

Sodium and potassium intakes in Ireland

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There is considerable interest in the intakes of sodium and potassium, particularly in relation to the significance of these nutrients in the control of blood pressure. In the present review a number of aspects of Na and K are addressed. Methodology for assessment of intakes is described and findings for dietary intakes and dietary sources in Ireland are presented and compared with studies in the UK. The health significance of Na and K intakes is considered and the present status of dietary guidelines for Na and K is discussed in the light of recent large epidemiological studies on the relationship of dietary intakes of these elements to blood pressure.

ASSESSMENT OF Na AND K INTAKES

Assessment of Na intake of free-living individuals by dietary record methods is unreliable for two reasons. Information on the average Na contents of foods do not reflect the very wide variation in the Na content of any given food type (Paul & Southgate, 1978) and accurate measurement of discretionary salt intake (i.e. salt added to food during preparation and at table) is very difficult. The most widely used method for estimating Na intake is from 24 h urinary Na excretion (Flynn, 1984). This is based on the observation that except under exceptional circumstances (e.g. excessive sweat loss, vomiting or diarrhoea), over 95% of dietary Na is excreted in urine (Schachter *et al.* 1980).

There is a large intra-individual (i.e. day-to-day) variation in 24 h urinary Na excretion (Liu *et al.* 1979; Joossens *et al.* 1980; Shortt *et al.* 1988a) and the implication of this is that assessment of the usual Na intake of an individual requires that urine collections be obtained for a number of days. It has been estimated (Liu *et al.* 1979) that seven to fourteen 24 h urine collections are necessary to characterize an individual's usual Na intake. However, mean 24 h urinary Na excretion based on a single 24 h urine collection for each individual in a group provides a good estimate of mean daily Na intake of that group (Joossens & Geboers, 1984). In addition, the sample size required for the estimation of the group mean 24 h urinary Na excretion can be determined from data on intra-individual and inter-individual variation (Van Staveren *et al.* 1982; Shortt *et al.* 1988a).

Dietary record methods are more reliable for assessment of K intake than for Na intake. However, 24 h urinary K excretion is widely used as an estimate of daily K intake. This is based on the observation that there is a very close relationship between 24 h urinary K excretion and daily K intake (Mathers, 1988). The large intra-individual variation in 24 h urinary K excretion (Shortt *et al.* 1988a) requires that a large number of urine collections must be made in order to assess the usual daily K intake of an individual. However, mean 24 h urinary K excretion based on a single 24 h urine collection for each individual in a group provides a good estimate of mean daily K intake of that group.

The 24 h urine collection method has been described by Shortt *et al.* (1987a). Each subject is provided with a large (approximately 2.5 litre) plastic container containing preservative (e.g. 10 ml glacial acetic acid containing 250 mg thymol) and given detailed written and oral instructions. Individuals are required to report the time of the first and last voiding of urine and to report whether or not a complete collection was made. In addition, sex, age, height, weight and social class are recorded.

Given the nature of this method it is not surprising that individuals do not always comply with instructions and over- and under-collection of urine can occur. Indeed, the single greatest difficulty with this method is in assessing the completeness of 24 h urine collection. Self-reporting is not reliable as a means of assessing completeness of collection, but nevertheless it is very useful as it allows the exclusion of samples freely admitted to being incomplete (Knuiman *et al.* 1986b).

Ever since Folin (1905) reported that 24 h creatinine excretion is constant in individuals on varied diets, creatinine has been used as a check for completeness of urine collections. Joossens & Geboers (1984) have proposed that completeness of 24 h urine collection for individuals can be assessed by a creatinine index, i.e. the ratio, observed creatinine excretion:that expected for sex and body-weight. However, while daily urine creatinine excretion is determined largely by muscle mass (Heymsfield *et al.* 1983), it is also influenced by a number of other factors including strenuous exercise, the stage of the menstrual cycle in women, age, severe emotional stress, acute infection, fever and trauma, and renal insufficiency (Heymsfield *et al.* 1983; Fuller & Elia, 1988). It is also influenced by dietary protein, creatine and creatinine and it has been found that changing from a meat-free to a meat-based diet rapidly results in a 10–30% increase in urinary creatinine excretion (Bleiler & Schedl, 1972). There is also a considerable variation between individuals in 24 h urinary creatinine excretion. Bingham & Cummings (1983) have shown that creatinine excretion of one individual can be almost double that of another when expressed on a fat-free-mass basis. They estimated that up to 40% of urine could be lost in a 24 h period, yet the remainder would still give a creatinine value within the normal range. Creatinine is, therefore, unsuitable as a means of assessing the completeness of 24 h urine collection in an individual, and is useful only in detecting gross errors in collection (Bingham & Cummings, 1985; Knuiman *et al.* 1986a).

Bingham & Cummings (1983) have proposed the use of *p*-aminobenzoic acid (PABA) as a marker for completeness of 24 h urine collection in individuals. PABA capsules are ingested by subjects during the collection period and completeness of urine collection determined from recovery of PABA in urine. While this method is more reliable than creatinine for assessing completeness in individuals, it is suitable only for detecting under-collection and does not give any indication of over-collection.

While completeness of 24 h urine collection is very difficult to assess for individuals, the mean completeness of collection for a group can be assessed by comparison of the observed mean 24 h urinary creatinine excretion for the group with suitable reference values. For example, Joossens *et al.* (1980) have developed a polynomial equation for calculating reference values for creatinine excretion which takes age, height, weight, sex and social class into account, based on creatinine excretions in a large number of free-living individuals in Belgium. Reliable reference values for average 24 h urinary creatinine excretion of male (1.82 g) and female (1.26 g) adults are available from a study in Cambridgeshire, England (Bingham & Cummings, 1985; Williams & Bingham, 1986; Bingham *et al.* 1988) in which 24 h urinary creatinine output was determined in a

randomly selected population sample of seventy-one males and fifty-one females whose collections were carefully monitored for completeness using PABA as a marker.

Na AND K INTAKES IN IRELAND AND UK

A study of Na and K intakes of selected groups in Cork was undertaken (Shortt *et al.* 1987a) as part of the EURONUT SALT Project involving eleven European centres. A total of 132 individuals between the ages of 19 and 60 years living in Cork city were recruited and a single 24 h urine collection obtained from each. Participants consumed their usual diet during the collection period and were not aware that there was a particular interest in Na or K intake. Height and weight were measured and a questionnaire was completed by each subject. The groups consisted of civil servants, army personnel, student nurses and laboratory workers. These groups have been classified as social group 2 in Ireland (Central Statistics Office, 1982). The mean age of the female group (n 62) was 24 (range 21–49) years, while mean age of the males was 32 (range 19–59) years.

Completeness of 24 h urine collection in individuals is shown in Table 1. For females forty-nine of sixty-one subjects reported collection to be complete and one of these was adjudged to be over-collected on the basis of the creatinine index. Fifty of sixty-six males reported collection as complete and four were adjudged as under-collected on the basis of the creatinine index. Only those collections adjudged to be complete by both self-reporting and by the creatinine index were included in the estimation of mean Na and K intakes. It is interesting to note that nine of twelve collections for females and five of sixteen collections for males which were reported as being incomplete would not have been detected as incomplete by the creatinine index method, indicating that this method is not a sensitive indicator of completeness in individuals.

Mean 24 h creatinine excretion of males (1.67 g) and females (1.25 g) (Table 2) were very similar to reference values calculated using the equation of Joossens *et al.* (1980) (1.77 and 1.28 g respectively) and also to reference values of Bingham & Cummings (1985) (1.82 and 1.26 g respectively) indicating that mean completeness of 24 h urine collection for the groups was good.

The average 24 h Na excretion for complete collections in this study (Table 2) was 165.6 mmol (equivalent to 3.81 g Na or 9.7 g sodium chloride) for males and 133.8 mmol (equivalent to 3.08 g Na or 7.8 g NaCl) for females (Table 2). The pooled mean 24 h urinary Na excretion of males and females was 150 mmol (equivalent to 3.45 g Na or 8.8 g NaCl). There are few values for Na intakes of groups in the Irish population with which these results can be compared. Connolly *et al.* (1980) estimated the mean daily Na intake from 3 d weighed food records in selected adults (thirty-six male, thirty-five female) living in a semi-rural area. Average daily Na intakes were 3.74 g (9.5 g NaCl) and 2.98 g (7.8 g NaCl) for males and females respectively, with a pooled mean of 3.36 g (8.9 g NaCl). However, this did not include discretionary salt intake and, as indicated earlier, estimation of Na intake from food records using tables of food composition is not reliable.

Madden *et al.* (1983) reported that the average 24 h urinary excretion of twenty-five male and twenty-six female students, aged 19–21 years, living in Cork city, were 4.76 g (12.2 g NaCl) and 3.08 g (7.9 g NaCl) respectively, with a pooled mean of 3.9 g (10.0 g NaCl). However, completeness of 24 h urine collection was not assessed in this study.

Table 1. Comparison of self-reported completeness of 24 h urine collection with completeness as assessed by the creatinine index*

Urine collections	No. of collections	Creatinine index†		
		<60%	60–140%	>140%
Reported as complete				
Females	49	0	48	1
Males	50	4	46	0
Reported as incomplete				
Females	12	3	9	0
Males	16	5	11	0

* Shortt *et al.* (1987a).

† Joossens & Geboers (1984).

Table 2. Excretion of sodium, potassium and creatinine in complete 24 h urine collections* (Mean values and standard deviations)

	Na (mmol/24 h)	K (mmol/24 h)	Creatinine (g/24 h)
Females (n 48)			
Mean	133.8	60.1	1.25
SD	42.6	21.5	0.22
Range	63.2–275.4	17.4–106.4	0.85–1.84
Males (n 46)			
Mean	165.6	79.1	1.67
SD	63.6	31.1	0.35
Range	42.4–351.8	18.0–155.0	0.85–2.4

* Shortt *et al.* (1987a).

Data for Na intakes of selected groups in Cork are similar to most recent data for randomly selected population samples in Great Britain and Northern Ireland (Table 3). Mean 24 h urinary Na excretion was estimated in a randomly selected group of seventy-one males and fifty-one females in Cambridgeshire in whom urine collections were carefully monitored for completeness using the PABA method (Bingham & Cummings, 1985; Williams & Bingham, 1986). Average 24 h urinary Na excretion was 3.96 g (10.0 g NaCl) for males and 2.94 g (7.5 g NaCl) for females with a pooled mean of 3.45 g Na (8.8 g NaCl). Similar values were found for mean 24 h urine Na excretion in groups of randomly selected adults in Belfast, South Wales and Birmingham in the Intersalt Study (Table 3), but the values reported for randomly selected adults in the Scottish Heart Health Study (Smith *et al.* 1988) were somewhat higher (Table 3).

It is noteworthy that the measured mean Na intake of adults in the British Isles reported in Table 3 are all significantly lower than the value of 12 g NaCl used in the NACNE Report (National Advisory Committee on Nutrition Education, 1983) and by the Irish Food Advisory Committee (Food Advisory Committee, 1984a,b) in promul-

Table 3. Mean 24 h urine sodium and potassium excretion (U_{Na} and U_K respectively) of adults in Ireland and UK

Location	U_{Na} (mmol/24 h)	U_K (mmol/24 h)	Reference
Scotland	168	61	Smith <i>et al.</i> (1988)
Birmingham	153	63	Intersalt Cooperative Research Group (1988)
S. Wales	152	63	Intersalt Cooperative Research Group (1988)
Belfast	151	75	Intersalt Cooperative Research Group (1988)
Cambridgeshire	150	66	Bingham & Cummings (1985)
Cork	150	70	Shortt <i>et al.</i> (1987a)

Table 4. Dietary sources of sodium and potassium in Ireland and UK

Food group	Na (% total)		K (% total)	
	Ireland*	UK†	Ireland*	UK‡
Cereal (bread)	42 (27)	41	15 (7)	16
Meat (and eggs)	22	23	10	14
Dairy	21	20	29	24
Fruit/vegetables	4	14	32	40
Other	11	2	14	6
Total	100	100	100	100

* Downey *et al.* (1982), excluding salt used in the home.

† Bull & Buss (1980a), excluding salt used at table but including salt used in cooking.

‡ Bull & Buss (1980b).

gating dietary guidelines for salt reduction for the general population. Indeed, the measured values are all very close to the target value of 9 g NaCl recommended in these reports. The COMA Report (Department of Health and Social Security, 1984) estimated the average daily salt intake in Britain to be 7–10 g, and this appears to be close to the most recently reported values.

It would appear that the marked divergence in estimates of salt intake may arise from overestimation of salt used in the home (James *et al.* 1987). Sanchez-Castillo *et al.* (1987) determined salt intake in a randomly selected population living in Cambridgeshire, UK. Using lithium as a marker in table salt they showed that 15% of total salt intake is derived from salt used in cooking (6%) and at table (9%). This is considerably lower than previous estimates which suggested that about one-third of Na intake was derived from discretionary salt use (Upton & Gibney, 1977; Bull & Buss, 1980a).

The contribution of different food groups to Na intake in Ireland and the UK is outlined in Table 4. The Irish findings (Downey *et al.* 1982) are based on the study of Connolly *et al.* (1980) of Na intakes in selected individuals using 3 d weighed food records, while the UK values (Bull & Buss, 1980a) are based on analysis of 'total diet' samples from six areas in the UK and include salt added in food preparation but not that added at table. The results indicate that the cereals group is the single greatest source of Na in both the Irish and UK diets, contributing over 40% of total Na intake. Most of this

is obtained from bread. Bull & Buss (1980a) have estimated that about 86% of total Na intake from foods was derived from processed foods, and most of this comes from salt added during processing.

Thus, there is an apparent conflict between dietary recommendations to reduce salt intake and increase cereal consumption (National Advisory Committee on Nutrition Education, 1983; Department of Health and Social Security, 1984; Food Advisory Committee, 1984a,b). Furthermore, the other food groups which make a significant contribution to Na intake, i.e. meat and dairy products, also make a major contribution to the intake of essential nutrients in the Irish diet (Upton & Gibney, 1987). Given these considerations it would seem that a reduction in the quantity of salt added to foods during processing would be the most effective and nutritionally most prudent means of reducing average Na intake of the population. Strategies for reducing the average Na intake of the population will not be successful unless food manufacturers can be persuaded to reduce the salt content of foods, particularly foods that are commonly consumed, e.g. bread. Salt serves many functions in processed foods (Institute of Food Technologists, 1980), including flavour enhancement and preventing the growth of spoilage micro-organisms. Food manufacturers may need to be convinced that there is sufficient evidence of a clear benefit to public health from reducing the average Na intake of the population before they undertake a programme of salt reduction in processed foods.

The average 24 h K excretion in the present study was 79.1 mmol for males and 60.5 mmol for females, with a pooled mean of 69.8 mmol. There are few values for K intakes of groups in Ireland. Madden *et al.* (1983) reported 24 h urinary K excretion for young male (3.1 g) and female (2.2 g) adults living in Cork city; however, completeness of urine collection was not assessed. Downey *et al.* (1982) estimated average K intakes of 3.9 g for male and 3.2 g for female adults, living in a semi-rural area in Cork, using 3 d weighed food records. The value for 24 h K excretion for the Cork groups is similar to values for the Cambridgeshire study, but slightly higher than those obtained in the Scottish Heart Health Study and in the three UK centres for the Intersalt Study (Table 3).

The contribution of different food groups to K intake in Ireland and the UK is outlined in Table 4. The fruit and vegetable and dairy groups are the major dietary sources of K. Dietary recommendations for increased K intake by the general population (Food Advisory Committee, 1984a,b) should, therefore, emphasize both these food groups. While increased intake of fruits and vegetables as a general recommendation is widely promoted (National Advisory Committee on Nutrition Education, 1983; Food Advisory Committee, 1984a,b) recommendations on dairy products must be qualified so as not to conflict with guidelines for reduced fat intake. Thus, increased intake of reduced-fat dairy products (e.g. semi-skimmed milk) may be recommended as a measure to increase average K intake in the population. Given the importance of milk as a source of many essential nutrients in the Irish diet (Upton & Gibney, 1987), this may have other benefits for the average diet.

HEALTH SIGNIFICANCE OF DIETARY Na AND K

While Na and K are both essential nutrients and serve many important physiological functions, the effect of these electrolytes on blood pressure has attracted most attention

in terms of public health (Altschul *et al.* 1984). Hypertension is a common problem in many populations and is a major risk factor for stroke and coronary heart disease (World Health Organization, 1982). There is considerable evidence from epidemiological studies, clinical trials and animal studies that increasing K intake is associated with decreasing blood pressure (Langford, 1983; Tannen, 1983). This association has been confirmed within populations in two large recent studies of electrolyte excretion and blood pressure (Intersalt Cooperative Research Group, 1988; Smith *et al.* 1988). However, estimates of the strength of this association in the Intersalt Study indicate that the effect of a significant increase in average K intake of the population on mean population blood pressure would be small (about 4.5 mm Hg decrease in systolic pressure per 100 mmol increase in K). Thus, increasing the daily K intake of a population by 25%, e.g. from 70 to 87.5 mmol would be equivalent to a reduction of only about 0.8 mm Hg in mean systolic blood pressure. Thus, dietary guidelines for increased K intake by the general population (Food Advisory Committee, 1984b) cannot be justified entirely on the basis of a potential reduction in mean population blood pressure. However, guidelines which promote increased intake of fruit and vegetables and low-fat dairy products are consistent with an increase in K intake and may be justified on other public health grounds.

The relationship between Na and blood pressure has been debated since the last century (Porter, 1983), but despite many studies the issue remains unresolved. While the idea that high salt intake is a major determinant of increased blood pressure is now deep-rooted among many doctors and members of the public, the evidence for this is weak. Two of the reports which have been most influential in establishing this idea (Dahl, 1972; Gliberman, 1973) are based on a small number of often unreliable findings on Na intakes and blood pressures of different populations. Findings from two large recent studies (Intersalt Cooperative Research Group, 1988; Smith *et al.* 1988) show that the relationship between Na intake and blood pressure within populations is, at best, weak. It can be estimated from the Intersalt Study that, assuming Na intake to be causal, the effect of a large reduction in mean Na intake of a population on mean population blood pressure would be small (about 2.2 mm Hg decrease in systolic pressure per 100 mmol Na). Thus, decreasing mean daily Na intake of a population by 25% (e.g. from 150 to 112.5 mmol) would be equivalent to a reduction of only about 0.8 mm Hg in mean systolic pressure.

While the rise in blood pressure with age was more strongly related than blood pressure to urinary Na excretion (Intersalt Cooperative Research Group, 1988), it can be estimated that a 25% decrease in mean Na intake would be associated with a smaller rise in mean population blood pressure from age 25 to 55 years by only about 3.4 mm Hg systolic and about 1.7 mm Hg diastolic.

Thus, dietary guidelines for a reduction in Na intake by the general population which have been widely promulgated (National Advisory Committee on Nutrition Education, 1983; Department of Health and Social Security, 1984; Food Advisory Committee, 1984a,b;) are difficult to justify entirely on the basis of a potential reduction in mean population blood pressure.

Other potential benefits of a reduction in Na intake in the population have been proposed, but the evidence for these is incomplete at this time. Epidemiological evidence of a possible relationship between Na intake and stomach cancer has been presented in a number of studies (Joossens & Geboers, 1981, 1987; Tuomilhto *et al.* 1984).

There is also growing interest in a possible relationship between Na intake and osteoporosis. This is based on the observation that increased Na intake leads to increased urinary excretion of calcium (McCarron *et al.* 1981; Sabto *et al.* 1984; Castenmiller *et al.* 1985; Shortt *et al.* 1988*b*). Furthermore, there is also evidence that individuals differ in their susceptibility to increasing Na intake; with increasing Na an increase in urinary Ca is not evident in some individuals, while increases of variable size are seen in others (Shortt *et al.* 1988*b*). In rats high salt intake leads to increased urinary Ca excretion and bone loss (Goulding & Gold, 1986; Shortt *et al.* 1987*b*). However, whether the Na-induced urinary Ca loss results in increased Ca requirements or contributes to bone loss in humans are important questions which have yet to be answered.

Thus, on the basis of present evidence there is a weak case for recommending a reduction in Na intake for the general population, either on grounds of potential benefits for blood pressure or on other grounds.

It is important to distinguish between dietary guidelines for the general population and dietary advice for individuals who may be at 'high risk', e.g. hypertensive patients. Increased dietary K and reduced dietary Na intake should be recommended for these on the basis of the reduction in blood pressure achieved by such dietary changes in some hypertensives in clinical trials (McGregor *et al.* 1982; Grobbee & Hofman, 1986).

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