Timing of eating across ten European countries – results from the European Prospective Investigation into Cancer and Nutrition (EPIC) calibration study

Ena Huseinovic[1], Anna Winkvist[1, 2], Heinz Freisling[3], Nadia Slimani[3], Heiner Boeing[4], Genevieve Buckland[5], Lukas Schwingshackl[4], Anja Olsen[6], Anne Tjønneland[6], Magdalena Stepien[3], Marie-Christine Boutron-Ruault[7, 8], Francesca Mancini[7, 8], Fanny Artaud[7, 8], Tilman Kühn[9], Verena Katzke[9], Antonia Trichopoulou[10, 11], Androniki Naska[10, 11], Philippos Orfanos[10, 11], Rosario Tumino[12], Giovanna Masala[13], Vittorio Krogh[14], Maria Santucci de Magistris[15], Marge C Ocké[16], Magritt Brustad[17], Torill Enget Jensen[17], Guri Skeie[17], Miguel Rodríguez-Barranco[18,19], José María[19], Eva Ardanaz[19,20,21], José Ramón Quirós[22], Emily Sonestedt[23], Ulrika Ericson[23], Maria Wennberg[2], Timothy J Key[24], Dagfinn Aune[25], Elio Riboli[25], Elisabete Weiderpass[26, 27, 28, 29] and Heléne Bertéus Forslund[1]

[1]Department of Internal Medicine and Clinical Nutrition, The Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

[2]Department of Public Health and Clinical Medicine, Nutritional Research, Umeå University, Umeå, Sweden

[3]Nutrition and Metabolism Section, International Agency for Research on Cancer, 150 Cours Albert Thomas, 69372 Lyon Cedex 08, France

[4]Department of Epidemiology, German Institute of Human Nutrition, Nuthetal, Germany

[5]Unit of Nutrition and Cancer, Cancer Epidemiology Research Programme, Catalan Institute of Oncology (ICO-IDIBELL), Barcelona, Spain

[6]Danish Cancer Society Research Center, Copenhagen, Denmark

[7]Université Paris-Saclay, Université Paris-Sud, UVSQ, CESP, INSERM, Villejuif, France

[8]Gustave Roussy, F-94805, Villejuif, France

[9]German Cancer Research Center (DKFZ), Division of Cancer Epidemiology, Heidelberg, Germany

[10]Hellenic Health Foundation, Athens, Greece

[11]WHO Collaborating Center for Nutrition and Health, Unit of Nutritional Epidemiology and Nutrition in Public Health, Dept. of Hygiene, Epidemiology and Medical Statistics, School of Medicine, National and Kapodistrian University of Athens, Greece

[12]Cancer Registry and Histopathology Department, "Civic - M.P.Arezzo" Hospital, ASP, Ragusa, Italy
[13]Cancer Risk Factors and Life-Style Epidemiology Unit, Cancer Research and Prevention Institute – ISPO, Florence, Italy
[14]Epidemiology and Prevention Unit Fondazione IRCCS Istituto Nazionale dei Tumori Via Venezian, Milano, Italy
[15]A.O.U Federico II, Naples, Italy
[16]Centre for Nutrition, Prevention and Health Services, National Institute for Public Health and the Environment (RIVM), Bilthoven, the Netherlands
[17]UiT the Arctic University of Norway
[18]Escuela Andaluza de Salud Pública. Instituto de Investigación Biosanitaria ibs.GRANADA. Hospitales Universitarios de Granada/Universidad de Granada, Granada, Spain
[19]CIBER de Epidemiología y Salud Pública (CIBERESP), Madrid, Spain
[20]Navarra Public Health Institute, Pamplona, Spain
[21]IdiSNA, Navarra Institute for Health Research, Pamplona, Spain
[22]Public Health Directorate, Asturias, Spain
[23]Department of Clinical Sciences in Malmö, Lund University, Sweden
[24]Cancer Epidemiology Unit Nuffield Department of Population Health University of Oxford, United Kingdom
[25]Department of Epidemiology and Biostatistics, School of Public Health, Imperial College London, Norfolk Place, London W2 1PG, United Kingdom
[26]Department of Community Medicine, Faculty of Health Sciences, UIT, The Arctic University of Norway, Tromsø, Norway.
[27]Department of Research, Cancer Registry of Norway - Institute of Population-Based Cancer Research, Oslo, Norway
[28]Department of Medical Epidemiology and Biostatistics, Karolinska Institutet, Stockholm, Sweden
[29]Genetic Epidemiology Group, Folkhälsan Research Center, and Faculty of Medicine, University of Helsinki, Helsinki, Finland

Corresponding author

Ena Huseinovic, Department of Internal Medicine and Clinical Nutrition, The Sahlgrenska Academy, University of Gothenburg, Box 459, SE-405 30, Gothenburg, Sweden. Phone: +4631-786 3283, Email: ena.huseinovic@gu.se

Short title

Timing of eating across EPIC countries

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Conflict of Interest

None

Authorship

A.W. and H.BF. initiated the study. E.H., A.W. and H.BF. formulated the research questions, performed the analysis and wrote the manuscript taking into account comments from all co-authors. H.F., N.S, H.B., G.B., L.S., and E.W. contributed to the conception, analysis and interpretation of the data and drafting of the manuscript. All other co-authors were local EPIC collaborators involved in the collection of dietary data and other data. All authors read and approved the final version.

Abstract

Objective: To examine timing of eating across ten European countries.

Design: Cross-sectional analysis of the European Prospective Investigation into Cancer and nutrition (EPIC) calibration study using standardized 24h diet recalls collected during 1995-2000. Eleven predefined food consumption occasions were assessed during the recall interview. We present time of consumption of meals and snacks as well as the ratio of later:earlier energy intake, with earlier and later intakes defined as 06:00-14:00 and 15:00-24:00, respectively. Type III tests were used to examine associations of socio-demographic, lifestyle and health variables with timing of energy intake.

Setting: Ten Western European countries.

Subjects: In total, 22 985 women and 13 035 men aged 35-74 years (N=36 020).

Results: A south-north gradient was observed for timing of eating, with a later consumption of meals and snacks in Mediterranean countries compared to Central and Northern European countries. However, the energy load was reversed with the ratio of later:earlier energy intake ranging from 0.68 (France) to 1.39 (Norway) among women, and from 0.71 (Greece) to 1.35 (The Netherlands) among men. Among women, country, age, education, marital status, smoking, day of recall and season were all independently associated with timing of energy intake (all $p<0.05$). Among men, the corresponding variables were country, age, education, smoking, physical activity, body mass index and day of recall (all $p<0.05$).

Conclusions: We found pronounced differences in timing of eating across Europe, with later meal timetables but greater energy load earlier during the day in Mediterranean countries compared to Central and Northern European countries.

Keywords

Meal patterns, chrono-nutrition, diurnal eating, meals, snacks, standardisation, 24h diet recall, EPIC

Introduction

In Europe, cardiovascular disease, diabetes, and cancer are some of the leading causes of death and account for a large proportion of the disease burden in the region [1]. Still, these conditions are all largely preventable by tackling modifiable risk factors, including unhealthy diet [2, 3]. More recently, the emerging field of "chrono-nutrition" has been emphasized as research suggests that eating at the "wrong time" may impair metabolism, and that misalignment between timing of eating and endogenous circadian systems has been associated with increased inflammation and adverse health outcomes [4-8]. For example, observational studies have shown that later-night eaters have an increased risk of coronary heart disease [9], and that shift workers have higher risk of developing type 2 diabetes compared to day workers, which is believed to reflect greater consumption of energy intake during the night [10, 11]. Furthermore, high evening- relative to morning-energy intake has been positively associated with body mass index (BMI) [12], and subjects consuming a larger proportion of daily calories at dinner (≥48% of total energy intake) have been found to have an increased risk of obesity, metabolic syndrome, and non-alcoholic fatty liver disease, even after adjusting for a set of covariates including breakfast skipping, total energy intake, and dietary fiber [13]. Thus, not only the amount and content of food intake, but also elements such as timing of food intake need to be considered as a potential risk factor for diet-related chronic diseases.

In the U.S, the American Dietetic Association states that greater consumption of energy intake during the day may be preferable to evening consumption for weight management [14]. In the European guidelines for obesity management in adults, a general advice is given to avoid breakfast skipping and eating at night [15]. However, despite the potential health implications of timing of eating, associated individual characteristics and their variation among different populations, cultures, and geographical regions have rarely been investigated. This is likely due to the inconsistent approaches used to examine meal patterns, including a lack of standardized terminology, heterogeneity in how meal patterns are analysed, and the wide range of assessment methods used, making interpretation and comparability between studies and countries problematic [16, 17]. Nevertheless, from a public health perspective, information on socio-demographic, sociocultural, and lifestyle characteristics associated with timing of eating is needed to guide development of evidence-based dietary recommendations, and identify at-risk groups for preventive actions.

In a recent report, we utilized the standardized and homogeneous methodology used in the European Prospective Investigation into Cancer and nutrition (EPIC) calibration study to characterize meal patterns across ten European countries. We found distinct differences in meals patterns across Europe with marked diversity for intake frequency and proportional energy contribution from meals and snacks between Mediterranean and Central/Northern European countries [18]. However, differences in timing of eating were not covered in that report. Such analyses have the potential to further map geographical differences in meal patterns, and provide a valuable resource and benchmark for Europe. Hence, the aim of this report was to describe meal timetables and to examine timing of eating and its association with socio-demographic, lifestyle, and health-related characteristics in women and men from ten European countries.

Methods

Study population

This report is based on data collected within the EPIC calibration study, a nested study within EPIC undertaken during 1995-2000. Details of the rationale, design, and populations of EPIC, and of the calibration study have been described elsewhere [19, 20]. In short, EPIC is a multi-centre cohort study aimed at investigating the association between dietary, biological, lifestyle, and environmental factors in the aetiology of cancer and other chronic diseases. The EPIC project began in 1992 and includes 520 000 participants recruited from 23 administrative centres (reclassified into 27 centres according to geographical region) in 10 Western European countries: Greece, Spain, Italy, France, Germany, The Netherlands, UK, Denmark, Sweden, and Norway. Participants were mostly recruited from the general population, with some exceptions: women attending mammography screening (one centre in the Netherlands and one in Italy), women members of a health insurance for employees of the National Education System (France), and blood donors (some centres in Italy and Spain). Hence, 19 of the 27 EPIC regions recruited both women and men while eight regions recruited women only. In Oxford (UK), most participants were vegetarians or vegans and/or had a special interest in health, and are therefore evaluated separately (the "UK Health-conscious" in contrast to the "UK General population"). The EPIC project was approved by the ethical review boards of the International Agency for Research on Cancer (Lyon, France) and from all local centers. Written informed consent was obtained from all participants.

The calibration study was designed to account for random and systematic errors from food frequency-derived dietary data in EPIC, and to enable examination of dietary data according to the same reference scale. The calibration study population was an age- and sex-stratified random sample of 36 994 participants from the total EPIC cohort (~8%) and involved a single 24h diet recall to be used as reference calibration method [20-22]. The results in this paper are based on dietary data from the standardized 24h diet recalls.

Dietary assessment

The 24h diet recalls were collected using the standardized and computerized software EPIC-Soft (now renamed GloboDiet). The structure and functions of the software program have been described in detail elsewhere [20, 23]. In short, EPIC-Soft was administered by trained interviewers through face-to-face interviews in all countries except in Norway, where telephoned interviews were performed. The interviews were structured into two steps; a first step where participants were asked to recall all foods and drinks consumed during the previous day, and a second step where they were asked to quantify and describe their intake. To standardise the memory aids used by the interviewers during the recall, eleven predefined food consumption occasions (FCO) were asked for, and information on all foods and drinks consumed were entered as one of the following FCOs according to the participants' description: 1) before breakfast, 2) breakfast, 3) during morning, 4) before lunch, 5) lunch, 6) after lunch, 7) during afternoon, 8) before dinner, 9) dinner, 10) after dinner, and 11) during evening. These FCOs were defined to chronologically cover the different occasions of consumption during the day, and consider the different food habits among the participating countries. Hence, a FCO could consist of single or combined foods and/or drinks. For each FCO, time of consumption was indicated per hour as integer values (e.g. 08:00, 09:00 etc.) and each FCO, except for breakfast, lunch, and dinner, could be selected several times during the day because of intakes in different hours (e.g. FCO "during afternoon" consumed at both 14:00 and 17:00 hours). During the interview, participants were asked to list all foods and drinks consumed between waking up on the recall day to waking up on the next day, usually the interview day. However, interviews with regard to diet on Saturdays were conducted on Mondays in most countries for logistical reasons. The mean duration of the recalled day was always about 24 hours [20] and interviews were conducted over various seasons and days of the week. For calculation of energy intake, the EPIC Nutrient Database, developed to standardize the national nutrient databases across the ten EPIC countries, was used [24, 25].

Non-dietary variables

The baseline examination in EPIC was performed during 1992-1998 and included detailed self-administered questionnaires on diet, medical history and lifestyle, which have been described elsewhere [19, 26, 27]. Through these questionnaires, data were collected on education level (none, primary, technical/professional, secondary, university), marital status (single, married/living together, divorced/separated and widowed), smoking (never, former, current), physical activity (inactive, moderately inactive, moderately active, active), diabetes (yes, no), and hyperlipidaemia (yes, no). To assess physical activity, the Cambridge physical activity index with four categories was used, which has been validated within the EPIC study and that showed no significant heterogeneity by country [28]. For the calibration study, information on age, body weight, and height were self-reported during the 24h diet recall, and BMI was calculated as the weight divided by the square of height. The mean time interval between the baseline examination and the 24h diet recall varied between countries, from 1 day to 3 years [20].

Meal timetables and temporal distribution of FCO

Meal timetables across the countries are displayed to illustrate time of consumption of meals (breakfast, lunch and dinner) and snacks (all other FCOs) during the 24h diet recall. Likewise, the number of FCOs per hour for all EPIC countries are displayed in Figure 1 to demonstrate temporal distribution. In line with our previous publication [18], we included all FCOs in the analyses except for FCOs consisting of water only (tap or mineral water), which were excluded. In addition, we also present Supplementary Figure 1 where only FCOs containing ≥50 kcal are included to enable comparison with other studies using an energy content criterion to define an intake occasion [16].

Ratio of later:earlier energy intake

Timing of eating was examined as the ratio of later:earlier energy intake, in line with previous research [12]. Earlier intakes were defined as 06:00-14:00, and later intakes as 15:00-24:00. These time points were selected after studying the distribution of FCOs and time of consumption of meals (Figure 1 and Table 1) with the aim to produce two time periods that could be compared across a broad geographical span. This cut off has previously been used to distinguish later vs earlier energy consumers [29]. Hence, a ratio <1.0 indicates greater energy load earlier during the day (06:00-14:00), and a ratio >1.0 indicates greater energy load later during the day (15:00-24:00). To enable calculation of the ratio among all participants, earlier energy intakes that equalled 0 kcal (i.e. the denominator) were replaced with 1 kcal.

Statistical analysis

Data are presented as mean (range), median (1st; 3rd quartile) and mode. Type III tests of the generalized linear model procedure were used to evaluate associations between *a priori* selected variables (based on previous research and available data) and the ratio of later:earlier energy intake, given all covariates in the model. The variables evaluated were country, age, educational level, marital status, smoking status, physical activity, BMI, prevalence of hyperlipidaemia and diabetes, day of recall, and season. All variables were entered into the model as categorical variables except for age and BMI. The ratio was log transformed before entered into the model to correct for positive skewness. Adjusted R2 is presented to display the variation in the ratio explained by the model, given all entered variables. Only data on participants who had complete covariate information were used in the model. All analyses are stratified by sex. Data were analysed using SPSS version 21.0 (IBM, Somers, NY, USA). Statistical significance was considered at $p<0.05$.

Results

Study participants

A total of 36 020 participants (22 985 women and 13 035 men) with dietary data from the 24h diet recall were included after exclusion of participants aged under 35 or over 74 years due to low participation in these age groups (N=960), and individuals with incomplete information (N=14). Mean (range) age for women and men ranged from 49.0 (35.0-65.5) and 50.0 (35.2-65.2) years (Bilthoven, the Netherlands) to 61.4 (45.3-74.2) and 64.1 (50.5-74.3) years (Malmö, Sweden), respectively. Mean BMI of women ranged from 22.9 (14.4-37.6) (South of France, France) to 29.3 (17.9-48.8) kg/m^2 (Granada, Spain), and from 23.9 (18.2-31.8) (UK Health-conscious) to 29.3 (20.9-46.2) kg/m^2 (Granada, Spain) for men. For the Type III tests evaluating the association between the ratio and selected variables, 13 132 women and 5 680 men had complete covariate information.

Meal timetables

Overall, time of consumption of meals and snacks varied across the countries according to a south-north gradient (Table 1 and Supplementary Table 1). As for breakfast, this was most often consumed at 07:00 in Sweden, Norway, and France compared to 09:00 in Spain (Table 1). Following the time of breakfast, lunch was consumed earlier in the Nordic countries (12:00) compared to Spain and Greece (14:00). The greatest heterogeneity was observed for dinner, which was most frequently consumed between 16:00-19:00 in the Nordic countries compared to 20:00-21:00 in the Mediterranean countries. As for snacks, the largest difference was observed for the FCO "during afternoon", where the most common time of consumption ranged from 14:00 in Norway to 18:00 in Spain and Greece, and for the FCO "during evening", which ranged from 20:00 in Sweden to 24:00 in Spain.

Temporal distribution of FCO

In general, more distinct peak times for temporal distribution of FCO were observed in Mediterranean countries compared to Central/Northern European countries (Figure 1). This was particularly prominent in France and Italy, where three peak times emerged at 07:00-08:00, 12:00-13:00 and 19:00-20:00 hours. In contrast, less pronounced peaks were observed in e.g. the Nordic countries, where FCOs were more evenly spread across the day. Across all countries, the most defined peak time appeared at lunch time, with most countries displaying high frequency of FCOs at 12:00-14:00 hours. Similar patterns were observed when only

FCOs consisting of ≥50 kcal were included (Supplementary Figure 1), although the peak times appeared more distinct after removal of small energy intakes. Temporal distribution of energy intake is presented in Supplementary Figure 2.

Ratio of later:earlier energy intake

A south-north gradient for the ratio of later:earlier energy intake emerged with Mediterranean countries (median ratio of 0.76) demonstrating a lower ratio compared to Central and Northern European countries (median ratio of 1.13 and 1.15, respectively). For women, the median ratio ranged from 0.68 in France to 1.39 in Norway (Table 2), and for men from 0.71 in Greece to 1.35 in The Netherlands (Table 3). In addition, geographical differences for the ratio were observed within countries, with the ratio ranging from e.g. 0.66 (Navarra) to 2.04 (Granada) among women and from 0.72 (Navarra) to 2.58 (Granada) among men in Spain. In contrast, smaller within-country variations were observed for e.g. women in France (range 0.63-0.72) and men in Italy (range 0.73-0.88), see Supplementary tables 2 and 3.

Among women, the following variables were associated with the ratio: country ($p<0.001$), age ($p<0.001$), education ($p<0.001$), marital status ($p=0.021$), smoking ($p<0.001$), day of recall ($p<0.001$), and season ($p=0.024$) (Table 2). Importantly, female later energy consumers (i.e. a ratio >1.0) tended to be from Central/Northern Europe, younger, have higher educational level, be current smokers, and to have captured a weekend day (i.e. Saturday-Sunday) and the summer season during the recall interview. For men, statistically significant associations with the ratio were found for country ($p<0.001$), age ($p<0.001$), education ($p<0.001$), smoking ($p<0.001$), physical activity ($p=0.020$), BMI ($p<0.001$) and day of recall ($p<0.001$) (Table 3). Hence, importantly, male later energy consumers were more likely to be from Central/Northern Europe, younger, to have higher educational level, current smokers, physical inactive, and to have captured a weekend day during the recall interview. However, the models only explained 12.9% and 8.3% of the variation in the ratios among women and men, respectively.

Discussion

We set out to examine meal timetables and timing of eating across ten European countries. We found pronounced geographical differences across the countries, with later timing of meals and snacks but higher energy load earlier during the day in Mediterranean countries compared to Central/Northern European countries. Furthermore, among both women and men, we found that higher later compared to earlier energy load was associated with Central/Northern European countries, weekend days, and being younger, more educated, and current smoker.

These results add to our previous report where we demonstrated that lunch provides 38-45% of daily energy intake in Mediterranean countries, and 16-27% in Central/Northern European countries [(18)]. In the current report, we found that main meals are consumed later in most Mediterranean countries than in Central/Northern Europe (e.g. 09:00, 14:00, and 21:00 in Spain compared to 07:00, 12:00, and 16:00 in Norway, respectively). Still, within the Mediterranean countries, breakfast and lunch are consumed earlier in France than in Spain, Italy, and Greece. This is in line with previous research demonstrating main meals to be consumed at 07:00, 12:00, and 20:00 in France [(30)], compared to 09:00, 15:00, and 22.30 in Spain [(31)]. Furthermore, meal pattern analyses within the European Food Consumption Validation (EFCOVAL) study, conducted during 2007-2008, confirm our findings of more distinct peak times of eating in Mediterranean countries (represented by France in the EFCOVAL study) than in Central/Northern European countries (represented by the Netherlands, Norway, Belgium, and the Czech Republic), where eating times were more spread throughout the day [(30)]. This finding is also in agreement with our previous report, where we found daily energy intake provided by snacks to be 10-20% vs. 23-35% in the two regions, respectively, and the mean intake frequency to range from 4.9-5.0 (Greece and Italy) to 6.8-7.0 (the Netherlands) FCO per day [(18)], indicating more eating occasions between the main meals in Central/Northern European than in Mediterranean countries.

Eating behaviour is a complex process influenced by social, cultural, biological, and personal factors [(32, 33)]. Historically, social constraints have determined the daily number of eating occasions, and culture has dictated when eating is, or is not, appropriate [(17)]. In our report, we found a near doubling of the ratio of later:earlier energy intake from lowest to highest between the EPIC countries. This suggests that cultural habits within a country are stronger predictors of temporal eating than any of our measured individual-level characteristics. Likewise, in the EFCOVAL-study, country was found to be independently associated with all examined meal pattern aspects and to contribute the most to the variability in meal patterns [30]. Still, in the EPIC data, considerable variation in the ratio was observed across centres within the same country, for example in Spain. This indicates both between- and within-country variation in timing of eating. Nevertheless, for the two UK centres General population and Health-conscious, similar results were found for both timing of eating and the ratio of later:earlier energy intake, although dinner was consumed somewhat later in the UK Health-conscious population. Furthermore, meal patterns have been reported to have seasonal and weekly variations, and to be influenced by age. For example, meals have been found to be shifted to the later part of the day on weekends compared to weekdays [34, 35], and elderly have been reported to eat earlier in the day compared to younger individuals [36]. In addition, Leech et al. recently reported that individuals with a “grazing” meal pattern, characterized by later and less distinct peak times of eating, were younger, had higher education (women), and were less likely to be married (men), compared to individuals with a “conventional” or “later lunch” pattern [37]. This is in agreement with our findings demonstrating a higher ratio of later:earlier energy intake on weekends and among younger and higher educated individuals. Finally, and interestingly, we found that countries with later meal timetables (e.g. Mediterranean countries) had lower ratio of later:earlier energy intake compared to countries with earlier meal timetables. This indicates that later timing of meals and snacks does not necessarily translate into greater energy load later during the day. However, the suggested misalignment between timing of eating and endogenous circadian systems [6-7] may still apply, irrespective of temporal energy load. Future studies should evaluate how timing of eating, energy load across the day and irregularity in temporal distribution of eating affect metabolic circadian rhythm and diet-related disease risk.

We could not distinguish a clear and/or strong association between timing of eating and BMI, hyperlipidaemia, or diabetes. Although eating behaviours are highly inter-related, consuming a greater proportion of daily energy intake at dinner and breakfast skipping have both been independently associated with obesity and the metabolic syndrome, also after adjusting for total energy intake [13]. For example, Aljuraiban et al. found that individuals who ate more frequently and consumed most of their energy intake earlier in the day (a ratio of evening:morning energy intake of ≤1.8) had lower energy density and total energy intake, and higher nutrient quality compared to participants with lower eating frequency and who consumed most of their energy intake later in the day (ratio of >1.8). In addition, they found a positive association between BMI and the ratio of evening:morning energy intake also after adjusting for total energy intake [12]. Furthermore, in a 12-week weight loss trial among 90 women with metabolic syndrome, a high-calorie breakfast was found to reduce weight, fasting glucose, insulin, and triglycerides, and to increase satiety scores, more than a high-calorie dinner under iso-caloric conditions [38]. Also, others have shown that later Spanish lunch eaters (after 15:00), compared to earlier lunch eaters, lose less weight and have slower weight-loss trajectory [31], and that eating a later lunch or snack is associated with impaired metabolism and decreased resting energy expenditure and diet-induced thermogenesis [39, 40]. Thus, this suggests that a high caloric intake earlier in the day may influence health more favourably than corresponding energy consumed later during the day. Even though high evening intake might reflect other lifestyle habits and/or food choices compared to high morning intake, a growing body of evidence indicates that circadian timing of eating affects body weight irrespective of total energy intake, and may be a modifiable risk factor for diet-induced chronic disease.

The strengths of this report include a large and diverse population sampled across several European countries concurrent with standardized and homogeneous dietary assessment methodology, which enabled an objective comparison of timing of eating across a broad geographical span. As for the limitations, the data herein were collected during 1995-2000 and are not nationally representative samples of the European general populations. However, the results may still demonstrate significant geographical differences between the countries due to the harmonized methodology used. In addition, our findings are confirmed by more recent analyses of meal patterns in adult European populations [30, 31]. Second, the results are restricted to the methodology and definitions used through the earlier-later dichotomy approach, with earlier intakes defined as 06:00-14:00. This cut-off was chosen as it encompasses the time of lunch for most countries and has been used previously to define earlier energy consumers [29]. Nevertheless, for some Mediterranean countries such as Spain, the cut off was drawn during lunch hours, resulting in a higher ratio than if a later cut off had been used. Still, the biological and metabolic implications of consuming a large proportion of daily energy intake later in the day should be the same irrespective of whether the energy load is labelled later lunch or earlier dinner. Third, participants missing complete covariate information were excluded. Fourth, the large sample size might have increased the number of statistically significant findings and the models only explained a small proportion of the variance in the ratio. Fifth, due to the use of single 24h diet recalls and the cross-sectional design, we can only draw conclusions at the group level and interpret the results as hypothesis-generating that need to be evaluated in longitudinal and experimental settings. Finally, future research should examine what, and how, specific dietary factors relate to timing of eating, and could consider using data-driven approaches [37] to examine patterns in timing of eating across meals and snacks.

Conclusion

We found pronounced differences in timing of eating across Europe, with later meal timetables and greater energy load earlier during the day in Mediterranean countries compared to Central and Northern European countries. More research is needed within the emerging field of chrono-nutrition to improve our understanding of the health-implication of timing and patterning of eating throughout the day.

Table 1

Time of consumption of food consumption occasions (FCOs) across 10 European countries in the European Prospective Investigation into Cancer (EPIC) calibration study. Values are mode, similar results were observed for medians, see Supplementary Table 1.

	Before breakfast	**Breakfast**	**During morning**	**Before lunch**	**Lunch**	**After lunch**	**During afternoon**	**Before dinner**	**Dinner**	**After dinner**	**During evening**
Greece	8:00	8:00	10:00	12:00	14:00	15:00	18:00	20:00	21:00	22:00	23:00
Spain	8:00	9:00	11:00	14:00	14:00	16:00	18:00	20:00	21:00	23:00	24:00
Italy	7:00	8:00	10:00	12:00	13:00	15:00	17:00	19:00	20:00	22:00	22:00
France	7:00	7:00	10:00	12:00	12:00	13:00	16:00	19:00	20:00	21:00	22:00
Germany	7:00	8:00	10:00	11:00	13:00	14:00	16:00	17:00	19:00	20:00	21:00
The Netherlands	8:00	8:00	10:00	12:00	13:00	13:00	15:00	18:00	18:00	20:00	20:00
UK General population	7:00	8:00	11:00	12:00	13:00	14:00	15:00	18:00	18:00	19:00	21:00
UK Health-conscious	7:00	8:00	11:00	12:00	13:00	14:00	16:00	18:00	19:00	20:00	21:00
Denmark	7:00	8:00	10:00	12:00	12:00	14:00	15:00	17:00	19:00	20:00	21:00
Sweden	7:00	7:00	10:00	11:00	12:00	13:00	15:00	17:00	17:00	20:00	20:00
Norway	7:00	7:00	10:00	11:00	12:00	14:00	14:00	16:00	16:00	18:00	21:00

Table 2

Ratio of later:earlier energy intake across socio-demographic, lifestyle and health variables for women in the European Prospective Investigation into Cancer and Nutrition (EPIC) calibration study[*].

	Ratio of later:earlier energy intake			
	N (%)	Median	1^{st}; 3^{rd} quartile	P-value
Country				<0.001
Greece	1368 (6.0)	0.73	0.40; 1.76	
Spain	1443 (6.3)	0.91	0.53; 2.90	
Italy	2510 (10.9)	0.83	0.57; 1.20	
France	4735 (20.6)	0.68	0.48; 0.99	
Germany	2147 (9.3)	0.93	0.61; 1.46	
The Netherlands	2946 (12.8)	1.37	0.93¸1.99	
UK General population	571 (2.5)	1.08	0.69; 1.64	
UK Health-conscious	196 (0.9)	1.04	0.68; 1.59	
Denmark	1994 (8.7)	1.28	0.87; 1.95	
Sweden	3278 (14.3)	1.05	0.71; 1.62	
Norway	1797 (7.8)	1.39	0.91; 2.12	
Age				<0.001
35-44 years	2391 (10.4)	1.13	0.74; 1.86	
45-54 years	8934 (38.9)	1.03	0.66; 1.72	
55-64 years	8958 (38.9)	0.92	0.60; 1.48	
65-74 years	2702 (11.8)	0.80	0.51; 1.31	
Educational level[a]				<0.001
None/primary school	7165 (31.7)	0.91	0.56; 1.54	
Secondary/technical school	10534 (46.6)	1.02	0.66; 1.63	
University	4905 (21.7)	0.95	0.61; 1.55	
Marital status[b]				0.021
Married or cohabitant	15037 (79.0)	0.94	0.60; 1.50	
Single, divorced or widowed	3988 (21.0)	0.95	0.60; 1.54	
Smoking status[c]				<0.001
Never smoker	13206 (58.4)	0.87	0.57; 1.41	
Former smoker	5235 (23.2)	1.06	0.69; 1.69	
Current smoker	4140 (18.3)	1.20	0.77; 2.00	
Physical activity[d]				0.559

Inactive	2715 (13.8)	0.98	0.64; 1.59	
Moderately inactive	7087 (36.1)	0.85	0.56; 1.38	
Moderately active	8331 (42.5)	0.95	0.60; 1.60	
Active	1480 (7.5)	1.11	0.70; 1.73	
Body Mass Index				0.140
<25 kg/m^2	12637 (55.0)	0.95	0.62; 1.53	
≥25 to <30 kg/m^2	7135 (31.0)	1.01	0.62; 1.67	
≥30 kg/m^2	3213 (14.0)	0.95	0.59; 1.68	
Hyperlipidaemia[e]				0.879
Yes	2992 (18.2)	0.82	0.54; 1.34	
No	13490 (81.8)	0.91	0.58; 1.49	
Diabetes[f]				0.881
Yes	583 (2.6)	0.89	0.59; 1.52	
No	21561 (97.4)	0.96	0.61; 1.58	
Day of recall				<0.001
Monday-Friday	17124 (74.5)	0.95	0.62; 1.53	
Saturday-Sunday	5861 (25.5)	1.01	0.59; 1.79	
Season				0.024
Spring	6810 (29.6)	0.92	0.59; 1.53	
Summer	4723 (20.5)	1.02	0.66; 1.66	
Autumn	5179 (22.5)	0.98	0.62; 1.66	
Winter	6273 (27.3)	0.96	0.61; 1.54	

[*]Type III tests of the generalized linear model procedure were used to evaluate associations between *a priori* selected variables and the ratio, given all covariates in the model. The ratio was log transformed before entered into the model to correct for positive skewness. In total, the following number of women were missing covariate information: 381 women for educational status, 3960 women for marital status, 398 women for smoking status, 1808 women for physical activity, 6503 women for hyperlipidaemia status, and 841 women for diabetes status. Only data on participants who had complete covariate information were used in the model (n=13 132).

Table 3

Ratio of later:earlier energy intake across socio-demographic, lifestyle and health variables for men in the European Prospective Investigation into Cancer and Nutrition (EPIC) calibration study[*].

	Ratio of later:earlier energy intake			
	N (%)	Median	1^{st}; 3^{rd} quartile	P-value
Country				<0.001
Greece	1324 (10.2)	0.71	0.43; 1.92	
Spain	1777 (13.6)	0.88	0.54; 2.65	
Italy	1442 (11.1)	0.85	0.61; 1.24	
France	-	-	-	
Germany	2267 (17.4)	1.00	0.67; 1.54	
The Netherlands	1020 (7.8)	1.35	0.93; 2.03	
UK General population	406 (3.1)	1.01	0.71; 1.54	
UK Health-conscious	113 (0.9)	1.03	0.69; 1.63	
Denmark	1923 (14.8)	1.18	0.81; 1.80	
Sweden	2763 (21.2)	1.04	0.69; 1.61	
Norway	-	-	-	
Age				<0.001
35-44 years	1198 (9.2)	1.18	0.75; 1.94	
45-54 years	4083 (31.3)	1.12	0.73; 1.89	
55-64 years	5974 (45.8)	0.97	0.64; 1.58	
65-74 years	1780 (13.7)	0.80	0.49; 1.39	
Educational level[a]				<0.001
None/primary school	5024 (38.9)	0.89	0.57; 1.52	
Secondary/technical school	4645 (36.0)	1.08	0.71; 1.74	
University	3233 (25.1)	1.09	0.71; 1.85	
Marital status[b]				0.098
Married or cohabitant	7717 (84.7)	0.97	0.64; 1.57	
Single, divorced or widowed	1389 (15.3)	1.12	0.72; 1.82	
Smoking status[c]				<0.001
Never smoker	4268 (33.1)	0.94	0.62; 1.54	
Former smoker	5055 (39.2)	1.01	0.65; 1.66	
Current smoker	3570 (27.7)	1.10	0.70; 1.90	
Physical activity[d]				0.020

Inactive	2241 (19.2)	1.14	0.69; 2.02	
Moderately inactive	3596 (30.8)	0.97	0.62; 1.67	
Moderately active	4487 (38.4)	0.96	0.62; 1.62	
Active	1357 (11.6)	1.03	0.69; 1.76	
Body Mass Index				0.002
<25 kg/m^2	4140 (31.8)	1.00	0.68; 1.59	
≥25 to <30 kg/m^2	6687 (57.2)	1.01	0.64; 1.73	
≥30 kg/m^2	2208 (18.9)	1.00	0.61; 1.80	
Hyperlipidaemia[e]				0.542
Yes	2774 (30.2)	0.98	0.63; 1.65	
No	6401 (69.8)	0.97	0.62; 1.71	
Diabetes[f]				0.084
Yes	664 (5.3)	0.89	0.57; 1.41	
No	11979 (94.7)	1.01	0.65; 1.69	
Day of recall				<0.001
Monday-Friday	9813 (75.3)	1.00	0.66; 1.63	
Saturday-Sunday	3222 (24.7)	1.04	0.62; 1.89	
Season				0.586
Spring	3553 (27.2)	0.98	0.63; 1.65	
Summer	2785 (21.4)	1.05	0.69; 1.78	
Autumn	2867 (22.0)	1.04	0.67; 1.78	
Winter	3830 (29.4)	0.98	0.63; 1.58	

*Type III tests of the generalized linear model procedure were used to evaluate associations between *a priori* selected variables and the ratio, given all covariates in the model. The ratio was log transformed before entered into the model to correct for positive skewness. In total, the following number of men were missing covariate information: 133 men for educational status, 3929 men for marital status, 142 men for smoking status, 1354 men for physical activity, 3860 men for hyperlipidaemia status, and 392 men for diabetes status. Only data on participants who had complete covariate information were used in the model (n=5680).

Figure 1 (a-c)

Number of food consumption occasions (FCO) reported per hour throughout the day for the 10 countries in the European Prospective Investigation into Cancer and Nutrition (EPIC) calibration study. All FCO except for FCO consisting of water only are included.

Supplementary figure 1 (a-c)

Number of food consumption occasions (FCO) reported per hour throughout the day for the 10 countries in the European Prospective Investigation into Cancer and Nutrition (EPIC) calibration study. Only FCOs containing ≥50 kcal are included.

Supplementary figure 2 (a-c)

Median energy intake reported per hour throughout the day for the 10 countries in the European Prospective Investigation into Cancer and Nutrition (EPIC) calibration study. Number of individuals reporting energy intake each hour is provided above each bar.

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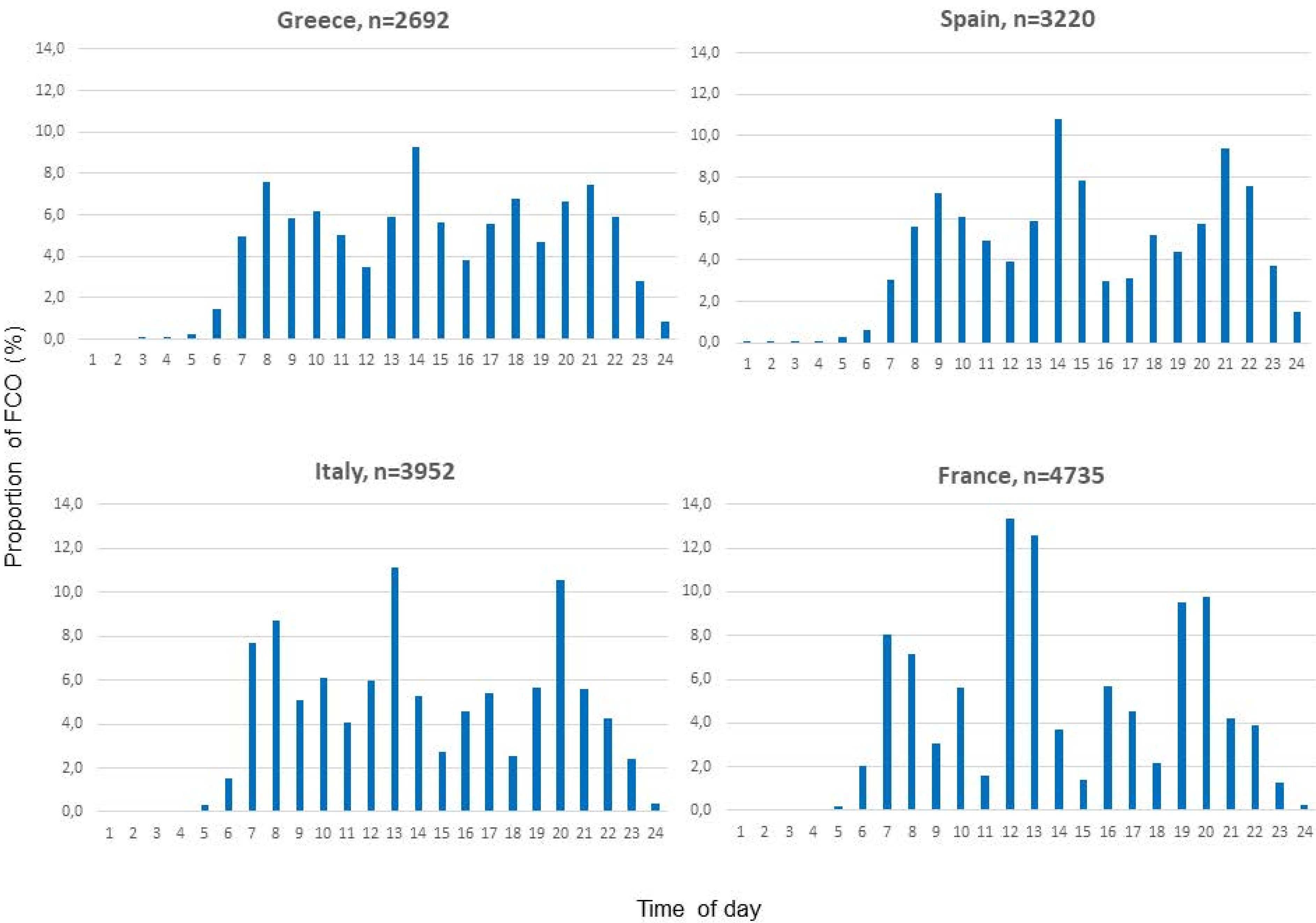

Greece, n=2692
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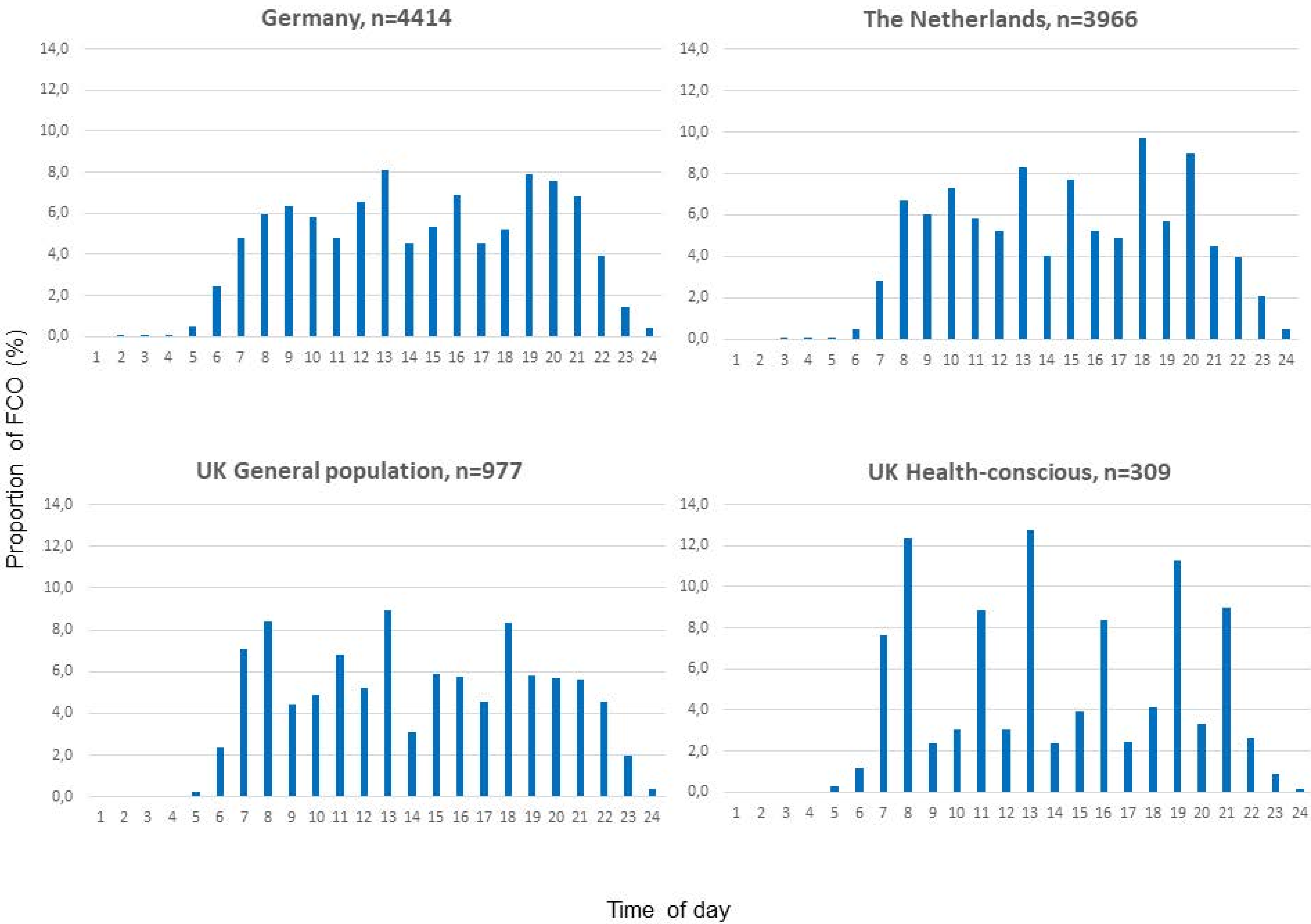
Italy, n=3952
France, n=4735
Proportion of FCO (%)
Time of day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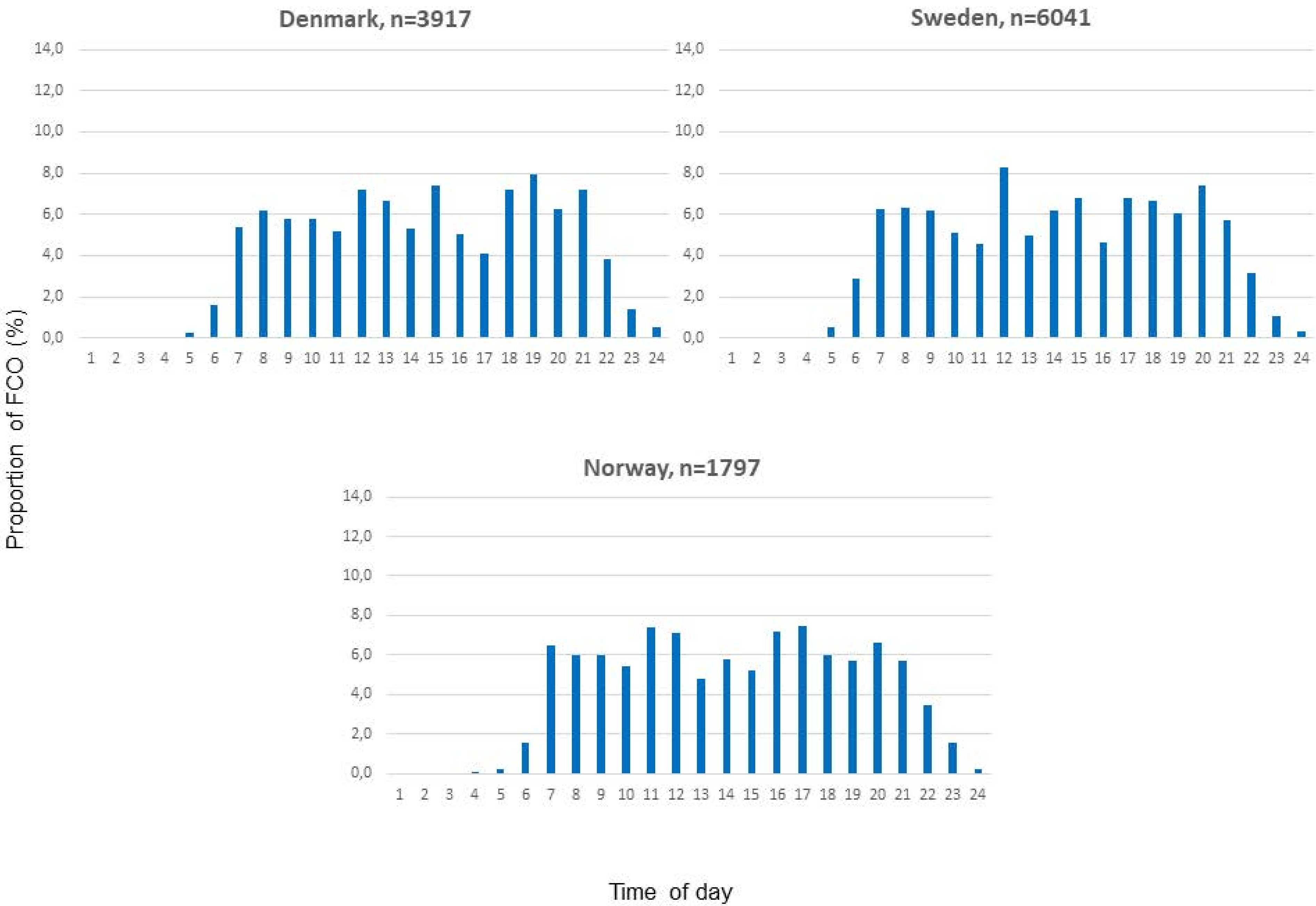
The Netherlands, n=3966
UK General population, n=977
UK Health-conscious, n=309
Proportion of FCO (%)
Time of day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Sweden, n=6041
Norway, n=1797
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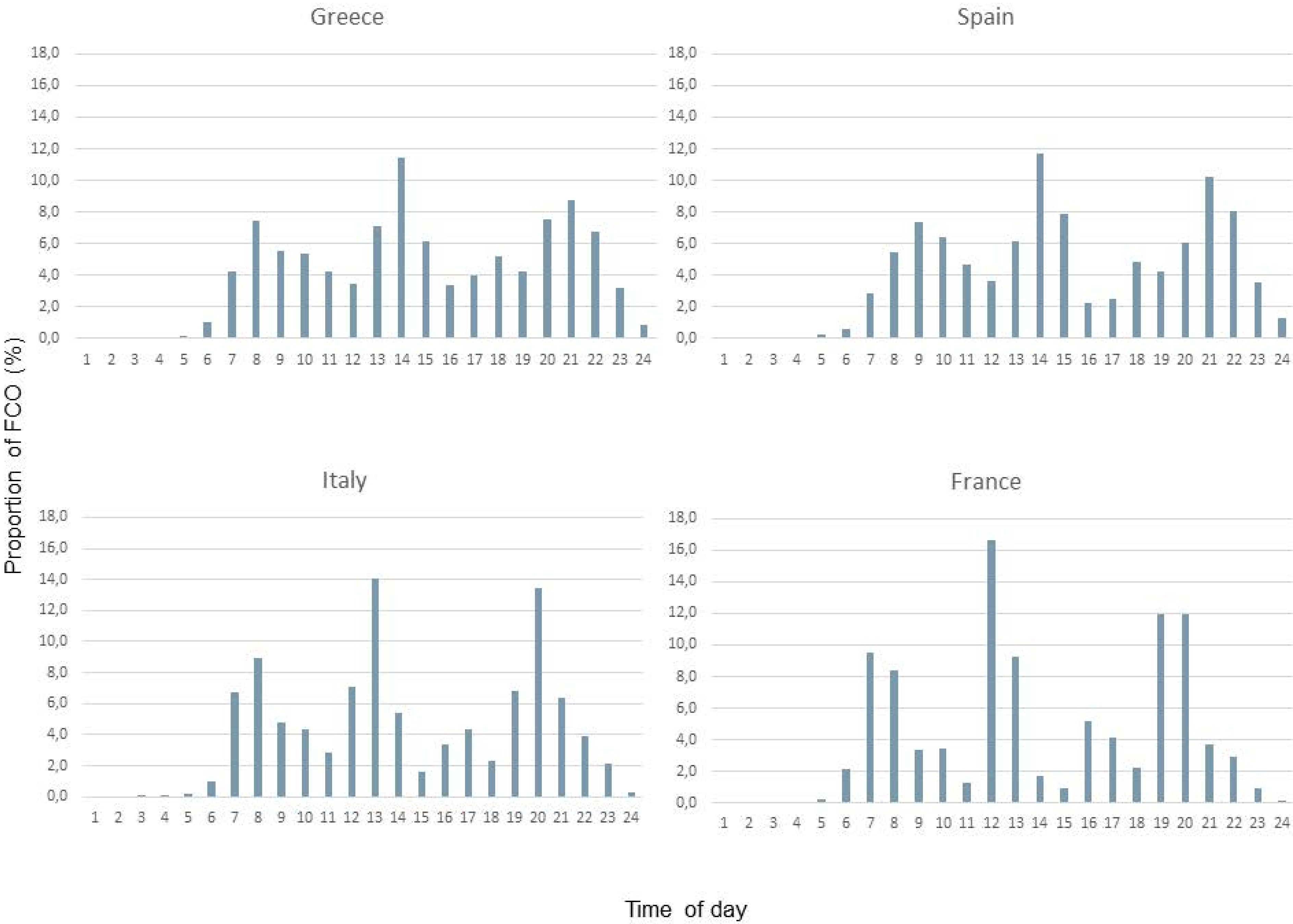
Proportion of FCO (%)
Time of day


Greece
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France
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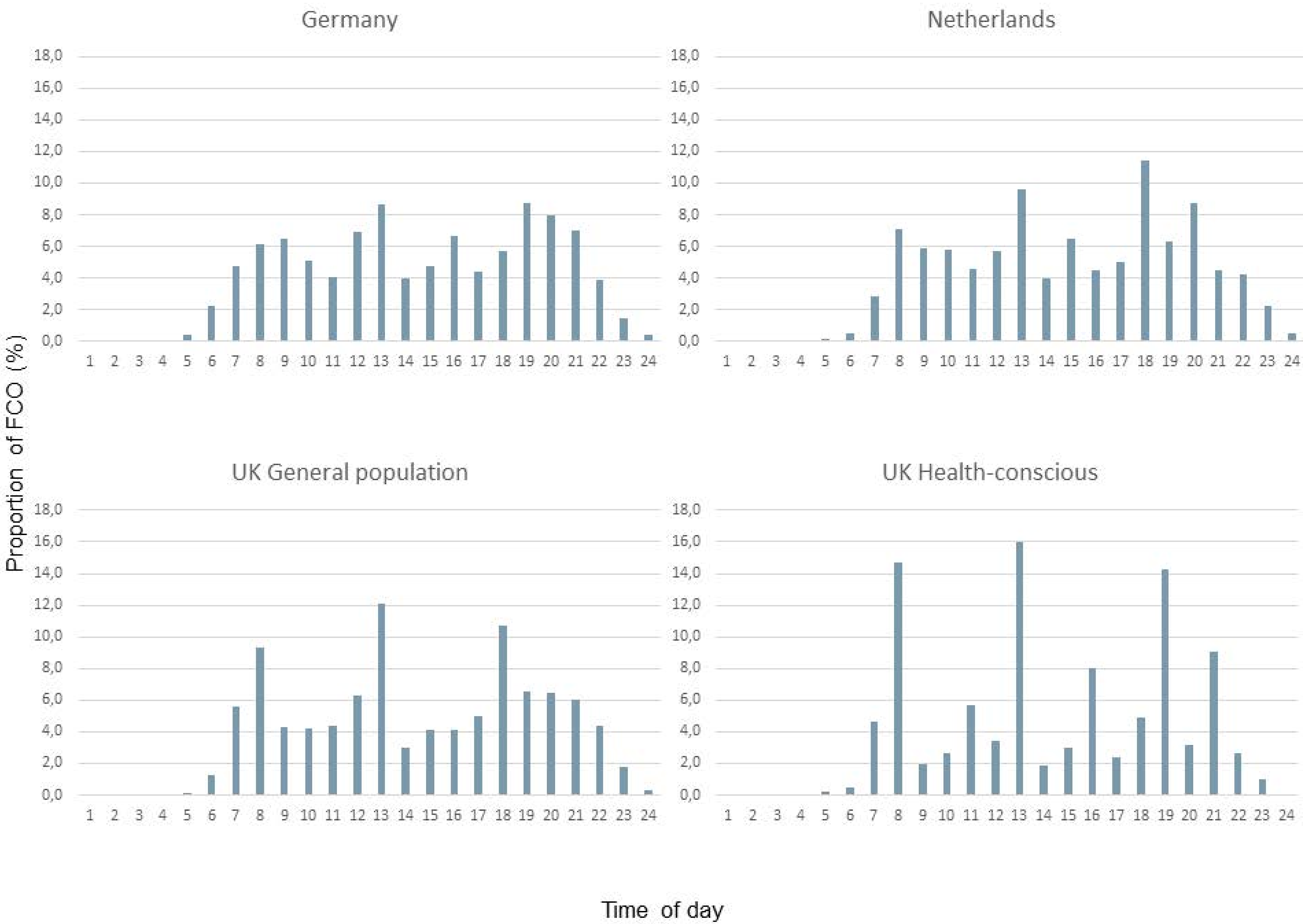
Proportion of FCO (%)
Time of day


Germany
Netherlands
UK General population
UK Health-conscious
Proportion of FCO (%)
Time of day
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16,0
14,0
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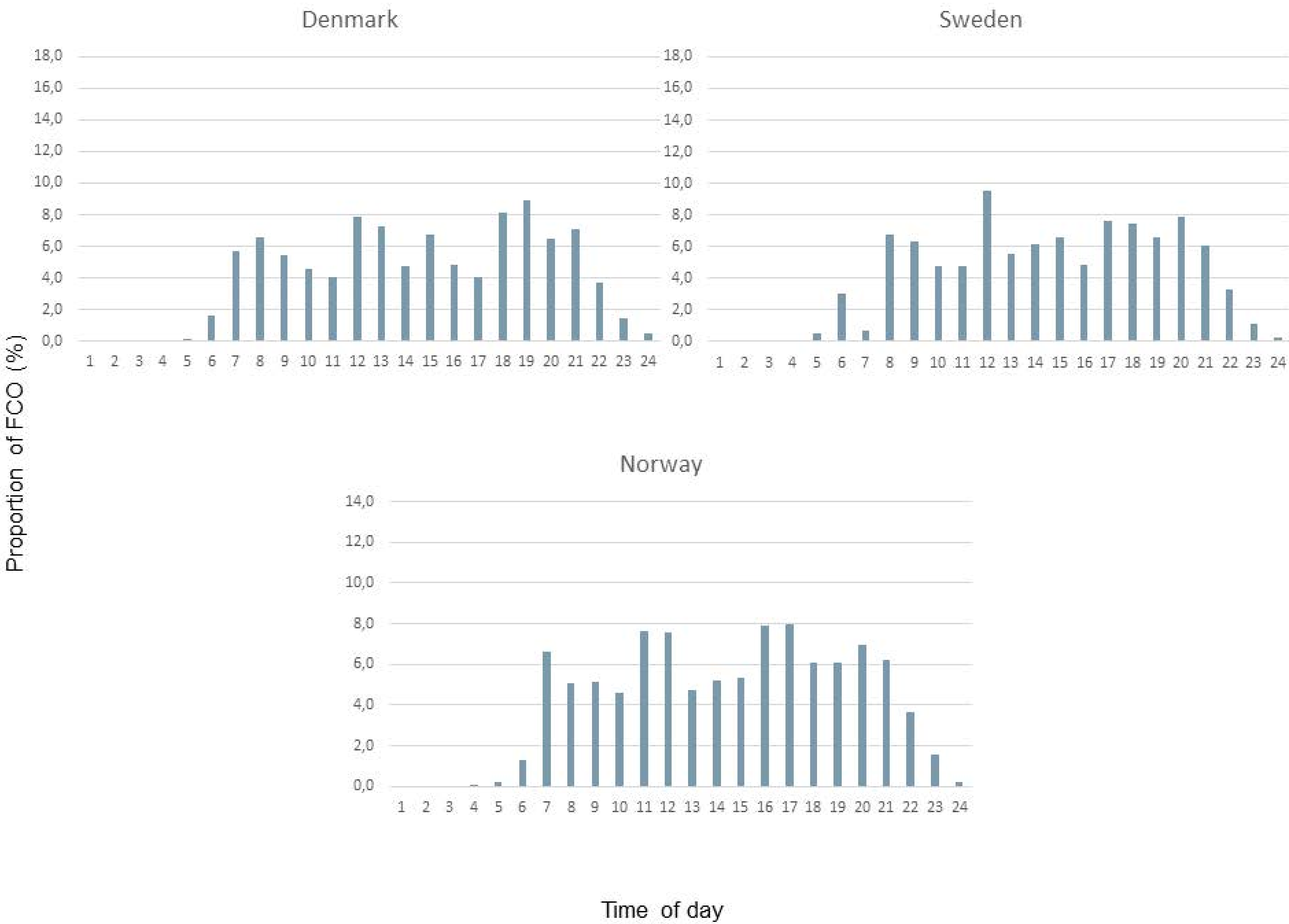
Denmark
Sweden
Norway
Proportion of FCO (%)
Time of day
18,0
16,0
14,0
12,0
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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Supplementary table 1

Time of consumption of food consumption occasions (FCOs) across 10 European countries in the European Prospective Investigation into Cancer (EPIC) calibration study (N=22 985). Medians (1st; 3rd quartiles) are presented.

	Before breakfast	**Breakfast**	**During morning**	**Before lunch**	**Lunch**	**After lunch**	**During afternoon**	**Before dinner**	**Dinner**	**After dinner**	**During evening**
Greece	7 (7; 8)	8 (7; 9)	10 (10; 11)	12 (12; 13)	14 (13; 15)	16 (15; 16)	18 (17; 18)	20 (19; 20)	21 (20; 22)	22 (22; 23)	24 (23; >24)
Spain	8 (7; 9)	9 (8; 10)	11 (10; 12)	13 (13; 14)	14 (14; 15)	16 (15; 16)	18 (18; 19)	20 (20; 21)	21 (21; 22)	23 (22; 24)	24 (23; >24)
Italy	7 (7; 8)	8 (7; 8)	10 (10; 11)	12 (11; 12)	13 (13; 13)	15 (14; 15)	17 (16; 17)	19 (18; 19)	20 (20; 20)	22 (21; 22)	22 (22; 23)
France	7 (6; 8)	8 (7; 8)	10 (10; 10)	12 (12; 12)	12 (12; 13)	13 (13; 14)	16 (16; 17)	19 (18; 19)	20 (19; 20)	21 (20; 21)	22 (22; 22)
Germany	7 (6; 8)	8 (7; 9)	10 (9; 11)	11 (11; 12)	13 (12; 13)	14 (13; 14)	16 (15; 16)	18 (17; 18)	19 (18; 20)	20 (20; 21)	21 (21; 22)
The Netherlands	8 (7; 9)	8 (8; 9)	10 (10; 11)	12 (12; 13)	13 (12; 13)	13 (12; 13)	15 (15; 16)	18 (17; 18)	18 (18; 19)	20 (19; 21)	21 (20; 22)
UK General population	7 (6; 8)	8 (7; 8)	11 (10; 11)	12 (11; 12)	13 (12; 13)	14 (14; 15)	16 (15; 16)	18 (17; 18)	18 (18; 19)	19 (19; 20)	21 (20; 22)
UK Health-conscious	7 (7; 7)	8 (8; 8)	11 (10; 11)	12 (11; 12)	13 (13; 13)	14 (13; 14)	16 (15; 16)	18 (18; 19)	19 (19; 19)	19 (18; 20)	21 (21; 22)
Denmark	7 (6; 8)	8 (7; 9)	10 (9; 11)	11 (11; 12)	13 (12; 13)	14 (13; 14)	15 (15; 16)	17 (17; 18)	19 (18; 19)	20 (20; 21)	21 (21; 22)
Sweden	7 (6; 8)	8 (7; 8)	10 (9; 11)	11 (11; 12)	12 (12; 13)	13 (13; 14)	15 (14; 15)	17 (17; 18)	18 (17; 18)	20 (19; 20)	21 (20; 22)
Norway	7 (7; 9)	8 (7; 9)	10 (9; 11)	11 (10; 12)	12 (11; 13)	14 (13; 15)	15 (14; 16)	16 (15; 17)	17 (16; 18)	18 (17; 20)	21 (20; 22)

Supplementary table 2

Ratio of later:earlier energy intake across the 27 centres for women in the European Prospective Investigation into Cancer and Nutrition (EPIC) calibration study (N=22 985).

		Ratio of later:earlier energy intake	
	N	Median	1st; 3rd quartile
Country and center			
Greece	1368	0.73	0.40; 1.76
Spain	1443	0.91	0.53; 2.90
Granada	300	2.04	0.65; 4.23
Murcia	304	1.38	0.64; 4.20
Navarra	271	0.66	0.41; 1.18
San Sebastian	244	0.72	0.48; 1.10
Asturias	324	0.94	0.58; 2.66
Italy	2510	0.83	0.57; 1.20
Ragusa	137	0.82	0.56; 1.20
Florence	783	0.81	0.54; 1.19
Turin	392	0.83	0.60; 1.21
Varese	795	0.81	0.58; 1.15
Naples	403	0.93	0.56; 1.39
France	4735	0.68	0.48; 0.99
South coast	620	0.67	0.46; 0.97
South	1425	0.63	0.45; 0.93
North-West	631	0.65	0.48; 0.91
North-East	2059	0.72	0.50; 1.05
Germany	2147	0.93	0.61; 1.46
Heidelberg	1087	0.97	0.61; 1.60
Potsdam	1060	0.90	0.61; 1.33
The Netherlands	2946	1.37	0.93; 1.99

Bilthoven	1076	1.45	0.96; 2.14
Utrecht	1870	1.31	0.92; 1.90
United Kingdom	767	-	-
General population	571	1.08	0.69; 1.64
Health-conscious	196	1.04	0.68; 1.59
Denmark	1994	1.28	0.87; 1.95
Copenhagen	1484	1.27	0.86; 1.93
Aarhus	510	1.31	0.88; 2.01
Sweden	3278	1.05	0.71; 1.62
Malmö	1711	1.09	0.70; 1.79
Umeå	1567	1.01	0.71; 1.48
Norway	1797	1.39	0.91; 2.12
South and East	1004	1.32	0.87; 2.04
North and West	793	1.48	0.96; 2.27

Supplementary table 3

Ratio of later:earlier energy intake across the 27 centres for men in the European Prospective Investigation into Cancer and Nutrition (EPIC) calibration study (N=13 035).

		Ratio of later:earlier energy intake	
	N	Median	1st; 3rd quartile
Country and center			
Greece	1324	0.71	0.43; 1.92
Spain	1777	0.71	0.43; 1.92
Granada	214	2.58	0.77; 4.96
Murcia	243	1.37	0.59; 3.94
Navarra	444	0.72	0.47; 1.40
San Sebastian	490	0.78	0.53; 1.39
Asturias	386	0.87	0.53; 3.11
Italy	1442	0.85	0.61; 1.24
Ragusa	168	0.73	0.54; 1.07
Florence	271	0.88	0.64; 1.35
Turin	676	0.87	0.63; 1.33
Varese	327	0.85	0.58; 1.12
Naples	0	-	-
France	0	-	-
South coast	0	-	-
South	0	-	-
North-West	0	-	-
North-East	0	-	-
Germany	2267	1.00	0.67; 1.54
Heidelberg	1034	1.07	0.67; 1.67
Potsdam	1233	0.96	0.67; 1.46
The Netherlands	1020	1.35	0.93; 2.03
Bilthoven	1020	1.35	0.93; 2.03

Utrecht	0	-	-
United Kingdom	519	-	-
General population	406	1.01	0.71; 1.54
Health-conscious	113	1.03	0.69; 1.63
Denmark	1923	1.18	0.81; 1.80
Copenhagen	1356	1.17	0.79; 1.82
Aarhus	567	1.21	0.84; 1.77
Sweden	2763	1.04	0.69; 1.61
Malmö	1421	1.06	0.67; 1.75
Umeå	1342	1.02	0.71; 1.49
Norway	0	-	-
South and East	0	-	-
North and West	0	-	-