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Original article

Seasonality of nutrient intake – An analysis including over 44,000 participants in 4 countries

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SUMMARY

Background and aims: Dietary intake is believed to follow a seasonal pattern, so adjusting for seasonality in nutritional epidemiology is usually requested. The aim of this study was to assess the seasonality of energy and macronutrients intake (expressed as % of total caloric intake) using a large set of population-based studies.
Methods: Cross-sectional data from 9 population-based studies from 4 countries (3 in the Northern Hemisphere and 1 in Southern Hemisphere), with a total sample size of 44,611 subjects. Data were derived from FFQ or repeated 24 h-recalls. Dietary markers included total energy intake, protein, carbohydrates, fat, alcohol, sugars and fatty acids (saturated, mono and poly-unsaturated). Seasonality was assessed using the cosinor method stratifying on hemisphere and gender.
Results: Most nutrients did not show a significant seasonal variation. When individual studies were considered, the number of nutrients showing significant seasonal variations varied from 5 to none in men and from 6 to none in women. Jointly, in the Northern hemisphere, significant seasonal variations were found for sugar intake in both genders and for alcohol consumption in men only; in the Southern Hemisphere, significant seasonal variations were found for fat and monounsaturated fatty acids in women. Analysis of the three consecutive periods of the Bus Santé study in Switzerland showed that the number of significant seasonal variations decreased from 5 in 1993–1999 to 1 in 2006–2012 in men, and from 6 in 1993–1999 to none in 2006–2012 in women. Seasonal variation decreased over time for most nutrients, with the exception of monounsaturated fatty acids in men.
Conclusions: Seasonality of energy and macronutrients intake varies considerably according to study, with no common pattern and small magnitude of variation. Its amplitude appears to be declining over time. Systematic adjustment for season might not be necessary when assessing the effects of total energy and macronutrient intake on disease.

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1. Introduction

Dietary intake is believed to follow a seasonal pattern, following the seasonality of food availability and/or production. Indeed, several studies identified significant seasonality in food or nutrient intake [1–4], and a meta-analysis on this topic has been recently published [5]. Most epidemiological studies assessing dietary intake adjust for seasonality, i.e. for the impact of the month or the season [6,7].

In recent years, the development of global trade has increased the all-year availability of previous "seasonal" products; in winter, countries from the Northern hemisphere can import fruits produced in the Southern hemisphere where summer is ongoing. Further, modern housing facilities in developed countries decrease the need of nutritional adaptation to high or low temperatures, making dietary intake relatively constant throughout the year. Thus, the previous paradigm of seasonality in dietary intake has been challenged [8], but whether seasonality is still important in nutritional epidemiology remains an open debate. For instance, a survey reported a seasonality in food pattern but not in dietary intake [9] and it has been suggested that the effect of seasonality does not impact the interpretation of most epidemiologic studies [10]. Further, most studies on seasonality were conducted in single countries or using small samples, and no analyses grouping several studies in several countries has ever been made.

Thus, we analyzed pooled individual data from nine studies conducted in four different countries on 44,611 subjects (Northern Hemisphere: 35,177, Southern Hemisphere: 9434) to 1) assess whether total energy and macronutrient intake presents a seasonal pattern, and if so, if this pattern is reproducible between countries; and 2) to evaluate trends in the magnitude of the seasonal effect in dietary intake using monthly data from 3 surveys conducted in 3 consecutive periods in Switzerland (1993–1999; 2000–2005 and 2006–2012).

2. Methods

2.1. Studies included and data collection

Several groups with dietary data were invited to join and nine accepted to share their information. Thus, data from nine population-based studies from four countries were included (France, New Zealand, Russia and Switzerland). Seven studies were from the Northern Hemisphere and two from the Southern Hemisphere. Data were derived from FFQ or repeated 24 h-recalls and pooled from individual data. The characteristics of the studies have been published elsewhere [11–20]. Inclusion criteria were participants a) aged between 18 and 85 and b) without extreme total energy intakes (between 850 and 4500 kcal/day); pregnant women were excluded when information was available.

For each participant, the % of total caloric intake of: total protein, total carbohydrates, sugar, total, saturated, monounsaturated and polyunsaturated fat, and alcohol was computed. No micronutrients such as calcium or vitamins were compared as they were not present in all studies. Within each study, monthly adjusted means and their associated standard errors for each nutrient were calculated, separately for each sex. Averages were adjusted for age, body mass index and current smoking (yes/no).

2.2. Statistical analyses

Statistical analyses were performed using R Development Core Team (2014) [21] and stratified by sex. Seasonality of energy and macronutrients intake was assessed using weighted fixed effects models including cosinor in order to describe variation over months [22]. First, the analysis was conducted for each individual study; then, for all studies combined. Due to the opposite seasons in Northern and Southern hemispheres, specific models for each hemisphere were applied. Details for the estimation of the amplitude, peak and nadir are shown in the Appendix A.

To evaluate trends in the magnitude of the seasonal effect in dietary intake, two cosinor models were computed: a model assuming that the seasonal variation was constant over time, and a model assuming that the seasonal variation changed over time. The choice of the final model was made according to previous results from the three separate periods, using a graphical approach of the decomposed series. Seasonal variation was considered as statistically significant if at least one of the associated p-values of sine or cosine functions was <0.05 (two-sided test). Sensitivity analyses were performed by comparing the seasonal model to a linear model.

Institutional review boards at participating institutions approved all protocols, all studies were approved by the respective ethic committees and all participants provided written informed consent.

3. Results

3.1. Characteristics of participants

The characteristics of studies are summarized in Table 1. There were 35,177 participants in the Northern Hemisphere and 9434 in the Southern Hemisphere. Most studies included participants aged between 50 and 55 years. Women represented over half of the sample, with the exception of the Workforce Diabetes Survey where this percentage was considerably lower. The percentage of current smokers varied between 18% and 30% in men and between 15% and 24% in women.

3.2. Seasonality analyses

The presence of a seasonal variation and the peak month (in the case of a significant variation) in total energy intake and macronutrients according to sex and study is summarized in Supplementary Table S1. The number of significant seasonal variations per study varied from 5 to nil in men and from 6 to nil in women. Interestingly, no consistent pattern with a common peak month was found between studies for most nutritional variables considered, with the possible exception of saturated fatty acids in women.

Table 2 summarizes, for all studies grouped, the estimated seasonal variation and the corresponding peak month according to sex and hemisphere. In the Northern hemisphere, significant seasonal variations were found for proteins, alcohol, sugar intake and saturated fatty acids in both sexes; for carbohydrates in men and for total energy intake, fat and monounsaturated fatty acids in women. In the Southern Hemisphere, significant seasonal variations were found for fat and monounsaturated fatty acids in women. Figs. 1 and 2 show a graphical approach for total energy intake, respectively, in men and women.

Sensitivity analyses were conducted by comparing the percentages of explained variability (R^2) using seasonal and linear (non-seasonal) models. Relative to the linear model, the cosinor model brought only small improvement in R^2 (Supplementary Table S2).

3.3. Trends in seasonality

Analysis of the three consecutive periods of the Bus Santé study showed that the number of significant seasonal variations

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