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Evaluating energy intake measurement in free-living subjects: when to record and for how long?

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Abstract

Objective: To nutritionally analyse mean energy intake (EI) from different 3 d intervals within a 7 d recording period and to evaluate the seasonal effect on energy and nutrient intake.
Design: Cross-sectional study of dietary intake collected with 7 d food diaries.
Setting: Aberdeen, north-east Scotland, UK, between 2002 and 2004.
Subjects: Participants from two long-term trials were pooled. These trials, investigating genetic and environmental influences on body weight, were the Genotyping And Phenotyping (GAP) study and a cohort observational study, Rowett Assessment of Childhood Appetite and metaboLism (RASCAL). There were 260 Caucasian adults, BMI range 16·7–49·3 kg/m^2, age range 21–64 years.
Results: Mean EI for Wednesday, Friday and Saturday had the closest approximation to the 7 d mean (0·1 % overestimate). A gender × season interaction ($P = 0·019$) with a different intake pattern for females and males was observed. For females, lower mean (SE) EI was recorded in summer (8117 (610) kJ) and autumn (7941 (699) kJ) compared with spring (8929 (979) kJ) and winter (8132 (1041) kJ). For males, higher mean (SE) EI was recorded in summer (10 420 (736) kJ) and autumn (10 490 (1041) kJ) compared with spring (9319 (1441) kJ) and winter (9103 (1505) kJ).
Conclusions: The study results indicate that 3 d weighed intakes recorded from Wednesday, Friday and Saturday are most representative of 7 d habitual intake in free-living subjects. They also indicate that seasonality has a limited effect on EI and no effect on macronutrient intake.

Keywords
Dietary assessment
Seasonal food intake
Weighed intake
Food diary
Metabolic rate

Weighed diet records are considered the 'gold standard' when examining free-living energy and nutrient intake, with seven days of recording regarded as the best compromise between accuracy, investigator workload and subject compliance[1]. In practice however, 3 d weighed dietary records are often the assessment tool chosen by investigators for intervention studies, as they are deemed to be less intrusive for subjects[2] and can therefore improve subject recruitment. With the shorter recording period comes the concern whether the three recording days are representative of habitual intake[3]. Therefore, much research has focused on identifying feasible intakes and attempting to correct intake data. Specifically, the effects of 'misreporting' or 'under-reporting' of food intake[4] has been a main focus of attention, following better energy expenditure (and thus energy balance) methodology[5]. Within the literature, there has been less emphasis on the practical issues such as when to ask subjects to record, i.e. which day(s) or the effect of season, which may have an effect on achieving an assessment of habitual intake. Hartman *et al.*[6] reported that non-consecutive days were preferable due to a correlation between eating behaviour on consecutive days and Bingham[7] recommended a 3 d diary to include one weekend day and two weekdays, since weekend days are known to indicate higher reported energy intakes[8,9]. Food intake patterns have changed since these recommendations were made over 20 years ago[10], with the potential that intake towards the end of the working week may reflect similar patterns to weekend intake. It is also anecdotally thought that season can affect food patterns, e.g. increased salad intake in summer and soup intake in winter, but it is not clear whether this actually influences habitual nutrient intake.

Thus, the aims of the present study were: (i) to compare different 3 d periods with the 7 d mean to identify if a shorter recording period is representative of habitual intake; and (ii) to compare energy and nutrient results

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from different seasons to assess if seasonality has an effect on energy and nutrient intake. The weekday and weekend energy and nutrient intakes were also analysed to assess whether our results agree with previous findings[8,9]. All of these issues could have practical implications for large nutritional assessment studies where baseline data are collected over a prolonged time.

Materials and methods

Subject characteristics

Data from two nutritional studies based at the Human Nutrition Unit, Rowett Institute of Nutrition and Health, Aberdeen, UK, were pooled for the present analysis, totalling 260 adult subjects.

Subjects were recruited for Study 1 by newspaper advertisement to participate in a study investigating genetic and environmental influences on body weight, why do some people gain weight more easily than others? The aim of the Genotyping And Phenotyping (GAP) study was to explore the hypothesis that the susceptibility of people to be obese results from an interaction between environment and genotype. Measurements of metabolism, food intake, physical activity and health status (e.g. blood pressure, cholesterol) were carried out over a period of 8 d to phenotype and genotype obese individuals to determine if there was an interaction present. More details on this study population are given elsewhere[11,12].

Study 2 was a cohort observational study recruiting whole families; more details of this study population are given elsewhere[13,14]. The aim of the Rowett ASsessment of Childhood Appetite and metaboLism (RASCAL) study was to investigate how much influence genetic and environmental factors have on a child's susceptibility or resistance to becoming overweight. The same measurements of metabolism, food intake, physical activity and health status recorded in the GAP study were carried out on the RASCAL families. The data from the children participating in the RASCAL study are not analysed in the current paper.

For both studies, subjects were only included if they were not eating any special diet; had stable weight (weight change of no more than 2 kg in the previous 3 months); and were otherwise healthy, based on a medical examination and by contacting their general practitioner for recent medical and medication status. They took no regular prescribed medication, vitamin or mineral supplements, with the exception of the contraceptive pill or hormone replacement therapy for women. The North of Scotland Research Ethics Service approved both studies. Written informed consent was obtained.

Measurement of baseline anthropometry and BMR

Subjects attended for measurements of body composition and metabolic rate (BMR_{meas}) under standardised fasted conditions. Subjects were instructed not to consume caffeinated products or to smoke prior to attending the unit, and arrived between 07.00 and 08.30 hours. They were allowed to relax for about 30 min prior to measurements being conducted. Height was measured to the nearest 0·1 cm using a stadiometer (Holtain Ltd, Crymych, UK). Subjects were weighed after voiding, wearing light clothing, to the nearest 100 g on a digital scale (DIGI DS-410; CMS Weighing Equipment Ltd, London, UK). BMR was measured by indirect calorimetry over 30–40 min using a ventilated hood system (Deltatrac II, MBM-200; Datex-Ohmeda Instrumentarium Corporation, Helsinki, Finland). During the measurement, subjects lay on a bed in a thermoneutral room and were instructed to lie still but not to fall asleep. BMR was calculated from minute-by-minute data, using the equations of Livesey and Elia[15]. This method analyses the mean of 15 min of stable measurements, with the first and last 5 min excluded. Details of calibration burns and repeatability testing have been described previously[11].

Early on in the analysis process we removed data from apparent 'under-reporters'. The EI:BMR_{meas} ratio was calculated for each subject and compared with the two cut-off points defined by Goldberg *et al.*[16] and Black *et al.*[1]. Where BMR_{meas} data were missing for twenty-four subjects, estimated BMR (BMR_{est}), as defined by Schofield[17], was used instead. There were eighty-nine subjects (35 %) below cut-off 1 and thirty-four subjects (13 %) below cut-off 2, with the remaining 132 subjects (52 %) above cut-off 1. The same significant trends were observed between the results from the original data set and that of the data set minus the under-reporters. There was no discernible bias observed for gender. The mean EI:BMR_{meas} for all subjects was 1·39 (SE 0·02; range 0·60–2·40). We therefore present the results from the full data set in the current paper.

Food intake recording

For measurement of food and macronutrient intake, subjects in Study 1 (GAP) were asked to record all foods and drinks consumed for a consecutive 7 d period, using weighed dietary record methodology. They were provided with digital electronic scales (Soehnle model 820; Soehnle-Waagen GmbH & Co. KG, Murrhardt, Germany), which have a tare facility and weigh up to 1 kg with a resolution of 1 g. The scales were calibrated before each measurement period at four points over the scale's range using reference weights (Thomson Scientific, Cults, Aberdeen, UK). Subjects were also provided with a food diary notebook for recording a description of the food or drink, time of consumption, weight of food, cooking method and leftovers. They were encouraged to record all recipe formulations and to keep all packaging for ready-to-eat food products, as described by Bingham[7]. When the use of the scales was difficult, e.g. when eating out, the subjects were instructed to record as much information as possible about the quantity of the food they ate by using household measures (tablespoon, cup, slice, etc.). It has been previously reported that to be effective, the dietary record must provide adequate detail not only of the types of foods consumed but also details of the way in which they were prepared for consumption[18]. The subjects were therefore asked to indicate where applicable how their food was cooked (boiled, fried, baked, etc.) to assist analysis. A similar technique was used in the RASCAL study; subjects recorded their food intake for 7 d in a food diary but, due to measurement constraints, the foods were not weighed. Instead food portion sizes were estimated using images from the food portion atlas[19]. Both of these methods of food intake recording have different strengths[20]. Weighed intakes rely less on memory as portion size is recorded directly at the time of measurement. Un-weighed intakes place lower burden on subjects, who are therefore less likely to alter eating behaviour. From issues raised by Friedenreich[21] regarding pooled data, statistical analysis was carried out to compare the results from both studies. This was to ensure that there was no significant difference in results due to recording methodology (weighed *v.* un-weighed intakes). The difference in results was not significant; therefore the data were pooled.

Analysis of food intake data

All diets from both studies were analysed by trained staff using the WinDiets Nutritional Analysis Software Suite version 1·0 (The Robert Gordon University, Aberdeen, UK), a computerized version of *McCance and Widdowson's The Composition of Foods*[22]. To input foods recorded with household measures, or with missing weights or portion sizes, standard portions sizes were used[23]. Thus, total food energy and nutrient intake for every meal could be quantified. To reduce investigator bias and inputting errors, all diets were cross-checked by at least one other trained member of staff. The database of nutritional information was updated for unusual food products (from food packaging provided by subjects).

In order to examine seasonal effects of when intake was recorded, we designated the following classifications: spring was defined as March to May, summer was June to August, autumn was September to November and winter was December to February.

Weekdays were considered to be Monday to Friday inclusively, weekend as Saturday and Sunday. The 3 d diary periods examined were Tuesday–Thursday–Saturday, Wednesday–Friday–Sunday and Thursday–Saturday–Monday, following the suggestions of Hartman *et al.*[6] to use non-consecutive days of recording and of Bingham[7] to include one weekend day and two weekdays.

Statistical analysis

Bland and Altman plots[24] were examined to compare the results for 3 d and 7 d EI (kJ/d). The differences were calculated as the 3 d average minus the 7 d average. Intakes were analysed by hierarchical (split-plot) ANOVA with terms for study, gender, season and their interaction in the subject stratum, and week-day and its interaction with study and gender in the within-subject stratum. Subject age and BMI were included as covariates. All data were analysed using the GenStat for Windows statistical software package 9th edition (GenStat Committee; VSN International, Hemel Hempstead, UK). Results are expressed as mean and standard error of the mean, with P values below 0·05 considered indicative of a statistically significant effect.

For purposes of presentation of trends, the data were split first by study (GAP, n 150; RASCAL, n 110), then by gender (females, n 169; males, n 91), BMI (normal weight, BMI ≤ 24·9 kg/m^2, n 123; overweight and obese, BMI ≥ 25·0 kg/m^2, n 127) and age (21–44 years, n 177; 45–64 years, n 83).

Results

Subject characteristics

There were 260 subjects in total (169 females, ninety-one males), with a mean age of 40·1 (SE 0·6) years (range 21–64 years) and a mean BMI of 26·0 (SE 0·4) kg/m^2 (range 16·7–49·3 kg/m^2). There were 150 subjects in Study 1 (GAP; 107 females, forty-three males). The GAP subjects were, on average, 43·7 (SE 0·9) years of age (range 21–64 years) with a mean BMI of 26·5 (SE 0·5) kg/m^2 (range 16·7–49·3 kg/m^2). There were 110 adults in Study 2 (RASCAL; sixty-two females, forty-eight males), with a mean age of 35·5 (SE 0·5) years (range 23–50 years) and a mean BMI of 25·8 (SE 0·5) kg/m^2 (range 20·3–46·3 kg/m^2).

Energy intake: 7 d results

The mean 7 d EI results (range 3878–16 688 kJ) are shown in Table 1. The difference in mean EI between the GAP and RASCAL studies (GAP mean was −202 kJ, 2·3 % lower) was not significant and, on this basis, we pooled the data. Males reported a 1909 kJ (19 %, $P < 0·001$) higher EI than females and younger subjects ate slightly more (590 kJ, 6·5 %, $P < 0·001$) than the older subjects; however, obese and lean subjects reportedly ate a similar amount (97 kJ, 0·97 %, $P = 0·351$). The UK Department of Health Estimated Average Requirements[25] for EI is 10 676 kJ for males and 8122 kJ for females. Our results are 5 % lower (559 kJ) and 1 % higher (76 kJ), for males and females, respectively. The EI:BMR ratio was calculated by dividing average 7 d EI by measured or estimated BMR. There was a significant difference in EI:BMR between BMI groups (13 % greater in overweight compared with normal weight, $P < 0·001$) but not between age groups (4 % difference, $P = 0·244$).

Table 1 7 d energy intake among Caucasian adults (*n* 260), Aberdeen, north-east Scotland, UK, 2002–2004

			Energy (kJ)		EI:BMR	
		Gender (*n*)	Mean	SE	Mean	SE
Study	GAP	Male (43)	9917[a]	360	1·35	0·05
		Female (107)	8322[b]	178	1·46[a]	0·03
		Both (150)	8787	174	1·43	0·03
	RASCAL	Male (48)	10 266[a]	295	1·40	0·04
		Female (62)	7978[b]	217	1·31[b]	0·04
		Both (110)	8993	208	1·35	0·03
Gender		Male (91)	10 117[a]	230	1·38	0·03
		Female (169)	8198[b]	138	1·40	0·06
BMI	Normal: BMI $\leq$ 24·9 kg/m^2	Male (33)	10 696[a]	438	1·51[a]	0·06
		Female (90)	8267[b]	178	1·49[a]	0·03
		Both (123)	8916	200	1·49[a]	0·03
	Overweight: BMI $\geq$ 25·0 kg/m^2	Male (54)	9668[a,b]	261	1·28[b]	0·04
		Female (73)	8178[b]	224	1·31[b]	0·04
		Both (127)	8829	182	1·30[b]	0·03
Age	Younger: 21–44 years	Male (60)	10 450[a]	284	1·41	0·04
		Female (117)	8321[b]	171	1·41	0·03
		Both (177)	9068[a]	167	1·41	0·02
	Older: 45–64 years	Male (31)	9405[a,b]	370	1·30	0·06
		Female (52)	7907[b]	228	1·39	0·05
		Both (83)	8472[b]	214	1·36	0·04

GAP, Genotyping And Phenotyping study; RASCAL, Rowett Assessment of Childhood Appetite and metaboLism.
[a,b] Mean values within a column with unlike superscript letters were significantly different ($P < 0·05$).

Weekday (Monday–Friday) v. *weekend (Saturday–Sunday) energy intakes*

Figure 1 shows mean (SE) EI by day of the week and indicates that weekend intakes were significantly greater than weekdays ($P < 0·001$), with average intakes of 9830 (219) kJ and 9126 (183) kJ on Saturday and Sunday, respectively, in comparison to an average of 8634 (82) kJ for weekdays. This represents a 10 % increase on these days.

Weekday v. *weekend macronutrient intakes*

Mean macronutrient intakes were examined to explore the variance observed in EI between weekdays and weekend days. The results (mean (SE)) were 12 % higher (2896 (40) kJ *v.* 3248 (64) kJ, $P < 0·001$) for fat intake, 6 % higher (1329 (15) kJ *v.* 1416 (26) kJ, $P = 0·003$) for protein intake and 78 % higher (356 (20) kJ *v.* 627 (46) kJ, $P < 0·001$) for alcohol intake on weekend days *v.* weekdays, respectively. The difference in carbohydrate intake, a 3 % increase, was not significant (4023 (41) kJ *v.* 4148 (67) kJ, $P = 0·110$) between weekdays and weekend days, respectively.

7 d v. *3 d energy intakes*

Mean (SE) EI for the 3 d periods Tuesday–Thursday–Saturday (9018 (115) kJ), Wednesday–Friday–Saturday (8885 (106) kJ) and Thursday–Saturday–Monday (9015 (116) kJ) were not significantly different (2·6 % higher, 0·1 % and 1·6 %, lower respectively) from the 7 d mean (8874 (72) kJ). Bland–Altman plots of the 3 d *v.* 7 d energy intakes with 95 % confidence limits (±2SD) can be seen in Fig. 2. In all 3 d periods *v.* 7 d there is an upward trend, the difference becomes more positive at greater intakes. The bias, or average of the differences, should be close to zero if the two methods being compared are similar. Our results for bias were 160, −25 and 129 kJ for Tuesday–Thursday–Saturday, Wednesday–Friday–Sunday and Thursday–Saturday–Monday, respectively. This indicates that intake recorded on Wednesday–Friday–Sunday is the most comparable of the 3 d periods to the 7 d intake and Tuesday–Thursday–Saturday is the least comparable.

There was no significant difference between these 3 d periods and the 7 d mean for macronutrient intake (results not shown).

Micronutrient intake: 7 d results

Day-to-day variation in nutrient intake in free-living subjects is large, creating practical study design issues for researchers if more days of recording are required to evaluate habitual intake[6,26,27]. Willett[20] reported that shorter recording periods may provide a reasonable estimation of mean intake but with overestimated standard deviations.

The UK Food Standards Agency Recommended Daily Allowance[28] (RDA) for vitamin A is 700 μg and 600 μg for men and women, respectively. The mean (SE) intake from our weighed intakes was 533 (62) μg for men (24 % below the RDA) and 501 (71) μg for women (16 % below the RDA). The mean was 513 (51) μg for all subjects. The UK RDA for vitamin C is 40 mg. The mean (SE) intake from our weighed intakes was 95 (9) mg for men (137 % above the RDA) and 96 (7) mg for women (140 % above the RDA). The mean was 96 (5) mg for all subjects, 140 %

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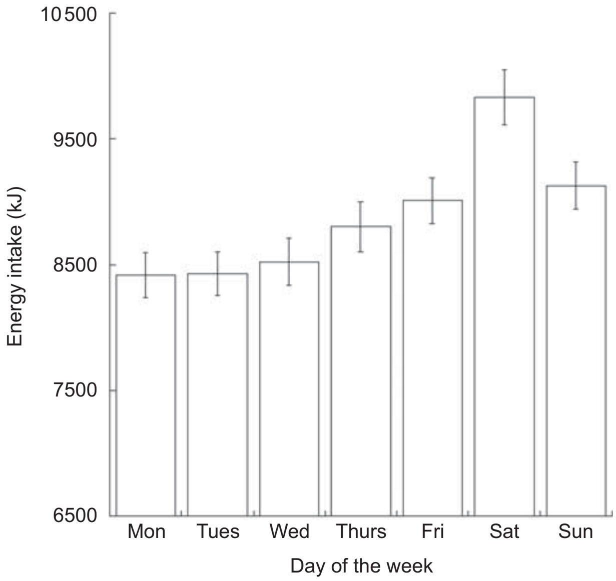

Fig. 1 Mean energy intake by day of the week among Caucasian adults (n 260), Aberdeen, north-east Scotland, UK, 2002–2004. Values are means with their standard errors represented by vertical bars. Energy intake was significantly different on Saturday and Sunday compared with the average of the weekday values ($P < 0.001$)

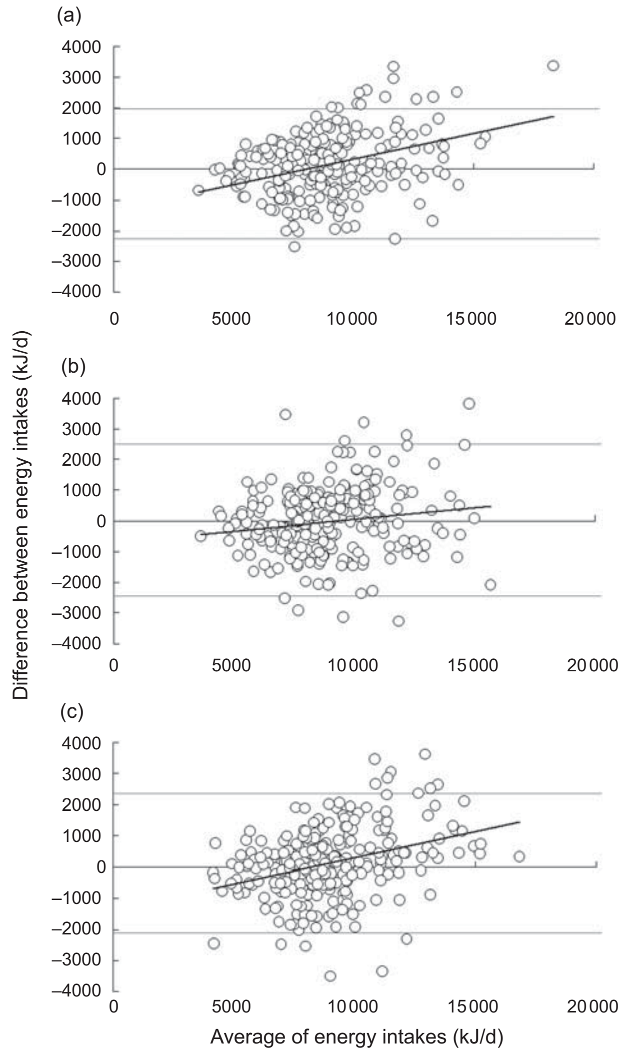

Fig. 2 Bland–Altman plots of 3 d *v.* 7 d energy intake, with 95 % confidence limits (±2 SD), among Caucasian adults (n 260), Aberdeen, north-east Scotland, UK, 2002–2004. (a) Tuesday–Thursday–Saturday *v.* Monday–Sunday ($y = 0.1663x - 1328.8$, $R^2 = 0.127$, $P = 0.29$); (b) Wednesday–Friday–Sunday *v.* Monday–Sunday ($y = 0.0749x - 689.45$, $R^2 = 0.0172$, $P = 0.94$); (c) Thursday–Saturday–Monday *v.* Monday–Sunday ($y = 0.1658x - 1352.1$, $R^2 = 0.1137$, $P = 0.30$)

above the RDA. The UK RDA for vitamin D is 2·50 μg. The mean (SE) intake from the weighed intakes was 2·98 (0·48) μg for men (19 % above the RDA) and 2·45 (0·29) μg for women (2 % below the RDA). The mean for all subjects was 2·64 (0·25) μg, 6 % above the RDA. The UK RDA for vitamin E is 4·0 mg and 3·0 mg for men and women, respectively. The mean (SE) intake from the weighed intakes was 6·1 (0·4) mg for men (52 % above the RDA) and 5·2 (0·3) mg for women (73 % above the RDA). The mean for all subjects was 5·5 (0·2) mg, well above the RDA.

Micronutrient intake: 7 d v. *3 d*

Mean (SE) vitamin A intake on Tuesday–Thursday–Saturday was 17 % lower than on Wednesday–Friday–Sunday (467 (16) μg *v.* 562 (40) μg, $P = 0.03$). However, none of the 3 d periods were significantly different (all within 12 %) from the 7 d mean (513 (51) μg). No significance was found for vitamin C (all within 4 %), D (all within 7 %) or E (all within 3 %) when comparing the 3 d periods with the 7 d mean or with each other.

Seasonal variation: energy and macronutrient intake

In comparing seasons, no significant difference was found in average EI ($P = 0.543$). However, there was a gender × season interaction ($P = 0.019$) with a different intake pattern for females than for males. This can be seen in Fig. 3. For females only, lower mean (SE) EI was recorded in summer (8117 (610) kJ) and autumn (7941 (699) kJ) compared with that recorded in spring (8929 (979) kJ) and winter (8132 (1041) kJ). Conversely for males, higher mean (SE) EI was recorded in summer (10 420 (736) kJ) and autumn (10 490 (1041) kJ) compared with spring (9319 (1441) kJ) and winter (9103 (1505) kJ).

There was no seasonal difference found for fat, protein or carbohydrate intake (results not shown).

Seasonal variation: micronutrient intake

Table 2 indicates the average seasonal intake for each gender of vitamins A, C, D and E over 7 d. Vitamin A is represented as a total of retinol and carotenoids, as retinol equivalents (1 μg RE = 12 μg carotenoids). A significant difference was found between genders for vitamins D and

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E across all seasons but not for vitamins A or C. The intake for males was 18% higher ($P<0\cdot01$) and 14% higher ($P<0\cdot001$) than that for females for vitamins D and E, respectively. When the data for both genders were combined, no significant difference was found with respect to season for vitamin C, D or E (results not shown) and, despite a difference of 28% between the intake of vitamin A in spring and summer, there was no statistical significance.

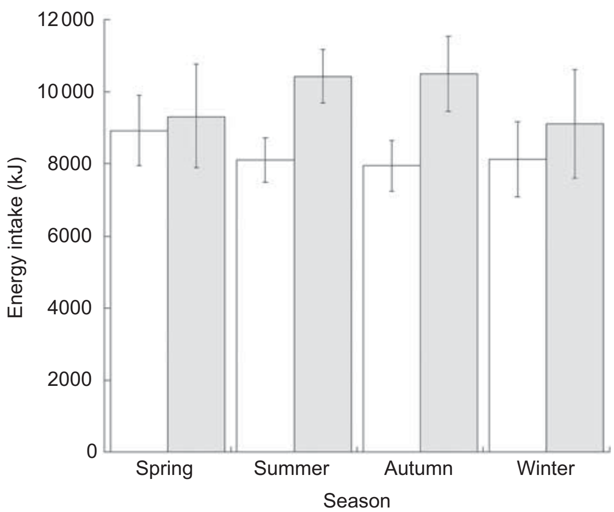

Fig. 3 Energy intake by gender (□, females; ■, males) and season among Caucasian adults (*n* 260), Aberdeen, north-east Scotland, UK, 2002–2004. Values are means with their standard errors represented by vertical bars. There was a significant gender × season interaction ($P=0\cdot02$); females recorded lower energy intakes in summer and autumn compared with spring and winter, while males recorded higher mean energy intakes in summer and autumn compared with spring and winter

Discussion

Energy and nutrient intake results from 7 d and 3 d records

The 3 d weighed intake is a common assessment tool in nutrition research. It has been recommended that the three days should consist of one weekend day and two weekdays[7] – but which three days are most representative of habitual intake? There are limited data on the variability of energy and nutrient intake with respect to either the effect of day(s) of recording or seasonal effect, but both of these issues may have practical implications for researchers conducting nutritional assessment studies. Therefore, the first aim of the current study was to compare EI results from 7 d food intakes with different 3 d periods within the same week. Average intakes for each of the seven days of the week were also examined. In accordance with previous work[8,9,29] we found that there was a significant difference between EI collected on Monday–Friday compared with Saturday and Sunday, with the weekend EI recorded to be higher. This could have implications in the selection of which days should be collected during a 3 d weighed record. Most importantly, the definition of what is a ‘weekend day’ may be an issue of interest. We found that there was a significant difference for EI between Monday–Thursday and Friday, but not between Friday and Sunday. Does this indicate that Friday could be classified as a ‘weekend day’ rather than a ‘weekday’? Our results for EI from all the 3 d periods we examined, most noticeably Wednesday–Friday–Sunday, were found to be comparable to the 7 d mean (within 3%). Similar findings have been noted previously when comparing 3 d and 7 d EI results[30]. Our results suggest that Wednesday–Friday–Sunday should be used in future comparisons with 7 d intakes.

Table 2 Micronutrient intake among Caucasian adults (*n* 260), Aberdeen, north-east Scotland, UK, 2002–2004

		Vitamin A (μg)		Vitamin C (mg)		Vitamin D (μg)		Vitamin E (mg)	
Season	Gender (*n*)	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Spring	Male (11)	550·16	223·73	75·44	28·23	2·73	1·21	5·16	1·05
	Female (26)	712·51	351·98	90·25	15·35	2·92	0·63	5·78	0·77
	Both (37)	662·17	252·57	85·74	13·72	2·86	0·57	5·59	0·62
Summer	Male (46)	510·27	88·52	100·96	12·75	2·86	0·62	6·39	0·66
	Female (67)	438·22	51·59	95·66	10·49	2·45	0·49	5·21	0·43
	Both (113)	467·55	47·35	97·82	8·10	2·62	0·38	5·69	0·38
Autumn	Male (23)	611·25	100·55	96·01	19·86	3·29	1·05	6·51	0·87
	Female (51)	436·82	61·99	98·84	11·28	2·29	0·49	5·20	0·48
	Both (74)	490·44	53·68	97·97	9·91	2·60	0·47	5·60	0·43
Winter	Male (11)	450·78	164·70	87·66	19·50	3·12	1·79	4·76	0·96
	Female (23)	595·37	268·09	97·49	20·28	2·26	0·79	4·51	0·68
	Both (34)	548·59	189·14	94·31	15·10	2·54	0·79	4·59	0·55
All	Male (91)	533·0	62·0	95·0	9·0	2·98[a]	0·48	6·10[a]	0·40
	Female (167)	501·0	71·0	96·0	7·0	2·45[b]	0·29	5·20[b]	0·30
	Both (258)	513·0	51·0	96·0	5·0	2·64	0·25	5·50	0·20

[a,b] Mean values within a column with unlike superscript letters were significantly different ($P<0\cdot05$).

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The fat, protein and alcohol intakes were also significantly higher at the weekend (Saturday and Sunday) compared with weekdays (Monday–Friday), explaining the elevated EI results. This supports work carried out by Haines *et al.*[31] and de Castro[9], who also found that weekend intakes were higher for energy, fat and alcohol. Our results showed no significant differences for macro- or micronutrient intake when comparing the 3 d results with the 7 d mean. This suggests that, for the evaluation of nutrient intake, a 3 d record is sufficient to be representative of habitual intake.

Seasonal variation in energy and nutrient intake

The second aim of the present study was to compare the energy and nutrient results for seasonal variation. Ideally, to examine seasonal variation each volunteer would have recorded four 7 d intakes, one in each of our designated seasons. However, this was not possible owing to practical limitations. There have been largely differing results published previously for the effect of seasonality on EI, showing no significance[32], higher values observed in autumn/winter compared with spring/summer[33–35] or higher values observed in winter/spring compared with summer/autumn[36,37]. Some studies compared winter and summer intakes only, and reported winter intakes to be significantly higher[38–40]. It should be noted that the methodology for all of these studies varied, either in terms of subjects studied (females only[32–34,37,38], males only[40] or both[35,36,39]) or recording techniques for EI (7 d recorded intakes[33,34,38,39], FFQ[36,37,40] or 24 h recalls[32,35]), with no obvious pattern between methodology and results.

It has been suggested that any seasonal effect may be less pronounced in an industrialised society[7], as more foods are available throughout the year due to improved food preservation techniques and increased importation[32]. Despite fewer volunteers in winter/spring compared with summer/autumn (seventy-one *v.* 187), our results are in line with this suggestion; with no difference on average between seasons for the 7 d data from all subjects. However, there was found to be a gender × season interaction. The EI for females was lower in summer and autumn compared with spring and winter, with the converse observed for males. These results support work published previously from studies in the USA[36,38], China[37] and Spain[39] for females' EI and in Finland[6] for males' EI. This may be in part explained by females being more selective with food choices e.g. low-fat foods during the warmer months of the year, perhaps as an attempt at 'healthy eating', or by being more prone to 'comfort eat' in the winter.

Our results for micronutrient intake were above recommended UK values for all the vitamins we analysed for except vitamin A, supporting results published from the National Diet and Nutrition Survey[41]. This is a positive finding for the Scottish population, which is reported to have the lowest vitamin levels in Great Britain[42–44] and is often referred to as the 'sick man of Europe' with respect to mortality and morbidity risk. When examining the variation in vitamin intakes, significance was found only for vitamins D ($P < 0{\cdot}01$) and E ($P < 0{\cdot}001$) between genders. No significance was found between seasons for males, females or all subjects. Previous studies[6,36,37,40,45] have looked at the actual food groups eaten, e.g. fruit and vegetables, with respect to vitamin intakes and seasonality. This could be a further area of research for this data set to examine the vitamin intakes more closely.

Implications

To collect data on habitual EI in free-living subjects, the 'gold standard' 7 d weighed record should ideally be used. However, our results support the use of a 3 d record as a suitable tool to obtain data in large nutritional studies if use of a 7 d record is not feasible, despite 3 d records being more affected by variability. Errors in self-reported dietary intakes have long been an issue under research. At least nine possible sources of errors in food intake assessment have been identified[7,46]. These errors can be attributed to subject compliance (reporting errors, wrong weights of foods, variation with time, wrong frequency of consumption, change in diet and response bias) or to the study investigators (errors from food tables, coding errors and sampling bias). In conclusion, the most representative 3 d period of the 7 d mean and therefore the best compromise in addressing the issues above is Wednesday–Friday–Sunday.

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