European Journal of Clinical Nutrition (2009) 63, 1169–1175
 0954-3007/09 $32.00
www.nature.com/ejcn

ORIGINAL ARTICLE

Dietary sources and correlates of sodium and potassium intakes in the French general population

P Meneton[1], L Lafay[2], A Tard[2], A Dufour[2], J Ireland[2], J Ménard[3] and JL Volatier[2]

[1]*INSERM U872, Centre de Recherche des Cordeliers, Paris, France;* [2]*Unité Nutrition, Agence Française de Sécurité Sanitaire des Aliments, Maisons-Alfort, France and* [3]*Département de Santé Publique et d'Informatique Médicale, Université Paris Descartes, Paris, France*

Background/objectives: To investigate the dietary sources of sodium and potassium and to explore the biological, behavioural and socio-demographic factors associated with a high sodium and low potassium diet in a general population.
Subjects/methods: Cross-sectional dietary survey carried out in 1998 and 1999 in nationally representative samples of adults ($n=1474$) and children ($n=1018$). Daily sodium and potassium intakes were estimated using a 7-day food record after exclusion of underreporters.
Results: Mean sodium intake was well above, whereas mean potassium intake was largely below the current recommendations in adults and children. The consumption of a high sodium and low potassium diet appeared very early in life and increased up to adulthood, especially in men living in small communities. Despite the fact that sodium and potassium intakes were positively correlated to each other and to total food intake, several food categories showed a sodium/potassium intake ratio well above one (cheeses, cooked pork meats, breads, breakfast cereals, soups, fast foods, pastries and sugary products) whereas others presented a ratio well below one (fruits, vegetables, dairy products, meats and hot beverages).
Conclusions: High sodium and low potassium intakes were widespread in the population. The fact that the main dietary sources of sodium and potassium were, for the most part, not the same demonstrates the feasibility of simultaneously increasing sodium intake and decreasing potassium intake at the individual level.
European Journal of Clinical Nutrition (2009) **63,** 1169–1175; doi:10.1038/ejcn.2009.57; published online 22 July 2009

Keywords: sodium and potassium intakes; dietary sources; cross-sectional survey; general population

Introduction

A large number of studies provide strong evidence of a causal link between high sodium intake, hypertension and cardiovascular diseases (Institute of Medicine, 2004; Meneton *et al*., 2005). A high sodium diet has also been associated with an increased risk of bone demineralization, kidney stones and stomach cancer (Institute of Medicine, 2004). There is an equally large body of evidence showing that potassium intake exerts a blood pressure lowering effect and is associated with a decreased risk of cardiovascular disease, bone demineralization and kidney stones, thus potentially offsetting the harmful effects of high sodium intake (He and MacGregor, 2001; Institute of Medicine, 2004). Most guidelines on the prevention of chronic diseases and the management of hypertension emphasize the necessity both to reduce sodium intake and to increase the consumption of potassium-rich foods, such as fruits and vegetables (National High Blood Pressure Education Program, 2003; World Health Organization, 2003, 2007; Mancia *et al*., 2007). However, they usually provide little information on the different sources of sodium and potassium in the diet and whether general consumers can easily achieve a reduction in sodium intake concomitantly with an increase in potassium intake (Arbeit *et al*., 1992). This study analyzes a dietary survey that was performed in 1998 and 1999 in representative samples of the French population. It aims to identify the main food sources of sodium and potassium and to investigate the

Correspondence: Dr P Meneton, Département de Santé Publique et d'Informatique Médicale, Université Paris Descartes, 15 rue de l'Ecole de Médecine, 75006 Paris, France.
E-mail: pierre.meneton@spim.jussieu.fr
Guarantors: P Meneton and JL Volatier.
Contributors: PM performed and interpreted statistical analyses and drafted the article; LL, AT, AD and JLV supervised the survey and data collection, JI compiled sodium and potassium food composition table; JM contributed to the writing of the final article.
Received 25 September 2008; revised 20 May 2009; accepted 21 May 2009; published online 22 July 2009

biological and socio-behavioural factors associated to a sodium-rich and potassium-poor diet in adults and children.

Methods

Survey population

We analyzed the data of the national food consumption survey that was performed between August 1998 and June 1999 by the French Food Safety Agency (Volatier, 2000). This cross-sectional survey was primarily designed to assess food intake patterns in adults (15 to 92 year olds) and children (2 to 14 year olds). The sampling design used to select nationally representative samples of adults and children living in French households included a stratification by region of residence and community size and a distribution according to age, gender, household size and head of household socio-professional status by the quota method (Deville, 1991). In comparison to the distribution of age in the French population as observed in the national census in 1999, the child sample ($n=1018$) was proportionally larger than the adult sample ($n=1985$) to include a sufficient number of individuals for the statistical analyses.

Assessment of dietary sodium and potassium intakes

The survey was randomly distributed over 11 months to cover all seasons. Participants used a 7-day record to note all their food and drink consumption. They estimated portion sizes by comparing their actual consumption with photographs in a reference manual (Le Moullec *et al*., 1996). The biological, behavioural and socio-demographic parameters were self-reported using a specific questionnaire. Just before the week of the survey, a trained investigator delivered the documents at home and explained to the parents and their children how to fill them in. Parents completed both documents together with their children when the children were 9-year-old or under. On the last day of the survey, the investigator checked the accuracy of the information reported in the food record and the specific questionnaire. Average daily sodium and potassium intakes were calculated using a food composition table issued by the French Centre Informatique sur la Qualité des Aliments (Favier *et al*., 1995). Sodium intake did not include discretionary salt (salt added by the consumer during food preparation or at the table) for which no reliable information was gathered.

This type of dietary record based on a photographic manual of portion sizes was validated by comparing the data with 24-h urinary excretion measurements that are considered to be the most accurate way for evaluating sodium and potassium intakes (Clark and Mossholder, 1986). This was carried out in a group of 149 healthy volunteers who provided a total of three dietary records and 24-h urinary collections in the previous study (Meneton *et al*., 2008). In this group, sodium and potassium intakes determined by the food records were correlated with 24-h urinary excretion values ($r=0.27$, $P=0.05$ for sodium and $r=0.35$, $P=0.02$ for potassium). These correlations were comparable with those reported by several other investigators (Schachter *et al*., 1980; Caggiula *et al*., 1985; Kesteloot and Joossens, 1990; McKeown *et al*., 2001; Reinivuo *et al*., 2006).

Statistical analyses

To limit potential misreporting, 511 underreporters whose dietary intakes were unusually low in regard to their basal energy needs (energy intake to basal metabolic rate ratio less than 1.14) were excluded from the analyses (Goldberg *et al*., 1991). These analyses were conducted separately in children and adults. Pearson's correlation coefficients and partial correlation coefficients adjusted for age and body mass index were computed to test the associations between sodium and potassium intakes, their ratio and total food intake (that is, all food and beverage items that were consumed by the participants). Dietary sources of sodium and potassium were evaluated through 19 major food and beverage categories that were constituted by grouping together items with similar characteristics. Multiple linear regression models were used to investigate the associations of sodium and potassium intakes and their ratio with the biological, behavioural and socio-demographic variables available in the survey. The associations were simultaneously adjusted for all the variables included in the models: total food intake, sex, age, region of residence, community size, household monthly income, household size, body mass index, occupation, physical activity, smoking and will to avoid salt (the four latter variables were only available in adults). Thus, a significant association reflects the fact that individuals had a qualitatively different diet with respect to sodium or potassium content. All analyses were performed with the statistical discovery software JMP 7 (SAS, Cary NC, USA).

Results

Overall distributions of sodium and potassium intakes and of their ratio

The minimal and maximal values and percentage quantiles of sodium and potassium intakes and of their ratio are reported for adults and children in Table 1. In adults, mean sodium intake (95% CI) was 136 (134–139) mmol per day, mean potassium intake was 77 (76–78) mmol per day and the sodium/potassium intake ratio was 1.80 (1.78–1.83). In children, mean intakes were 103 (100–105) mmol of sodium per day, 64 (63–65) mmol of potassium per day and their ratio was 1.64 (1.61–1.67).

Correlations between sodium and potassium intakes, their ratio and total food intake

As shown in Figure 1, sodium and potassium intakes were positively correlated to each other and to total food intake in

adults and children. These correlations were also observed after adjustment for age and body mass index ($r=0.50$, $P<0.0001$; $r=0.44$, $P<0.0001$; $r=0.62$, $P<0.0001$ in adults and $r=0.57$, $P<0.0001$; $r=0.63$, $P<0.0001$; $r=0.76$, $P<0.0001$ in children). In contrast, the sodium/potassium intake ratio was not correlated with total food intake in adults and children after adjustment for age and body mass index (not shown).

Table 1 Distributions of sodium and potassium intakes and of their ratio in participants

	Sodium intake	Potassium intake	Sodium/potassium intake ratio
Adults			
Min	27	16	0.47
10th	83	53	1.17
25th	104	63	1.43
50th	129	74	1.75
75th	160	89	2.11
90th	199	103	2.50
Max	442	237	4.36
Children			
Min	18	19	0.37
10th	60	43	1.08
25th	76	52	1.30
50th	97	62	1.56
75th	120	74	1.89
90th	153	87	2.28
Max	378	163	3.90

Sodium and potassium intakes are expressed in mmol/24 h.

Dietary sources of sodium and potassium

Table 2 lists food and beverage categories with their relative contributions to daily sodium and potassium intakes in adults and children. Breads, soups, cooked pork meats, convenience foods, cheeses, pastries and sugary products, fast foods, breakfast cereals and dairy products were the main contributors to sodium intake in adults as well as in children. The main contributors to potassium intake were also similar in adults and children with vegetables, dairy products, meats, fruits, beverages, soups, hot beverages, pastries and sugary products, convenience foods and breads being the major sources. Among these major sodium and potassium contributors, cheeses, cooked pork meats, pastries and sugary products, breakfast cereals, breads, soups and fast foods showed the highest sodium/potassium intake ratios, whereas fruits, hot beverages, meats, vegetables and dairy products displayed the lowest ratios.

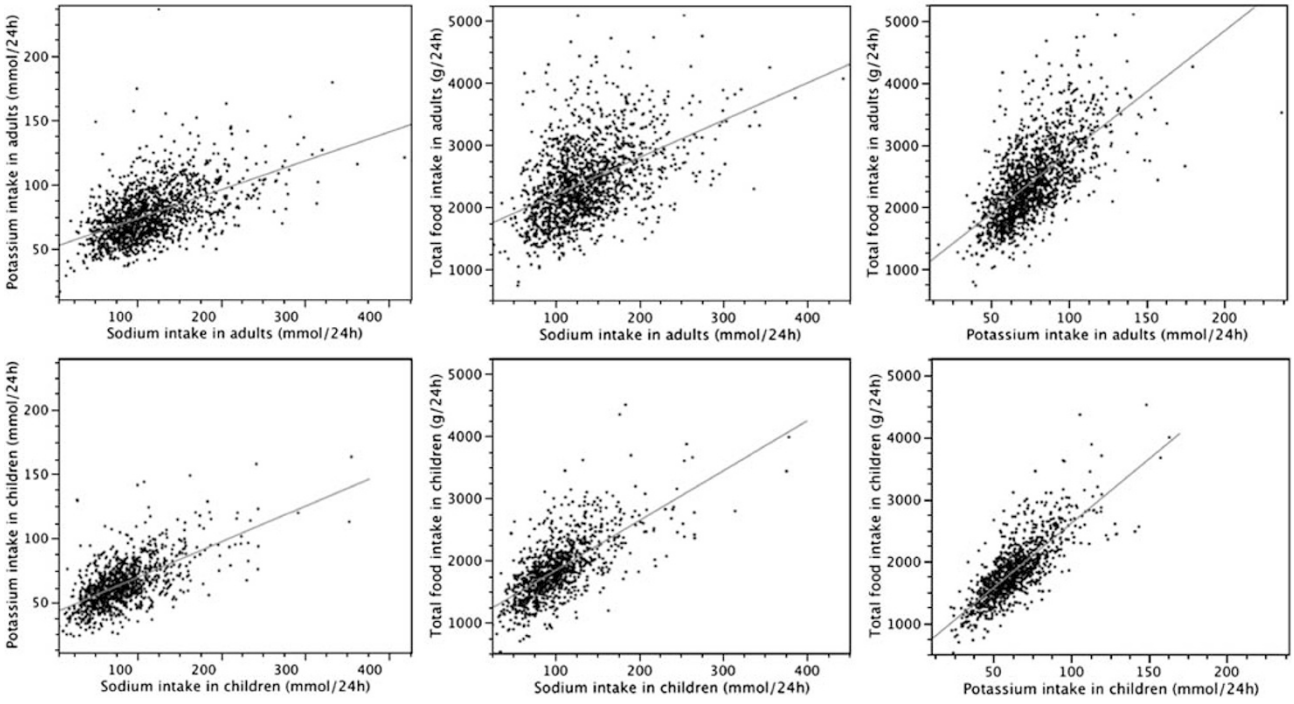

Figure 1 Correlations between sodium and potassium intakes and total food intake in adults (upper panels) and children (lower panels). Total food intake included all food and beverage items that were consumed by the participants. In adults, the equations of the linear regression lines are: potassium intake $=46+0.22\times$ sodium intake ($r=0.52$, $P<0.0001$), total food intake $=1596+6.03\times$ sodium intake ($r=0.46$, $P<0.0001$) and total food intake $=913+19.6\times$ potassium intake ($r=0.64$, $P<0.0001$). In children, the equations are: potassium intake $=35+0.28\times$ sodium intake ($r=0.61$, $P<0.0001$), total food intake $=1024+8.06\times$ sodium intake ($r=0.67$, $P<0.0001$) and total food intake $=530+20.7\times$ potassium intake ($r=0.78$, $P<0.0001$).

Table 2 Dietary sources of sodium and potassium

	Sodium		*Potassium*		*Sodium/potassium ratio*	
	Adults	*Children*	*Adults*	*Children*	*Adults*	*Children*
Beverages[a]	0.7 ± 0.8	0.6 ± 1.1	7.5 ± 7.6	7.7 ± 7.9	1.7 ± 15.9	2.0 ± 8.4
Breads	24.2 ± 13.7	15.7 ± 11.0	5.3 ± 3.6	3.2 ± 2.8	5.1 ± 1.8	5.6 ± 1.9
Breakfast cereals	5.2 ± 5.7	7.5 ± 7.3	3.2 ± 4.0	2.2 ± 3.1	5.3 ± 5.8	7.1 ± 5.1
Cereals[b]	0.1 ± 0.6	0.1 ± 1.5	0.7 ± 1.4	1.0 ± 1.8	0.1 ± 0.7	0.1 ± 0.3
Cheeses	9.2 ± 6.6	7.0 ± 5.6	1.7 ± 1.2	1.2 ± 1.0	6.2 ± 3.0	6.6 ± 3.2
Convenience foods[c]	10.5 ± 9.9	11.6 ± 9.9	6.3 ± 5.7	5.8 ± 5.3	1.9 ± 1.7	2.2 ± 1.4
Cooked pork meats	13.6 ± 9.1	13.3 ± 8.5	2.9 ± 2.2	2.7 ± 2.1	5.4 ± 3.3	5.7 ± 3.1
Dairy products[d]	3.4 ± 3.0	6.6 ± 4.2	11.3 ± 8.5	20.3 ± 10.3	0.3 ± 0.1	0.3 ± 0.1
Eggs	2.2 ± 1.9	2.1 ± 1.7	1.3 ± 1.1	1.2 ± 0.8	1.7 ± 0.7	1.8 ± 0.7
Fast foods[e]	7.1 ± 8.8	6.8 ± 7.5	2.4 ± 3.3	2.1 ± 2.4	3.2 ± 1.4	3.4 ± 1.3
Fats[f]	0.2 ± 0.3	0.2 ± 0.2	0.1 ± 0.1	0.1 ± 0.1	4.1 ± 4.5	4.1 ± 2.4
Fish and seafood	3.4 ± 4.5	3.1 ± 4.2	3.3 ± 3.3	2.5 ± 2.7	1.3 ± 1.5	1.5 ± 1.7
Fruits[g]	0.2 ± 0.4	0.2 ± 0.5	9.3 ± 8.1	7.7 ± 7.2	0.1 ± 0.1	0.1 ± 0.1
Hot beverages[h]	0.2 ± 0.7	0.7 ± 1.1	7.6 ± 7.5	4.2 ± 4.6	0.1 ± 0.1	0.2 ± 0.1
Meats[i]	2.7 ± 1.9	2.7 ± 1.9	11.3 ± 6.1	10.1 ± 5.6	0.2 ± 0.1	0.3 ± 0.1
Pastries and sugary products[j]	8.5 ± 8.1	15.8 ± 10.3	5.6 ± 4.6	9.3 ± 5.8	4.9 ± 93.7	1.9 ± 1.1
Seasonings and dressings	3.1 ± 3.8	2.6 ± 3.7	0.3 ± 0.6	0.4 ± 0.7	28.7 ± 346.7	16.4 ± 12.5
Soups	17.9 ± 11.7	13.3 ± 9.4	7.7 ± 5.6	5.1 ± 4.2	3.3 ± 4.4	3.8 ± 4.8
Vegetables[k]	3.4 ± 3.3	4.2 ± 3.2	19.5 ± 8.0	18.0 ± 7.7	0.2 ± 0.2	0.3 ± 0.2

The contributions of each food category are expressed in percentage of daily sodium and potassium intakes. The sodium/potassium ratio is the ratio between the daily amounts of sodium and potassium provided by each food category. Values are means ± s.d.
[a]Water, alcoholic beverages, soft drinks, fruit juices;
[b]Pasta, rice, semolina, and other cereals;
[c]Foods that need little or no preparation, from canned or frozen foods to pre-packaged heat and serve meals;
[d]Milk and yogurts;
[e]Rapidly consumed foods such as sandwiches, hamburgers, pizzas, quiches, savoury pies;
[f]Butter, margarines, oils, and other fats;
[g]Fresh fruits, dried fruits, nuts, jams, compotes;
[h]Tea and coffee;
[i]Beef, lamb, pork, poultry, games, offal;
[j]Pastries, cakes, croissants, puddings, biscuits, sugar, ice creams, chocolates, and other sweetened desserts;
[k]Vegetables, potatoes, pulses.

Associations of sodium and potassium intakes and of their ratio with other covariates

In adults, after adjustment for all the variables included in the linear regression model, sodium intake was higher in men than in women, positively correlated with body mass index and negatively correlated with community size. It also varied across occupational categories with farmers and manual workers showing the highest intakes (Table 3). Potassium intake was higher in men than in women and varied across occupation categories with farmers having the highest intake (Table 3). The sodium/potassium intake ratio was higher in men than in women and was positively correlated with community size (Table 3). Physical activity, smoking, the will of avoiding salt, the region of residence, household monthly income and size were not associated with sodium intake, potassium intake or their ratio (not shown).

In children, sodium intake was higher in boys than in girls and was positively correlated with age (Table 3). No significant association was observed with potassium intake but the sodium/potassium intake ratio was higher in boys than in girls and was positively correlated with age (Table 3). Body mass index, the region of residence, community size, household monthly income and size were not associated with sodium intake, potassium intake or their ratio (not shown).

Discussion

The dietary survey performed in 1998 and 1999 by the French Food Safety Agency provided us with useful information on sodium and potassium intakes in nationally representative samples of adults and children. The underestimation of sodium intake due to the non-assessment of discretionary salt and the potential bias of dietary records for evaluating the actual intake were not critical for the present analysis whose main objective was to assess the dietary sources and correlates rather than the absolute values of sodium and potassium intakes. Despite these limitations, the reported values of sodium and potassium intakes in the French population are very similar to the figures described in other industrialized populations (Intersalt Cooperative Research Group, 1988; Maldonado-Martin *et al.*, 2002; Ervin *et al.*,

Table 3 Associations of sodium and potassium intakes and of their ratio with biological and socio-demographic characteristics of participants

	Sodium intake		*Potassium intake*		*Sodium/potassium intake ratio*	
	Mean (95% CI)	P	*Mean (95% CI)*	P	*Mean (95% CI)*	P-*value*
Adults (n = *1474)*						
Sex						
Male (*n* = 672)	151 (144–158)	*<0.0001*	83 (80–86)	*<0.0001*	1.86 (1.75–1.97)	*<0.0001*
Female (*n* = 802)	126 (118–133)		75 (72–78)		1.71 (1.59–1.82)	
15–24 years (*n* = 254)	134 (124–143)	*0.26*	77 (73–81)	*0.19*	1.79 (1.65–1.92)	*0.22*
25–44 years (*n* = 586)	137 (130–145)		78 (76–81)		1.78 (1.67–1.90)	
45–64 years (*n* = 389)	137 (129–145)		81 (78–84)		1.73 (1.61–1.85)	
65–92 years (*n* = 245)	145 (134–156)		81 (77–85)		1.84 (1.68–2.00)	
Body mass index						
Optimal (<25 kg/m^2) (*n* = 1023)	133 (127–139)	*0.04*	77 (75–79)	*0.15*	1.77 (1.67–1.87)	*0.89*
Overweight (⩾25, <30 kg/m^2) (*n* = 380)	138 (131–145)		79 (76–82)		1.79 (1.68–1.90)	
Obese (⩾30 kg/m^2) (*n* = 70)	144 (132–157)		81 (76–86)		1.79 (1.62–1.97)	
Community size						
<2000 inhab (*n* = 370)	148 (141–156)	*0.0002*	79 (76–82)	*0.48*	1.92 (1.81–2.04)	*<0.0001*
2000–19 999 inhab (*n* = 236)	139 (130–148)		80 (76–83)		1.76 (1.63–1.88)	
20 000–99 999 inhab (*n* = 175)	138 (129–148)		79 (75–82)		1.80 (1.67–1.94)	
⩾100 000 inhab (*n* = 420)	137 (129–145)		78 (75–81)		1.79 (1.67–1.90)	
Paris and its suburbs (*n* = 273)	130 (120–140)		81 (77–85)		1.65 (1.51–1.79)	
Occupation						
Farmer (*n* = 22)	157 (135–180)	*0.04*	94 (86–103)	*0.004*	1.65 (1.35–1.95)	*0.11*
Self-employed (*n* = 37)	132 (116–148)		74 (68–81)		1.84 (1.62–2.05)	
Upper management (*n* = 87)	132 (120–143)		74 (70–79)		1.80 (1.65–1.96)	
Middle management (*n* = 160)	136 (126–145)		78 (75–82)		1.79 (1.67–1.92)	
White-collar (*n* = 224)	138 (129–147)		77 (73–80)		1.86 (1.75–1.98)	
Manual worker (*n* = 160)	149 (139–158)		79 (75–83)		1.91 (1.78–2.03)	
Unemployed (*n* = 104)	135 (124–146)		78 (74–82)		1.74 (1.60–1.89)	
Not working (*n* = 347)	134 (126–142)		79 (76–82)		1.73 (1.62–1.84)	
Pensioner (*n* = 322)	133 (124–142)		78 (75–82)		1.74 (1.62–1.86)	
Children (n = *1018)*						
Sex						
Male (*n* = 530)	103 (93–113)	*0.0009*	67 (63–71)	*0.28*	1.57 (1.40–1.73)	*0.01*
Female (*n* = 488)	96 (86–106)		66 (62–70)		1.48 (1.32–1.64)	
Age						
2–5 years (*n* = 243)	89 (79–99)	*<0.0001*	66 (61–70)	*0.20*	1.37 (1.19–1.54)	*<0.0001*
6–10 years (*n* = 442)	101 (91–111)		67 (63–71)		1.54 (1.37–1.70)	
11–14 years (*n* = 333)	108 (99–118)		66 (62–70)		1.67 (1.50–1.83)	

Sodium and potassium intakes are expressed in mmol/24 h. Values are adjusted for total food intake (which included all food and beverage items consumed by the participants), sex, age, body mass index, physical activity, smoking, will of avoiding salt, region of residence, community size, household monthly income and size.

2004; Heird *et al*., 2006; He *et al*., 2008). In adults, the average sodium intake is well above the current recommendations (<90 mmol per day) whereas the average potassium intake is largely below the recommended adequate intake (120 mmol per day) (Institute of Medicine, 2004; World Health Organization, 2007). In children, the situation is even worse as the reference nutrient intake for sodium is much lower than the current intake (Scientific Advisory Committee on Nutrition, 2003). This underlines the urgent necessity to develop and implement policies aimed at reducing sodium intake and increasing potassium intake at the population level.

As part of these policies, the guidelines for the prevention of chronic diseases and the management of hypertension should give more specific advices for reducing the sodium/potassium intake ratio of the diet. It is all the more necessary that, as reported here, the individual will of avoiding salt is a totally inefficient way of controlling sodium intake, which is a direct consequence of the low contribution of discretionary salt to daily sodium intake and of the lack of labelling on food items. Our results underline the possibility of simultaneously decreasing sodium intake and increasing potassium intake by judiciously choosing food categories. The main contributors to sodium and potassium intakes were essentially the same in adults and children. Breads, soups, cooked pork meats, convenience foods, pastries and sugary products were the major sources of sodium whereas vegetables, dairy products, meats and fruits were the major providers of potassium, similarly to what has been described in other industrialized populations (Allison and Walker, 1986; Witschi *et al*., 1987; Arbeit *et al*., 1992; Beer-Borst *et al*., 2009). When considering the sodium/potassium intake ratio, and apart from seasonings and dressings that have a very

unfavourable ratio but provide very little sodium and potassium, several food categories showed a ratio well above one (cheeses, cooked pork meats, breads, breakfast cereals, soups, fast foods, pastries and sugary products) whereas others presented a ratio well below one (fruits, vegetables, dairy products, meats and hot beverages). Thus, despite the strong positive correlation between sodium and potassium intakes at the population level, the main dietary sources of sodium and potassium were, for the most part, not the same. This emphasizes the feasibility of increasing the consumption of potassium-rich foods while reducing that of sodium-rich foods at the individual level. Although the main dietary sources of sodium and potassium may vary from one population to another, it is likely that the present classification of food categories according to their sodium/potassium intake ratio can be used in most industrialized countries.

The biological and socio-demographic characteristics associated with high sodium and low potassium intakes are not easily modifiable and hence are not very useful for preventive strategies. However, they can suggest specific population groups that could be targeted in priority. This study shows that sodium intake was higher in men than in women in both adults and children. Such a sex difference has been reported in many populations (Kesteloot *et al*., 1990), but in several cases this difference was no longer present after adjustment for energy intake (Pietinen, 1982; Van Cauwenbergh *et al*., 1999). Sodium intake rose progressively from 2–5 to 15–24 years of age and remained relatively constant into adulthood, indicating that the consumption of sodium-rich foods was a phenomenon that appeared very early in life and increased throughout infancy and adolescence. Sodium intake was also linked to the community size with the highest intake observed in adults living in a rural setting, as shown in other industrialized countries (Takemori *et al*., 1989). The sodium/potassium intake ratio was generally associated with the same characteristics than sodium intake as potassium intake was fairly constant in the different population groups. It is noteworthy that some participant characteristics such as the region of residence and household monthly income and size were not associated with sodium and potassium intakes and their ratio. This suggests that food habits are relatively uniform across the territory and the social categories with respect to sodium or potassium intakes in contrast to what has been described in other countries (Gerber *et al*., 1991; Leclercq and Ferro-Luzzi, 1991; Ganguli *et al*., 1997; Bates *et al*., 2001; Hajjar and Kotchen, 2003). In particular, it is of interest that potassium intake was not different on the Mediterranean coast as compared with other regions. This indicates that the current average diet in this region is not anymore a typical Mediterranean diet that is supposedly rich in fruits and vegetables, a situation which has also been reported in Italy, Greece, Portugal and Spain (Chen and Marques-Vidal, 2007).

The strong positive correlation between sodium and potassium intakes at the population level has important public health consequences as the beneficial effects of potassium somewhat limit the deleterious effects of sodium. This correlation can be explained by the ubiquitous nature of potassium that is naturally present in most foods and by the widespread use of sodium in processed foods (Kodama *et al*., 2005). Thus, the main determinant of sodium and potassium intakes appeared to be the total amount of food ingested that is strongly correlated with both sodium and potassium intakes in adults and children. This latter correlation has been described in other populations with energy intake as a surrogate measure of food intake (Pietinen, 1982; Uusi-Rasi *et al*., 1999; Cohen *et al*., 2006; Brion *et al*., 2008). It raises the question whether guidelines, which often provide a single intake in men and women whatever the body size, are not oversimplified (Institute of Medicine, 2004; World Health Organization, 2007). In view of the present results, it seems clearly inadequate to recommend the same sodium and potassium intakes for a large man and a small woman. However, it would be proper to recommend a single value for the sodium/potassium intake ratio that is not correlated with total food intake.

In summary, in representative samples of the French population surveyed in 1998 and 1999, mean sodium intake largely exceeded, whereas mean potassium intake was well below the recommended intake in adults and children. The consumption of a high sodium and low potassium diet started very early in life and was especially pronounced in men living in small communities. This situation could be improved at the individual level by promoting the consumption of food categories with a low sodium/potassium intake ratio such as fruits, vegetables, dairy products, meats and hot beverages and by discouraging the consumption of food categories with a high ratio such as cheeses, cooked pork meats, breads, breakfast cereals, soups, fast foods, pastries and sugary products.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

Joël Ménard received funding from the Association Robert Debré pour la Recherche Médicale and Pierre Meneton from the Institut National pour la Santé et la Recherche Médicale.

References

Allison ME, Walker V (1986). The sodium and potassium intake of 3 to 5 year olds. *Arch Dis Child* **61**, 159–163.

Arbeit ML, Nicklas TA, Berenson GS (1992). Considerations of dietary sodium/potassium/energy ratios of selected foods. *J Am Coll Nutr* **11**, 210–222.

Bates CJ, Cole TJ, Mansoor MA, Pentieva KD, Finch S (2001). Geographical variations in nutrition-related vascular risk factors in the UK: National Diet and Nutrition Survey of People Aged 65 Years and Over. *J Nutr Health Aging* **5**, 220–225.

Beer-Borst S, Coastanza MC, Pechere-Bertschi A, Morabia A (2009). Twelve-year trends and correlates of dietary salt intakes for the general adult population of Geneva, Switzerland. *Eur J Clin Nutr* **63**, 155–164.

Brion MJ, Ness AR, Davey Smith G, Emmett P, Rogers I, Whincup P *et al.* (2008). Sodium intake in infancy and blood pressure at 7 years: findings from the Avon Longitudinal Study of Parents and Children. *Eur J Clin Nutr* **62**, 1162–1169.

Caggiula AW, Wing RR, Nowalk MP, Milas NC, Lee S, Langford H (1985). The measurement of sodium and potassium intake. *Am J Clin Nutr* **42**, 391–398.

Chen Q, Marques-Vidal P (2007). Trends in food availability in Portugal in 1966–2003: comparison with other Mediterranean countries. *Eur J Nutr* **46**, 418–427.

Clark AJ, Mossholder S (1986). Sodium and potassium intake measurements: dietary methodology problems. *Am J Clin Nutr* **43**, 470–476.

Cohen HW, Hailpern SM, Fang J, Alderman MH (2006). Sodium intake and mortality in the NHANES II follow-up study. *Am J Med* **119**, 275.e7–275.e14.

Deville JC (1991). A theory of quota surveys. *Survey Methodol* **17**, 163–181.

Ervin RB, Wang CY, Wright JD, Kennedy-Stephenson J (2004). Dietary intake of selected minerals for the United States population: 1999–2000. *Adv Data* **341**, 1–5.

Favier JC, Ireland J, Toque C, Feinberg M (1995). Répertoire général des aliments. Tables de composition. *CIQUAL-REGAL*, 2nd edn.

Ganguli MC, Grimm RHJ, Svendsen KH, Flack JM, Grandits GA, Elmer PJ (1997). Higher education and income are related to a better Na:K ratio in blacks: baseline results of the Treatment of Mild Hypertension Study (TOMHS) data. *Am J Hypertens* **10**, 979–984.

Gerber AM, James SA, Ammerman AS, Keenan NL, Garrett JM, Strogatz DS *et al.* (1991). Socioeconomic status and electrolyte intake in black adults: the Pitt County Study. *Am J Public Health* **81**, 1608–1612.

Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA *et al.* (1991). Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cutoff limits to identify under-recording. *Eur J Clin Nutr* **45**, 569–581.

Hajjar I, Kotchen T (2003). Regional variations of blood pressure in the United States are associated with regional variations in dietary intakes: the NHANES-III data. *J Nutr* **133**, 211–214.

He FJ, MacGregor GA (2001). Fortnightly review: beneficial effects of potassium. *BMJ* **323**, 497–501.

He FJ, Marrero NM, Macgregor GA (2008). Salt and blood pressure in children and adolescents. *J Hum Hypertens* **22**, 4–11.

Heird WC, Ziegler P, Reidy K, Briefel R (2006). Current electrolyte intakes of infants and toddlers. *J Am Diet Assoc* **106**, S43–S51.

Institute of Medicine (2004). Dietary reference intakes for water, potassium, sodium, chloride and sulfate. *The National Academies Press*. http://books.nap.edu/catalog.php?record_id = 10925.

Intersalt Cooperative Research Group (1988). Intersalt: an international study of electrolyte excretion and blood pressure. Results for 24 h urinary sodium and potassium excretion. Intersalt Cooperative Research Group. *BMJ* **297**, 319–328.

Kesteloot H, Elliott P, Lesaffre E (1990). On the sex ratio of urinary cation excretion obtained from Intersalt and other epidemiological studies. *J Hum Hypertens* **4**, 603–607.

Kesteloot H, Joossens JV (1990). The relationship between dietary intake and urinary excretion of sodium, potassium, calcium and magnesium: Belgian Interuniversity Research on Nutrition and Health. *J Hum Hypertens* **4**, 527–533.

Kodama N, Morikuni E, Matsuzaki N, Yoshioka YH, Takeyama H, Yamada H *et al.* (2005). Sodium and potassium balances in Japanese young adults. *J Nutr Sci Vitaminol (Tokyo)* **51**, 161–168.

Le Moullec N, Deheeger M, Preziosi P, Montero P, Valeix P, Rolland-Cachera MF *et al.* (1996). Validation du manuel-photos utilisé pour l'enquête alimentaire de l'étude SU.VI.MAX. *Cah Nutr Diet* **31**, 158–164.

Leclercq C, Ferro-Luzzi A (1991). Total and domestic consumption of salt and their determinants in three regions of Italy. *Eur J Clin Nutr* **45**, 151–159.

Maldonado-Martin A, Garcia-Matarin L, Gil-Extremera B, Avivar-Oyonarte C, Garcia-Granados ME, Gil-Garcia F *et al.* (2002). Blood pressure and urinary excretion of electrolytes in Spanish schoolchildren. *J Hum Hypertens* **16**, 473–478.

Mancia G, De Backer G, Dominiczak A, Cifkova R, Fagard R, Germano G *et al.* (2007). 2007 Guidelines for the Management of Arterial Hypertension: The Task Force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). *J Hypertens* **25**, 1105–1187.

McKeown NM, Day NE, Welch AA, Runswick SA, Luben RN, Mulligan AA *et al.* (2001). Use of biological markers to validate self-reported dietary intake in a random sample of the European Prospective Investigation into Cancer United Kingdom Norfolk cohort. *Am J Clin Nutr* **74**, 188–196.

Meneton P, Galan P, Bertrais S, Heudes D, Hercberg S, Menard J (2008). High plasma aldosterone and low renin predict blood pressure increase and hypertension in middle-aged Caucasian populations. *J Hum Hypertens* **22**, 550–558.

Meneton P, Jeunemaitre X, de Wardener HE, MacGregor GA (2005). Links between dietary salt intake, renal salt handling, blood pressure, and cardiovascular diseases. *Physiol Rev* **85**, 679–715.

National High Blood Pressure Education Program (2003). The Seventh Report of the Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. http://www.nhlbi.nih.gov/guidelines/hypertension/express.pdf.

Pietinen P (1982). Estimating sodium intake from food consumption data. *Ann Nutr Metab* **26**, 90–99.

Reinivuo H, Valsta LM, Laatikainen T, Tuomilehto J, Pietinen P (2006). Sodium in the Finnish diet: II trends in dietary sodium intake and comparison between intake and 24-h excretion of sodium. *Eur J Clin Nutr* **60**, 1160–1167.

Schachter J, Harper PH, Radin ME, Caggiula AW, McDonald RH, Diven WF (1980). Comparison of sodium and potassium intake with excretion. *Hypertension* **2**, 695–699.

Scientific Advisory Committee on Nutrition (2003). Salt and Health. http://www.food.gov.uk/multimedia/pdfs/saltandhealth0503.pdf.

Takemori K, Mikami S, Nihira S, Sasaki N (1989). Relationship of blood pressure to sodium and potassium excretion in Japanese women. *Tohoku J Exp Med* **158**, 269–281.

Uusi-Rasi K, Fogelholm M, Nenonen A, Pasanen M (1999). The accuracy of estimating calcium, sodium and potassium intake with a food record. *Scand J Nutr* **43**, 66–69.

Van Cauwenbergh R, Hendrix P, Robberecht HJ, Deelstra HA (1999). Daily dietary sodium and potassium intake in Belgium, using duplicate portion sampling. *Eur Food Res Technol* **209**, 63–67.

Volatier JL (2000). *Enquête Individuelle et Nationale sur les Consommations Alimentaires*. Editions TEC & DOC: Paris.

Witschi JC, Capper AL, Hosmer DWJ, Ellison RC (1987). Sources of sodium, potassium, and energy in the diets of adolescents. *J Am Diet Assoc* **87**, 1651–1655.

World Health Organization (2003). Diet, nutrition and the prevention of chronic diseases. http://whqlibdoc.who.int/trs/WHO_TRS_916.pdf.

World Health Organization (2007). Reducing salt intake in populations. http://www.who.int/dietphysicalactivity/reducingsaltintake_EN.pdf.