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MODELLING OVER WEEK PATTERNS OF ALCOHOL CONSUMPTION

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Abstract — Aims: This study aims to analyze alcohol consumption patterns throughout a week, controlled by socio-demographic characteristics, and to discuss the adequacy of the complex models employed. **Methods:** The sample included 496 participants, from both sexes, ⩾40 years old and with 7-day dietary records. Bayesian generalized additive mixed models (GAMM) were applied using two approaches: a multinomial model, with three categories of alcohol consumption behaviour including; non-drinkers, alcohol during meals only and alcohol at any time; and a gamma model for drinkers which considered the total amount of alcohol ingested per day. **Results:** The multinomial model captured two different patterns of alcohol consumption: a sharp increase in consumption on weekends for mealtime only drinkers, the dominant behaviour among drinkers and a linear increase from Monday towards Sunday for those who drank at anytime. The effect of higher education changed from slightly protective for mealtime only drinkers to risky for anytime drinkers. The amount of alcohol consumed presents a pattern similar to the meals-only drinking. **Conclusions:** Alcohol consumption increased during the week. Two different alcohol consumption patterns were identified according to drinking behaviours. The methodological approach utilized was essential in uncovering these patterns.

INTRODUCTION

Alcohol abuse is an unequivocal public health problem. Although moderate alcohol consumption has been considered a protective factor for coronary heart disease (Mukamal *et al*., 2003; Tolstrup *et al*., 2006) it has been related to increased risk of death by homicide, suicide, road traffic and other accidents (WHO, 1997), as well as being a risk for haemorrhagic and ischemic stroke (Donahue and Abbott, 1986; Mukamal *et al*., 2005), increased blood pressure (Keil *et al*., 1998; McFadden *et al*., 2005), and being a well-established cause of cancer, particularly of the oral cavity, larynx, oesophagus and liver (IARC, 1988). Knowledge of the mean level of alcohol consumption is not, however, sufficient to describe the distribution of those drinking different amounts of alcohol. The observed increase in cardiovascular mortality during the weekend in Eastern European countries emphasizes the importance of the acute effect of alcohol on health (Chenet *et al*., 1998, 2001). A systematic review has also highlighted the importance of determining the pattern of drinking, in addition to investigating the average volume of alcohol consumed (Rehm *et al*., 2003). Moreover, a prospective cohort study in Russia found that the risk of death from cardiovascular disease seems to be increased in frequent heavy drinkers, but is not necessarily associated with episodic binge drinking (Malyutina *et al*., 2001).

The type of alcoholic beverage consumed, the proportion of total alcohol consumed during the weekend, the amount of alcohol ingested per drinking occasion and the drinking context (social drinking vs solitary drinking) vary across gender, age, countries and cultures (Hupkens *et al*., 1993). Women consume smaller amounts and less frequently than men (Wilsnack *et al*., 2000), but in some developed populations the tendency is for the levels of consumption to converge (McPherson *et al*., 2004). In several populational studies (Knupfer, 1989; Hulshof *et al*., 1991; van Oers *et al*., 1999), lower levels of education have been associated with heavy alcohol consumption in both sexes. However, not much is known about the association between socio-economic determinants and moderate consumption or abstinence.

In terms of the cultural environment, two essential features play a part including the habit of drinking with or without meals and the pattern of alcohol consumed throughout the week. It is usual for Mediterranean people to drink wine during the main meals, as opposed to consuming alcohol in public places, such as in bars and nightclubs, or to consuming distilled drinks to relax after work. It has been suggested (Kauhanen *et al*., 1997; McElduff and Dobson, 1997) that drinking large amounts of alcohol on a single occasion and drinking on an empty stomach may be particularly harmful, emphasizing the importance of evaluating alcohol consumption during meals compared to consumption outside of mealtimes. The other aspect is the difference in cultures of regular or daily consumption of alcohol which can be compared to binge drinking on certain days of the week.

Portugal purportedly presents an alcohol consumption pattern similar to the south-western European countries with regular drinking habits instead of binge drinking habits. However, there are no studies which report the patterns of drinking throughout the week. Furthermore, compared to other western European countries, Portugal presents one of the higher levels of alcohol consumption (World Drink Trends, 2005), particularly in men older than 40 years (Marques-Vidal and Dias, 2005).

To analyze these aspects through the simultaneous modelling of drinking behaviour, based on factors such as the amount of alcohol consumed, intake by day of the week and other characteristics is highly complex. The modelling techniques employed should allow for non-linear effects of time, in order to detect the consumption throughout the week,

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while at the same time allowing for the correlation between repeated observations of the same individual and allowing for heterogeneity between individuals. Generalized additive mixed models (GAMM), in a Bayesian framework, combine the ability to estimate a smooth time trend and random effects, controlling for known important fixed covariates.

This study aims to evaluate alcohol consumption patterns throughout the week, in a sample of Portuguese adults, while at the same time discussing the adequacy of the methods employed.

PARTICIPANTS AND METHODS

Participant data was obtained from those who took part in a Health and Nutrition Survey (EPIPorto study) between 1998 and 2001 (Ramos *et al*., 2004). For that survey, conducted in the second largest city in Portugal, the participants were selected by random digit dialling (participation proportion 70%). All participants were Portuguese, were older than 40 years, living in Porto, and for those older than 65 years, had normal scores in the Mini Mental State Examination (MMSE) (Folstein *et al*., 1975).

We analysed a sub-sample of 496 participants who accepted to fill a 7-day dietary record. Although we selected consecutive participants during the specified time period, only the participants who accepted to and only those with a minimum level of education filled in the diaries. This limitation could affect the representativeness of the sample. However, the proportion of women (56.6%) was similar compared to the general population (55.7%); and a comparison with the other participants in the survey (Ramos *et al*., 2004) showed similar mean levels of education (7.8 years, SD = 4.4 vs 7.7 years, SD = 5.5, $P = 0.220$) and alcohol consumption (19.8 g/day, SD = 27.4 vs 18.1 g/day, SD = 26.3, $P = 0.739$).

Daily amount, frequency and type of alcoholic beverages consumed during each day of the week were obtained using the self-reported information from dietary food records. All participants received verbal instructions on how to fill in the food record and also received pictures with different types of glasses, in order to estimate the portions of alcoholic beverages consumed. The pattern of alcohol consumption was categorized into three groups: non-drinkers (ND); those who drank exclusively during meals (OM); and those who drank at any time (AT). For those who drank (66.3%) we also analysed the total amount of alcohol ingested per day of the week.

Age, educational level, gender and day of the week were included as covariates in this study. Age was analysed as a continuous variable. Schooling was categorized as less than 4 years (reference group), 5–9 years, and 10 and more years of education.

This study was approved by the Ethical Committee of the institution and all participants provided written informed consent before participation. The survey data and information that could identify participants were kept in separate databases.

STATISTICAL METHODS

GAMM were employed to model the data. GAMM can be used to incorporate flexible semi-parametric forms of the predictor for modelling the dependence of responses on covariates and random effects to account for overdispersion caused by unobserved heterogeneity or for correlation in longitudinal data. Suppose a response variable or outcome y_{it} for each individual i at each week day t, with mean μ_{it} including non-linear time trend, dependency among repeated observations and heterogeneity among individuals. Thus, the GAMM for this data can be described by Equation (1)

$$g(\mu_{it}) = x_i'\beta + \gamma_i + \delta_t, \quad i = 1:n \text{ and } t = 1{:}7 \qquad (1)$$

where $g(.)$ is the link function allowing to model response variable from the exponential family (e.g. Normal, Poisson, Binomial distributions), x_i is the vector of individual covariates or predictors, and β is the vector of fixed effects covariates, *i.e*. effects that do not change with time or between individuals. The random effects, γ_i, are parameters specific for each individual taking into account the correlation between observations and heterogeneity between them. We also incorporated the smoothed function of time δ_t, which can accommodate non-linear and non-monotonic patterns between the response variable and time varying covariates, offering a flexible modelling tool to deal with non-linear time trend (Hastie and Tibshirani,1990; Fahrmeir and Tutz, 2001).

With the development of Markov Chain Monte Carlo (MCMC) methods and the availability of free software like BayesX (Brezger *et al*., 2004), GAMM in a Bayesian framework has been applied to analyse many social and health problems. Bayesian inference differs from frequentist statistics by being subjective, *i.e*. the inference of the unknown parameters is based on the observed data and also incorporates prior knowledge (although these prior beliefs can be sometimes very non-informative). In a nutshell, we formulated a prior distribution over the unknown parameters of the model, which was meant to capture our beliefs about the situation before seeing the data. After observing some data (the likelihood), we applied Bayes' Rule to obtain a posterior distribution for these unknowns, which is proportional to the product of prior distributions and the likelihood of the data.

In Bayesian inference modelling framework, all unknown parameters are considered random variables and appropriate prior assumptions are specified (Gelman *et al*., 1995). For the fixed effects β we used diffuse priors. To estimate the time trend we used a second order random walk prior $\delta_t = 2\delta_{t-1} - \delta_{t-2} + \varepsilon_t t = 1{:}7$, in order to avoid abrupt jumps between successive points in time, with Gaussian errors with zero mean and variance σ^2_ε. The individual γ_i random effects were assumed to be normally distributed with zero mean and variance σ^2_γ. The GAMM was fitted using MCMC as a standard Bayesian inference tool, using *BayesX* (Brezger *et al*., 2004). After specifying non-informative priors to the unknown model parameters, samples from their posterior distribution were drawn by the MCMC method and after this iterative process achieved convergence, summary quantities (median, standard deviation) were calculated in order to get point estimates and credible intervals (CI).

We fitted two different models. The first one was a multinomial model, using a logit link. No alcohol consumption (ND) was used as the reference category, and drinking only during meals (OM) and drinking at any time of the day (AT), were the comparison categories. In the second model we analysed the

total daily amount (in grams) of alcohol ingested for those who drank at least once during the week. As 167 (33.7%) people did not drink any alcoholic beverage during the week, only 329 people were included in the second analysis. This continuous response variable was assumed to follow a gamma distribution and the log link function was used.

A model allowing for a non-linear effect of age, using a P-spline smoother, was tested and the effect was found to be acceptably linear. Separate models for men and women were fitted as well, with results for men being very similar to those for the entire population, and results for women had a wide CI, due to much smaller numbers of drinkers, and therefore only the model for all participants, with linear effect of age and sex as a covariate is presented.

The model results were based on 1000 samples, selected from 310 000 simulations with a 'burn in' phase of 10 000, in the multinomial model, and 52 000 simulations with a 'burn in' phase of 2000 for the gamma model, in order to achieve convergence according to standard criteria (Gelman *et al*., 1995). The distribution of the 1000 posterior samples is presented graphically instead of a table of point estimates. When necessary we present the value of the estimated median and 95% CI.

RESULTS

Table 1 shows the demographic characteristics of the participants. Mean age was 58.7 years, ranging from 40–90 years. Women accounted for 56.6% of the participants, and the majority of participants (68.5%) had less than 10 years of schooling. Among drinkers, the mean amount of alcohol consumption was much lower in women (8.6 g) than in men (31.2 g), and decreased for those who were sixty years and older. For those drinking only at mealtime, the gender differences were similar, and the amounts ingested were larger for those who drank anytime.

From the 3472 days of observation, it was found that in 53.2% of the days there was no consumption of alcohol (70.2% of the days for women and 31.8% of the days for men). Both genders drank more often during meals, and in 56% of the days men drank only during meals. The men drank approximately twice more often, either only at meals or at any time, when compared to the women.

Figure 1 presents the posterior density of fixed effects of the multinomial model; in the left column the effects of OM drinkers, in the right hand column the AT drinkers, both compared to ND. If $\beta = 0$ is included in the CI, we assume that no significant effect was detected. Gender presents the largest effect of all covariates for OM drinkers (odds ratio (OR) = exp(3.83) = 46.1) and even larger for AT drinkers (OR = exp(6.06) = 428.4). The chance of drinking only during meals reduces 6% for each additional year of age (OR = 0.94; 95% CI = 0.91–0.98) and the chance of drinking at anytime reduces 10% for each additional year of age (OR = 0.90; 95% CI = 0.85–0.96). The effect of education changes according to the drinking behaviour. Education has a borderline protective effect for OM drinkers, although this protection decreases as the number of years of schooling increases (OR = 0.44 for 5–9 years and OR = 0.52 for 10 years or more compared to 4 years or less of education). On the other hand, for AT drinkers, these estimated effects were opposite in direction, increasing the chance of drinking as the number of years of schooling increases (OR = 2.25 for 5–9 years and OR = 2.61 for 10 years or more compared to 4 years or less of education), in spite of the fact that 95% CI include zero.

Figure 2 illustrates the posterior estimated time trend (the values of δ_t in model equation 1) throughout the week for both OM (left) and AT drinkers (right). The time effect is important for both behaviours, as the 95% CI does not include the horizontal line at zero. The trend is linear, from Monday until Sunday, for AT drinkers, whilst drinking only at meals increases slowly until Friday, then bends sharply upward on the weekend. The same curves were obtained when modelling men separately.

The estimated fixed effects for the model of the total daily amount of alcohol ingested, presented in Figure 3, show similar results to the previous model. Among drinkers, men drink 4.8 times more alcohol than women, adjusted for age and schooling. Age presented a protective effect, that is, a 10 year increase in age decreased the amount of alcohol ingested by approximately 22%. Education presented a non-significant small protective effect, a similar effect as in the model for drinking only during meals. The daily trend of alcohol consumption (Figure 4) presents a similar pattern to the behaviour of OM drinkers, increasing towards the weekend, but with a smoother upwards bend.

In Table 2 the average daily alcohol consumption (g/day) for males and females according to different ages and levels of education using the gamma model can be observed. Since age was entered in the model as a continuous variable the point estimates were calculated for the mid-point of the age classes used in Table 1. The highest levels of alcohol consumption were found in younger males who had lower

Table 1. Socio-demographic characteristics of participants ($N = 496$), average of daily mean alcohol consumption among drinkers, and drinking behaviour per day

Characteristics	Total	Female	Male
Participants	496	281 (56.6%)	215 (43.4%)
Age	*N* (%)	*N* (%)	*N* (%)
<50 years	110 (22.2)	66 (13.3)	44 (8.9)
50–60 years	146 (29.4)	87 (17.5)	59 (11.9)
60–70 years	153 (30.9)	83 (16.7)	70 (14.1)
70 years+	87 (17.5)	45 (9.1)	42 (8.5)
Education			
1–4 years	214 (43.1)	132 (26.6)	82 (16.5)
5–9 years	126 (25.4)	63 (12.7)	63 (12.7)
10 years+	156 (31.5)	86 (17.3)	70 (14.2)
Daily alcohol consumption			
(g/day)	Mean (SD)	Mean (SD)	Mean (SD)
Overall mean	20.8 (20.30)	8.6 (9.03)	31.2 (21.49)
Only at main meals	24.0 (17.61)	13.7 (9.30)	33.1 (18.22)
At any time	42.8 (25.45)	23.5 (16.07)	49.3 (24.79)
Drinking behaviour per day	Days (%)	Days (%)	Days (%)
No alcohol	1858 (53.5)	1380 (70.2)	478 (31.8)
Only during meals	1392 (40.1)	551 (28.0)	841 (55.8)
Any time	222 (6.4)	36 (1.8)	186 (12.4)

Table 2. Estimated average profile of alcohol consumption (g/day) by sex, age and education. (Gamma model)

		45 years		55 years		65 years		75 years	
		Male	Female	Male	Female	Male	Female	Male	Female
⩽4 years of education	Mon	27.2	5.7	23.2	4.8	19.7	4.1	16.8	3.5
	Tue	28.1	5.9	24.0	5.0	20.4	4.2	17.4	3.6
	Wed	27.8	5.8	23.7	4.9	20.2	4.2	17.2	3.6
	Thu	29.0	6.0	24.7	5.1	21.0	4.4	17.9	3.7
	Fri	32.3	6.7	27.5	5.7	23.4	4.9	19.9	4.1
	Sat	42.1	8.7	35.8	7.4	30.5	6.3	26.0	5.4
	Sun	56.2	11.7	47.8	9.9	40.7	8.5	34.7	7.2
5–9 years of education	Mon	23.9	5.0	20.3	4.2	17.2	3.6	14.7	3.0
	Tue	24.7	5.1	21.0	4.4	17.8	3.7	15.2	3.2
	Wed	24.4	5.1	20.7	4.3	17.6	3.7	15.0	3.1
	Thu	25.4	5.3	21.6	4.5	18.4	3.8	15.6	3.2
	Fri	28.3	5.9	24.1	5.0	20.5	4.3	17.4	3.6
	Sat	36.9	7.7	31.4	6.5	26.7	5.6	22.7	4.7
	Sun	49.2	10.2	41.8	8.7	35.6	7.4	30.2	6.3
⩾10 years of education	Mon	24.3	5.1	20.7	4.3	17.6	3.7	15.0	3.1
	Tue	25.1	5.2	21.4	4.4	18.2	3.8	15.4	3.2
	Wed	24.8	5.2	21.1	4.4	18.0	3.7	15.3	3.2
	Thu	25.9	5.4	22.0	4.6	18.7	3.9	15.9	3.3
	Fri	28.9	6.0	24.5	5.1	20.9	4.3	17.7	3.7
	Sat	37.6	7.8	32.0	6.7	27.2	5.7	23.1	4.8
	Sun	50.2	10.4	42.7	8.9	36.3	7.6	30.8	6.4

level of education and ranged between 27.2 g/day on Monday and 56.2 g/day on Sunday. The lowest levels were found in older women with 5–9 years of education and ranged from 3.2 g/day on Monday to 6.3 g/day on Sunday.

DISCUSSION

The present study evaluated the drinking pattern throughout a week considering the total amount of alcohol and the context of consumption (drinking only at principal meals and drinking also outside mealtimes).

We found, in our population, that the mean intake of alcohol by men was much higher than in women. The same description was made in other analyses including the Portuguese population (Marques-Vidal and Dias, 2005) and in other populations (Neve *et al*., 1996; Wilsnack *et al*., 2000; Sieri *et al*., 2002a). Also, men presented a higher frequency of alcoholic beverage consumption at meals and out of meals. As described for south European countries, namely Italy (Sieri *et al*., 2002b), both sexes drank most of their alcohol during meals, contrary to other countries in the European Community where people drink mainly outside mealtimes (Hupkens *et al*., 1993).

This study clearly shows the coexistence of two drinking behaviours in Portuguese adults: the traditional intake where alcohol is consumed with main meals, and the intake of alcohol outside of meals, but not related explicitly to hard drinking.

As the participants are adults above 40 years, the expected pattern was not of binge drinking on Fridays and Saturdays, but of the everyday after-hours drinking or the 'relaxing' drink before dinner, especially in middle classes and more highly educated people. The daily behaviour supports this hypothesis, as AT drinkers begin increasing the intake of alcohol just after Monday, linearly towards the weekend. On the other hand, the time trend of total amount of drinking is an average between both types of behaviours, increasing slightly from Wednesday onwards, with weekend behaviour equalling the sum of both groups.

Some other studies in the Dutch population (Veenstra *et al*., 1993) and in 10 European Countries in European Prospective Investigation into Cancer and Nutrition (EPIC) study (Sieri *et al*., 2002b) showed higher consumption during the weekends in both sexes. However, to our knowledge, no studies showed the increasing tendency during the week, because no studies analysed this tendency using prospective information during 7 consecutive days.

Alcohol consumption decreased with increasing age. As we included only subjects older than 40 years they could be considered to have surpassed the age of behaviour transition. In the Portuguese national survey (Marques-Vidal and Dias, 2005) a decrease of alcohol consumption in the age group of 35–44 years was found. As well as, a cross-sectional National Health Interview Survey in the United States (Breslow and Smothers, 2004) described a trend of decreasing alcohol intake between ages 60 and 84 years.

In the present study, the traditional pattern of drinking with meals only was frequently found among less educated participants. However, the pattern of drinking at any time of the day was more characteristic of subjects with a higher level of education.

In the European community, it has been described that more highly educated people consume new types of beverages more often than less educated people, who tend to consume the traditional beverages more frequently (Hupkens *et al*., 1993). This description is in accordance with our data since the

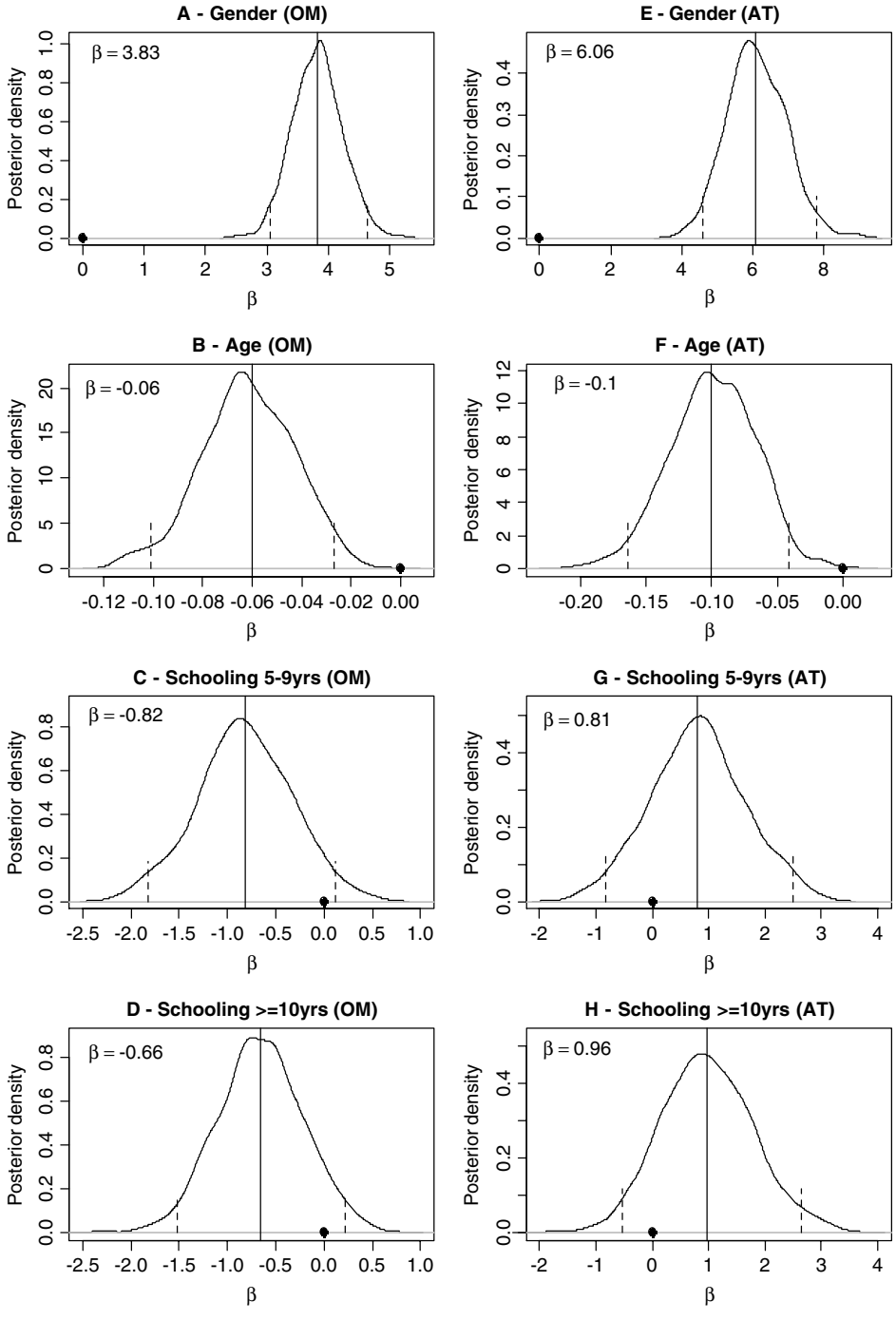

Fig. 1. Estimated Posterior distributions of fixed effects of the multinomial model comparing OM × ND and AT × ND. The centre line equals the estimated βs and the dotted segments refer to the 95% CI. The black dot on the horizontal axis is where β = 0.

consumption of traditional beverages was usually related with the drinking with meals pattern.

Other studies showed that women with higher levels of education were more likely to drink at least occasionally (Allamani *et al*., 2000), possibly during social events. In Israel, higher educational achievement was described as being protective against binge drinking in both Jews and Arabs (Neumark *et al*., 2003). A large American survey identified that 'moderate' drinkers were more common in the upper social classes than in the lower ones, while abstinence was more common and heavy drinking slightly more common in the lower socio-economic strata (Knupfer, 1989). In France, total alcohol, wine and beer consumption were negatively related to socio-economic status and educational level (Marques-Vidal *et al*., 2000).

Although suggested by the slightly different position of the education level, it was only through the weekly trend that the pattern was revealed. It was the choice of the

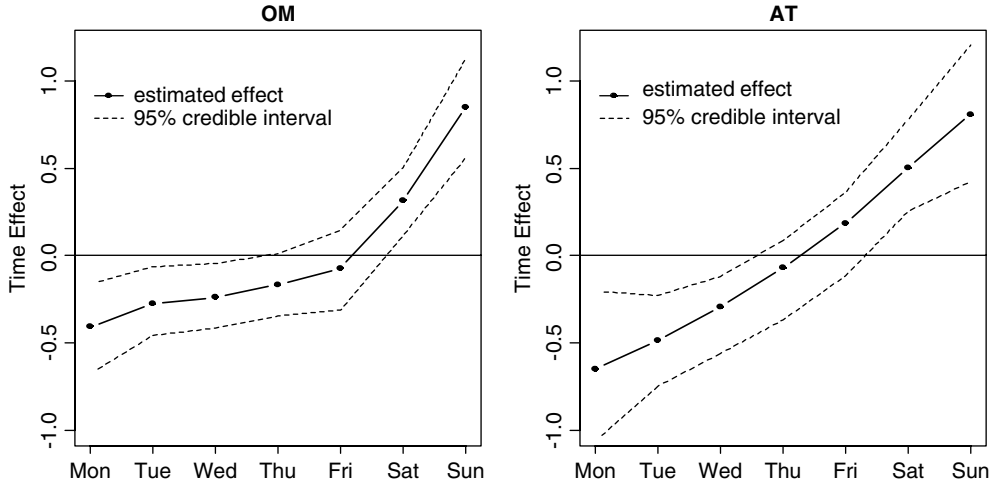

Fig. 2. Estimated time trend for the multinomial model.

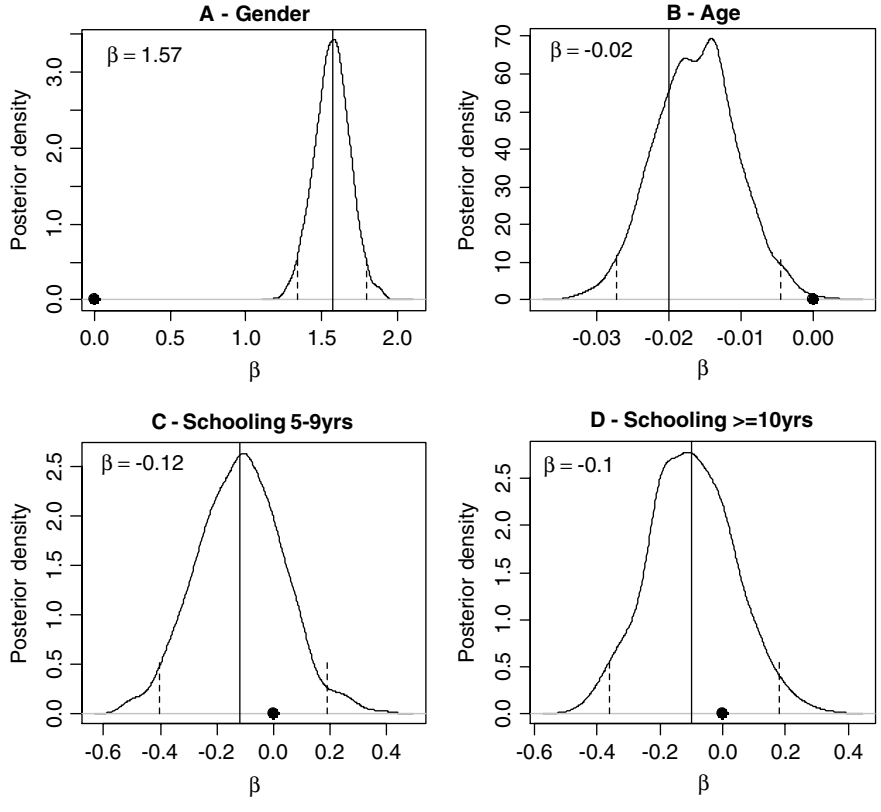

Fig. 3. Posterior estimates of fixed effects for the amount of alcohol ingested.

statistical approach, modelling simultaneously fixed effects, random effects and structured time effects that gave this extra information. Furthermore, presenting the estimated values of the parameters graphically is an interesting tool to discuss the effect of covariates, evaluating the density of possible values of parameters beyond the limits of usual confidence intervals.

The Bayesian techniques employed are still seldom used in epidemiological settings, although common in advanced training and research in statistics.

A brief search in PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=PubMed3 December 2006), the U.S. National Library of Medicine's digital archive of life sciences journal literature, using the word 'bayesian' in any field showed 4331 papers added to PubMed from 1 January 2001 to 3 December 2006, and just 121 published in journals with 'Epidemiology' in the journal title.

One of the main reasons for this low use is not related to the approach itself, as the Bayesian framework allows for fitting of more complex models, and thus more closely

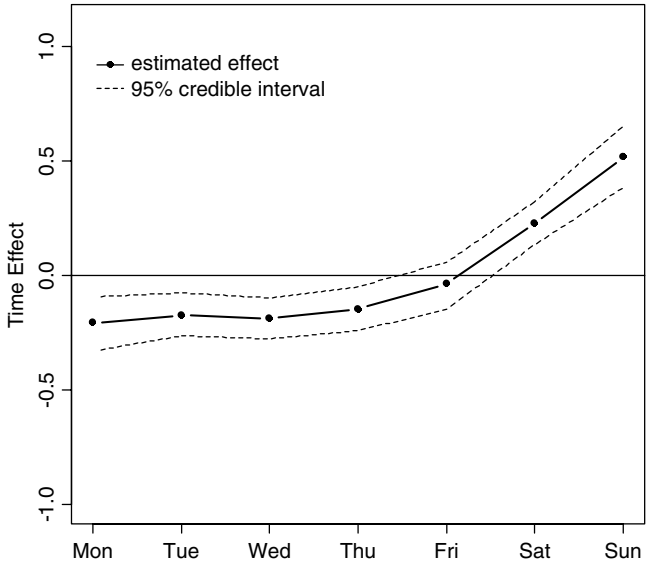

Fig. 4. Time trend estimate for the total daily amount of alcohol consumed over one week.

mirrors the real complexities of life sciences, particularly in epidemiology. We believe that the unfriendliness of the techniques and software present an obstacle, although a recently published paper (Greenland, 2006), points out that adequate and early training and misplaced philosophical discussion act as the true determinants. Nevertheless, as the techniques mature, the software will become more user friendly. Our results clearly show the advantages of using a flexible model, allowing for non-linear time trend and intra-individual dependence in observations and inter-individual variability. If a more naïve approach, such as summary analysis per day of the week, was used we would lose the strength of the longitudinal study in tracking the individual trajectory of the behaviour and alcohol consumption over the week when measuring the mean profile, while controlling for important factors.

An advantage of the present study is the use of prospective information of consumption using 7-day records. Although the drinking diary of self-reported data is in fact daily, hourly or minutely retrospective, it can be argued that it is more valid than long-term retrospective data and diaries have been used to validate retrospective measures (Poikolainen and Karkkainen, 1983; Poikolainen *et al*., 2002; Heeb and Gmel, 2005). A disadvantage of diaries was related to the possibility of changing habits during the registration period. However, some studies comparing dietary records with more objective measures showed validity (Brunner *et al*., 2001; McKeown *et al*., 2001), and even if there is a possibility of error in reporting what they drink, it may be more likely to affect the volume of consumption rather than the pattern. An additional disadvantage of self-reported data could be the possible underestimation of alcohol consumption, particularly for days with higher consumption. Even though this bias could be present in our data, probably this effect is in order to reduce the differences between week and weekend days, thus we can expect that our conclusions remain valid.

In conclusion, the present study showed an increase in alcohol consumption throughout the week, but with a different trend according to the context of consumption (drinking only at principal meals and drinking also outside mealtimes).

In the Porto population older than 40 years, the consumption decreased with increasing age. Drinking only at principal meals was frequently found among those who were less educated and the pattern of drinking at any time of the day was more common in individuals with a higher education level.

The multinomial modelling approach was successful in dealing with different time trends, one linear and the other non-linear, both conditioned for individual random effects. Although seldom used in epidemiological research, Bayesian modelling is a very powerful technique to deal with real life complexities, and its use is now possible with normal desktop computers and free and friendlier software.

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