., 2019). Strategies to improve intakes of these key micronutrients are needed not only to ensure the health of WCBA but also for any offspring that she may bear. In particular, micronutrient deficiencies during pregnancy (e.g. folate and iodine) can increase the risk of congenital disabilities in an occurring pregnancy and impaired brain development in the child. This study also found there was little risk of excessive intakes of micronutrients among WCBA with negligible proportions (<3%) of this population having intakes of vitamin B6 and iron greater than the UL. Important sources of vitamins and minerals were milk and milk products, meats, breads and cereals, especially fortified breakfast cereals, and fruits and vegetables.

Studies of WCBA across Europe have also highlighted low intakes of key micronutrients including vitamin D, folate, riboflavin, vitamin C, calcium, iron, magnesium, potassium and iodine (Ax et al., 2016, Bates et al., 2020, Beslenme et al, 2016, Dubuisson et al., 2020, Elmadfa et al., 2008, Helldán et al., 2013, Heuer et al., 2015, Institute of Food Safety et al., 2017, Leclercq et al., 2009, Lopes et al., 2017, Ministeri de Salut, 2013, Nagy et al., 2017, Pedersen, 2015, Pomerleau et al., 2001, Ruiz et al., 2016, Steingrimsdottir et al., 2014, Van Rossum et al., 2020, Vandevijvere et al., 2009).

The nutritional challenges identified for WCBA in Ireland from this study are similar to the nutrient imbalances identified for other age groups both in Ireland and across Europe (Kehoe et al., 2021, Walton et al., 2017). Future strategies are necessary to address these nutritional issues and may include prioritised strategies for the total population or overall food supply but may also include targeted strategies for WCBA. These strategies could include the continued promotion of healthy food choices in line with dietary guidelines, reformulation of the food supply in terms of fat, salt and sugar. With respect to low micronutrient intakes identified across many population groups, strategies to improve intakes could include voluntary food fortification or nutritional supplement recommendations (for nutrients which are unlikely to be met from food alone e.g. vitamin D). With respect to targeted strategies, there has long been guidance for WCBA in Ireland (and further afield) to take a folic acid supplement daily for the prevention of NTDs in potential pregnancies, however, this advice has had limited effectiveness on reducing the level of NTDs and mandatory fortification is likely to be necessary to address this nutritional issue (and has been effective in many countries globally). Similarly, a targeted strategy such as a salt iodisation programme may be necessary to optimise iodine intake and status for WCBA. However, it will be important to continue monitoring intakes of all nutrients among this vulnerable population group (as for other populations) in light of changing food consumption patterns and an evolving food supply.

The overall strengths of this study include the nationally representative sample included in the NANS and the detailed dietary intake data collected. While under reporting of energy intake was minimised by a number of methods (high-level of researcher–participant interaction and appropriate data analysis methodologies), it is difficult to fully account for under-reporting in dietary assessment, hence nutritional status biomarkers as objective measures of nutrient intake could strengthen dietary analysis of population groups in the future.

Findings from this thesis will be useful for both policy makers and the food industry. The data presented in this study will have important implications for public health guidance for this vulnerable population group and will support any specific dietary guidelines for this population group. Furthermore, information about the relative contributions of specific foods to nutrient intakes will be useful to both policy makers and the food industry to develop targeted dietary strategies to improve the diets of WCBA in Ireland.

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Appendix I

NANS 19 Food Groups

1. Grains, rice, pasta and savouries.

2. Bread & rolls

3. Breakfast cereals

4. Biscuits, cakes & pastries

5. Milk & yoghurt

6. Creams, ice-creams & chilled desserts

7. Cheeses

8. Butter, spreading fats & oils

9. Eggs & egg dishes

10. Potatoes & potato products

11. Veg & veg dishes

12. Fruit & fruit juices

13. Fish & fish dishes

14. Meat & meat products

15. Beverages

16. Sugars, confectionary, preserves & savoury snacks

17. Soups, sauces & miscellaneous foods

18. Nutritional supplements

19. Nuts, seeds, herbs & spices

Appendix II

NANS 68 Food Groups

1. Rice & pasta, flours. grains & starch
2. Savouries
3. White sliced bread & rolls
4. Wholemeal & brown bread & rolls
5. Other breads
6. RTEBC
7. Other breakfast cereals
8. Biscuits including crackers
9. Cakes, pastries & buns
10. Whole milk
11. Low fat, skimmed & fortified milks
12. Other milks & milk based beverages
13. Creams
14. Cheeses
15. Yoghurts
16. Ice creams
17. Desserts
18. Rice puddings & custards
19. Eggs & egg dishes
20. Butter (over 80% fat)
21. Low fat spreads (under 40% fat)
22. Other fat spreads (40%-80% fat)
23. Oils (not including those used in recipes)
24. Hard cooking fats
25. Potatoes (boiled, baked, mashed)
26. Processed & homemade potato products
27. Chipped, fried & roasted potatoes
28. Vegetable & pulse dishes
29. Peas, beans & lentils
30. Green vegetables
31. Carrots
32. Salad vegetables
33. Other vegetables
34. Tinned or jarred vegetables
35. Fruit juices & smoothies
36. Bananas
37. Other fruits
38. Citrus fruits
39. Tinned fruits
40. Nuts & seeds, herbs & spices
41. Fish & fish products
42. Fish dishes
43. Bacon & ham
44. Beef & veal
45. Lamb
46. Pork
47. Chicken, turkey & game
48. Offal & offal dishes
49. Beef & veal dishes
50. Lamb, pork & bacon dishes
51. Poultry & game dishes
52. Burgers
53. Sausages
54. Meat pies & pastries
55. Meat products
56. Alcoholic beverages
57. Sugars, syrups, preserves & sweeteners
58. Chocolate confectionary
59. Non-chocolate confectionary
60. Savoury snacks
61. Soups, sauces & miscellaneous foods
62. Nutritional supplements
63. Teas
64. Coffees
65. Other beverages
66. Carbonated beverages
67. Diet carbonated beverages
68. Squashes, cordials & fruit juice drinks