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The Northern Ireland dietary survey and related studies

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The 1980s heralded an increased consciousness of the potential relationships between diet, lifestyles and health. Northern Ireland had a poor health record, having one of the highest death rates from ischaemic heart disease in the world, and there was a paucity of information on the lifestyle and dietary characteristics of its population. In contrast Great Britain and the Republic of Ireland had been monitoring food and nutrient intake through household food surveys, thereby providing time-series trends in food consumption and nutrient intake. For these reasons the Northern Ireland Diet and Health Study (NIDHS) was undertaken; it had the primary objective of obtaining baseline information on the dietary behaviour of the population and the secondary objective to relate these to information on health and nutritional status.

NUTRIENT INTAKE IN NORTHERN IRELAND

A detailed account of the sampling methods, design of instruments and methods of data collection have already been provided (Barker *et al.* 1989). The study was based on a two-stage sample, first of Northern Ireland households and second of individuals from the sampled households. The method of Kish (1965) was used to select a sample of 797 eligible subjects aged between 16 and 64 years who reflected the sex and age distributions of the population. Of these, 616 subjects completed the full range of study measurements and 592 subjects satisfactorily completed the dietary element of the study.

Dietary data was collected through the direct weighing of intake over 7 d. The survey method has previously been described in detail (Barker *et al.* 1989). Nutrient intakes were calculated from a computerized version of food composition tables (Paul & Southgate, 1978; Wiles *et al.* 1980). Nutrient intakes were examined in relation to the variables of sex, age and socio-economic group using analysis of variance and results are given in detail elsewhere (Barker *et al.* 1989).

Table 1 shows the mean daily energy and nutrient intakes by sex. As expected men had significantly greater intakes of energy, fat, protein and carbohydrate. Men also consumed approximately three times more alcohol than did women. Table 2 shows that the proportion of energy from protein, fat and carbohydrate were similar for men and women, and when alcohol is excluded from total energy intake the contribution of protein, fat and carbohydrate to energy intake are virtually identical for both sexes.

Although not reported in detail here, intakes of energy and nutrients, with the exception of dietary fibre and iron, varied significantly with age. The general trend was for a decrease in intake with age. There was little variation between the socio-economic groups in nutrient intake, except for dietry fibre which was significantly greater in the non-manual group for both men and women (see Barker *et al.* 1989).

These findings can be compared with the results of similar 7 d weighed dietary record surveys carried out elsewhere in the UK and Ireland. Tables 3 and 4 show the energy and

Table 1. *Mean daily energy and nutrient intakes for men and women*

	Men (*n* 258)		Women (*n* 334)	
	Mean	SD	Mean	SD
Energy (MJ/d)	10·6	2·44	7·1	1·86
Protein (g/d)	85·0	19·44	59·7	15·02
Fat (g/d)	108·8	29·63	75·5	23·57
Carbohydrates (g/d)	292·2	81·50	198·7	56·87
Alcohol (g/d)	15·3	25·31	4·8	9·52

Table 2. *The mean contribution of various nutrients to energy intake*

	Percentage of energy intake			
	With alcohol		Without alcohol	
Energy Source	Men (*n* 258)	Women (*n* 344)	Men (*n* 258)	Women (*n* 344)
Protein	13·7	14·4	14·3	14·7
Fat	38·7	39·6	40·3	40·4
Carbohydrate	43·4	43·9	45·3	44·7
Alcohol	4·1	1·9	—	—

Table 3. *Mean daily energy and nutrient intakes of random samples* of men in different areas*

	Northern Ireland (*n* 258)	Caerphilly (*n* 493)	Cambridge (*n* 32)	Kilkenny (*n* 30)
Age-range (years)	16–64	45–59	20–79	35–44
Energy (MJ/d)	10·6	10·1	10·0	12·5
Protein (g/d)	85	83	77	107
Fat (g/d)	109	100	104	119
Carbohydrate (g/d)	292	277	285	344
Alcohol (g/d)	15	19	—	27
Dietary fibre (g/d)	21	19	20	24
Iron (mg/d)	14	13	13	16
Protein (%)†	14	14	13	15
Fat (%)†	39	37	40	36
Carbohydrate (%)†	43	43	45	43
Alcohol (%)†	4	5	—	6

* Caerphilly (Fehily *et al.* 1984), Cambridge (Bingham *et al.* 1981), Kilkenny (Gibney *et al.* 1989).
† As a percentage contribution to total energy intake.

nutrient intakes of men and women respectively in Northern Ireland compared with intakes in various regions of the British Isles. In men intakes of energy and nutrients were very similar to other studies within the UK but were less than intakes in the Kilkenny Health Project (Gibney *et al.* 1989). In the Northern Ireland female sample

Table 4. *Mean daily energy and nutrient intakes of random samples* of women in different areas*

	Northern Ireland (*n* 334)	Caerphilly (*n* 49)	Llantwit Major (*n* 101)	Cambridge (*n* 31)	Kilkenny (*n* 30)
Age-range (years)	16–64	45–59	18–75	20–79	35–44
Energy (MJ/d)	7·0	6·7	7·4	8·2	8·4
Protein (g/d)	60	58	62	67	77
Fat (g/d)	75	73	81	90	87
Carbohydrate (g/d)	199	182	203	229	232
Alcohol (g/d)	5	2	5	—	4
Dietary fibre (g/d)	16	15	15	20	20
Iron (mg/d)	10	10	10	12	12
Protein (%)†	14	15	14	14	16
Fat (%)†	40	41	41	41	39
Carbohydrate (%)†	44	43	43	44	44
Alcohol (%)†	2	1	2	—	1

* Caerphilly (Fehily & Bird, 1986), Llantwit Major (Barasi *et al.* 1985), Cambridge (Bingham *et al.* 1981), Kilkenny (Gibney *et al.* 1989).

† As a percentage contribution to total energy intake.

intakes of energy and nutrients were marginally greater than those recorded in Caerphilly and less than for Llantwit Major, Cambridge, and Kilkenny.

COMPARISON OF ENERGY INTAKES WITH ENERGY EXPENDITURES

One of the major problems in studies of diet and health such as the NIDHS is that of obtaining a valid estimate of habitual food intake, since each method of dietary assessment is ultimately dependent on subject co-operation, good will and honesty. Non-random errors or bias pose the greatest difficulty in quantifying food intake and, while recognized, their magnitude and direction have usually remained undetected in the absence of techniques to verify dietary survey methodology.

In a cross-validation study (Livingstone *et al.* 1990) conducted 1 year later, sixteen men and sixteen women who had previously participated in the NIDHS completed a seven consecutive day weighed dietary record, while total energy expenditure (TEE) was assessed simultaneously over 14 d by the doubly-labelled [$^2H_2{}^{18}O$] water method (Coward, 1988). Basal metabolic rate (BMR) was also measured under standardized conditions by indirect calorimetry. Subjects were selected to represent the range of intakes observed in the initial NIDHS and the final co-operation rate was related to the initial energy intakes, averaging 60% for subjects whose intake was greater than the mean and 32% for those with intakes below the mean. The final cohort included a wide range of occupations, socio-economic status, ages and body-weights. Ten subjects were grade I obese and three subjects were grade II obese as defined by Garrow (1981).

Paired *t* tests revealed no significant difference in the mean values for the repeat measurements of food intake in the men (11·16 (SE 0·84) *v.* 11·21 (SE 0·62) MJ/d), but a marginally significant increase in the women (7·35 (SE 0·50) *v.* 8·00 (SE 0·49) MJ/d, *t*

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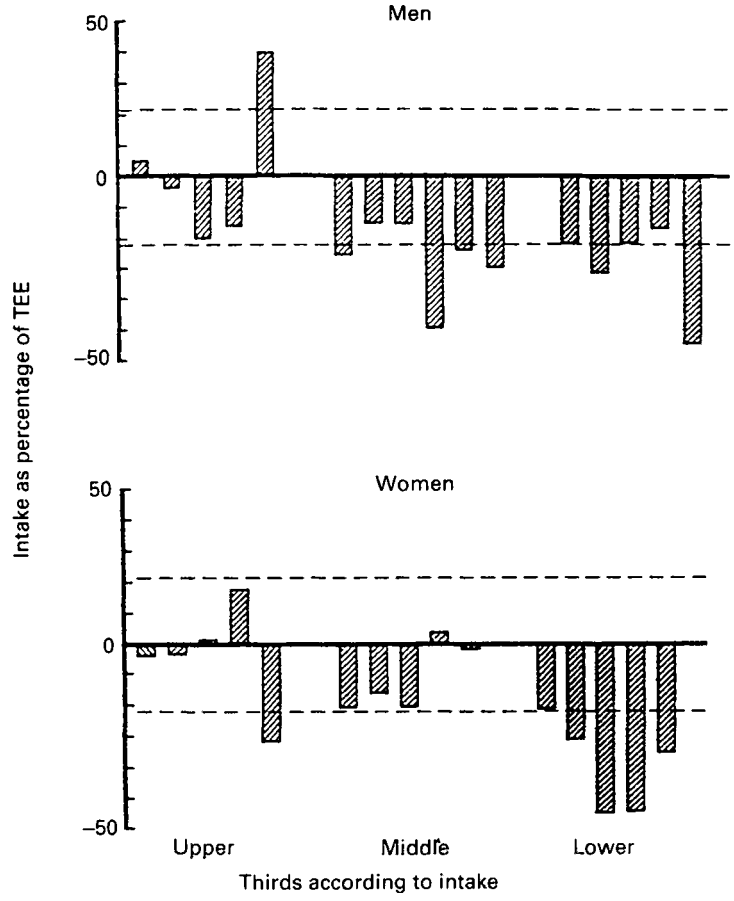

Fig. 1. Individual differences between energy intake and total energy expenditure (TEE). Subjects classified into thirds according to their energy intake. (– – –), 2SD of the anticipated precision for comparing the two estimates.

1·97, $P<0·05$). Correlation analysis yielded a moderately high degree of reproducibility of the individual measurements ($r + 0·79$).

Compared with simultaneous estimates of TEE the group mean energy intakes in the cross-validation study were significantly lower in both men and women (men: 11·21 (SE 0·62) *v.* 14·23 (SE 0·74) MJ/d, paired t 3·61, $P<0·01$; women: 8·00 (SE 0·49) *v.* 9·93 (SE 0·40) MJ/d, paired t 3·48, $P<0·01$).

When the data were divided into thirds by energy intake, the intake:expenditure ratios were close to unity (men 1·01 (SE 0·11), women 0·96 (SE 0·08)) in the upper third of the distribution, indicating no significant bias between the two measurements. However, in the middle and lower thirds the ratios were only 0·74 (SE 0·05) and 0·70 (SE 0·07) for men and 0·89 (SE 0·07) and 0·61 (SE 0·07) for women, indicating significant discrepancies.

The standard errors of the estimates were consistent with the known imprecision of the two measurements. For energy intake this was calculated from the day-to-day standard

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deviation of 25% yielding a precision over 7 d of 9·5%. The precision for the expenditures was estimated at 6% yielding a combined error for any estimates of the difference between the two techniques of 11%.

When individual differences between intake and expenditure were compared (Fig. 1), nineteen of the thirty-one measurements came within the known limits of precision for the comparison (2SD at 11% derived as described previously) and cannot themselves be deemed inaccurate. However, when viewed collectively the overall bias was clearly evident being more than 20% in eighteen subjects and as much as 50% in three subjects.

It is important to note that the bias observed in this cross-validation study is likely to be an overestimate of both the frequency and degree of error in the main NIDHS since the stratified sampling procedure employed deliberately recruited a disproportionate number of low recorders. Nevertheless the identified bias could generate seriously misleading intake–reponse associations and conclusions since the invalid results, by virtue of being outliers, may exert a powerful effect on regression analysis.

In the light of these findings it is important to consider possible mechanisms for identifying biased food records together with the interpretative implications of editing the main NIDHS data set. One approach is to employ a knowledge of minimal energy requirements to scrutinize food intake results. The Food and Agriculture Organization/World Health Organization/United Nations University (1985) have concluded that people following average activity patterns would expend about 1·55 × BMR. Similarly whole-body calorimetry studies of women employing very sedentary protocols have demonstrated that on average the minimum energy requirements compatible with normal life is about 1·30 × BMR (Prentice *et al.* 1985). However, the problem with such cut-offs is that at an individual level many of these intakes may be defensible given the acknowleged limitations of short-term dietary assessments, notably normal day-to-day and week-to-week variation in food intake. Allowing for the known imprecision of the 7 d weighed dietary record it has been calculated (A. M. Prentice, personal communication) that a cut-off of 1·13 × BMR (measured) or 1·07 × BMR (predicted; Schofield, 1985) is more appropriate to the definition of invalid food intakes. In the NIDHS, 15·5% of men and 25·4% of women had energy intakes below 1·07 × BMR (predicted). Even then this cut-off will only identify the most extreme values and it is likely that the credibility of some results above this criterion may also be suspect.

CORRELATIONS OF NUTRIENT INTAKES WITH FE STATUS MEASUREMENTS

Whilst the cross-validation study was concerned with dietary energy intakes any bias observed in energy intake is also likely to apply to other nutrients. One such nutrient is Fe and the mean dietary intakes of Fe have been published previously (Barker *et al.* 1989). Information on Fe status from blood measurements of these subjects is also available (Strain *et al.* 1989). Multiple criteria (Cook, 1986; Bindra & Gibson, 1986) were used to determine Fe deficiency (subjects having abnormally low values of any two of serum ferritin (SF; <12 g/l), transferrin saturation (TS; <16%) or mean corpuscular haemoglobin concentration (MCHC; <32%)) and Fe-deficiency anaemia (subjects having abnormally low values of any two of SF, TS or MCHC and an abnormally low haemoglobin (Hb; <130 g/l men, <120 g/l women)). Body Fe stores were calculated by the equations of Cook *et al.* (1986), as modified by Ballot *et al.* (1989), and were used as an index of Fe sufficiency.

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Table 5. *Spearman correlation coefficients between dietary measurements and haemoglobin (Hb) and body iron stores (FeS) for men aged 18–64 years and women aged 18–44 years and 45–64 years*

	Total sample		Energy intakes >1·2 BMR		Energy intakes >1·35 BMR	
	Hb	FeS	Hb	FeS	Hb	FeS
Men: *n*	218		158		125	
Fe intake	–0·05	0·04	–0·05	0·15*	–0·06	0·20
Meat	0·06	0·20**	0·05	0·16*	0·04	0·15
Fish	–0·13*	0·03	–0·16*	–0·02	–0·22**	–0·14
Poultry	0·06	–0·00	0·09	–0·02	0·13	0·02
Protein	0·12*	0·04	–0·11	0·12	–0·11	0·12
Fibre	–0·06	–0·11	–0·01	–0·05	0·02	–0·02
Vitamin C	–0·11*	–0·04	–0·08	0·03	–0·05	0·04
Alcohol	0·09	0·20**	0·11	0·26***	0·10	0·27**
Women:						
18–44 years *n*	189		120		87	
Fe intake	–0·09	0·00	0·08	0·12	0·05	0·10
Meat	0·04	0·07	0·06	0·14	0·05	0·16
Fish	–0·05	–0·07	–0·08	–0·06	–0·12	–0·04
Poultry	0·05	0·16*	0·09	0·20*	0·05	0·21*
Protein	–0·02	0·01	0·07	0·12	0·06	0·11
Fibre	–0·09	–0·01	0·11	0·06	0·14	0·06
Vitamin C	–0·06*	–0·08	0·05	–0·10	0·05	–0·10
Alcohol	0·19**	0·13*	0·17*	0·16*	0·11	0·12
Women:						
45–64 years *n*	91		44		34	
Fe intake	–0·10	–0·08	–0·07	–0·26*	–0·16	–0·04
Meat	0·09	0·10	–0·06	0·28*	0·00	–0·24
Fish	–0·07	0·09	–0·01	–0·10	–0·10	–0·14
Poultry	0·03	0·02	0·33*	0·21	0·29	0·13
Protein	–0·09	0·02	0·02	–0·14	0·02	–0·01
Fibre	–0·12	–0·10	–0·05	–0·40**	–0·10	–0·26
Vitamin C	–0·04	0·01	0·10	–0·09	0·03	0·04
Alcohol	0·17	0·20*	0·16	0·18	0·22	0·32*

BMR, basal metabolic rate.
* $P<0·05$, ** $P<0·01$, *** $P<0·001$.

Three distinct groups with respect to Fe stores were identified and mean (and SD) for the groups were 13·4 (SD 5·97) mM for men, 5·3 (SD 6·09) mM for women aged 18–44 years and 8·5 (SD 6·72) for women aged 45–64 years. These values were very similar to those found by Cook *et al.* (1986) for a representative sample of the US population. The prevalence of Fe-deficiency anaemia in the Northern Ireland population was low, ranging from 0·5% in men to 6·6 and 4·6 in the younger and older women respectively. The prevalence of Fe deficiency was also low in men (1·4%) and older women (5·7%) but was 11·0% in the younger women (Strain *et al.* 1989).

Although blood measurements are generally indicative of body Fe status, they can be distorted by a number of factors. Foremost amongst these factors is chronic inflam-

mation. Indeed, many of the abnormally low TS or MCHC found in this population were accompanied by moderately high SF and some by high caeruloplasmin and erythrocyte counts (Strain *et al.* 1990*a*). These observations indicate that inflammatory conditions might be influencing indices of Fe status. It is unlikely, however, that mild medical conditions were confounding the assessment of Fe sufficiency in the general population to an extent that explained the poor correlations found between dietary Fe values and measurements of Hb and body Fe stores (Table 5). Beaton (1986) has discussed possible reasons for the generally disappointing correlations which have been found between dietary and biochemical values for Fe status. Inaccuracies and/or imprecision due to calculating usual Fe intakes over 7 d from food composition tables must be considered as a partial explanation, but it is unlikely that inaccurate reporting was a major factor given that, in general, the magnitude of the correlation coefficients only improved slightly when suspiciously low energy intakes were removed from the analysis.

The consumption of alcohol during the 7 d inventory was most strongly correlated with Fe stores in men and Hb in the younger women (Table 5). This was unexpected since alcohol consumption is not usually considered to impact on Fe status and the levels of alcohol consumed by the majority of drinkers was unlikely to result in liver damage and the release of ferritin into the circulation (see Strain *et al.* 1990*b*). This interesting phenomenon merits further attention and is given as one example of the considerable potential to explore possible relationships among nutrients and the other data sets collected during the NIDHS.

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