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When, how much and what foods are eaten are related to total daily food intake

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Intake in the morning is associated with a reduction in the total intake for the day, while intake at night is associated with greater overall daily intake. These associations are macronutrient specific, with morning carbohydrate intake associated with reduced daily carbohydrate intake, morning fat intake associated with reduced daily fat intake and morning protein intake associated with reduced daily protein intake. Since different types of foods contain differing proportions of macronutrients, the present study investigated the associations of different types of foods ingested at various times of day with total daily and macronutrient intakes. The intakes of 388 male and 621 female free-living individuals reported in 7 d diet diaries were reanalysed. The intakes of twenty-four different types of foods and seven different drinks occurring during the morning (04.00–10.29 hours), afternoon (10.30–16.59 hours) and evening (17.00–02.00 hours) were identified and related to overall daily intakes. Dairy foods, ice cream, beef, other meats, potatoes, pastry, nuts, chips and snacks, condiments, alcohol and soda were significantly associated with higher total intake over the day, while fruit, soup, breakfast cereal, pasta, pizza, water, coffee/tea and diet soda were either not associated or were associated with lower overall intake. Dietary energy density appeared to mediate the associations between particular foods and beverages and overall energy intake. This suggests that eating low-density foods in the morning and avoiding high-density foods at night might aid in reducing overall intake and may be useful in dietary interventions for overweight and obesity.

Eating: Meal times: Diurnal rhythms: Energy density: Breakfast

Over the course of the day, the amount and pattern of food and fluid intake changes substantially[1]. People eat larger and larger amounts but eat again sooner as the day progresses[1–3]. This indicates that the satiating properties of ingested nutrients decline precipitously over the course of the day, with foods eaten in the morning producing greater satiety than foods eaten later in the day, and foods eaten in the evening producing much less satiety than foods eaten earlier. This has consequences for the total amounts ingested during the day. Eating a large proportion of intake in the morning has been associated with lower overall intake, while eating a high proportion of intake in the evening has been associated with higher overall intake[4].

The associations between the time of day of intake and total intake appear to be macronutrient specific[5]. That is, morning carbohydrate intake has been associated with reduced daily carbohydrate intake, morning fat intake associated with reduced daily fat intake and morning protein intake associated with reduced daily protein intake. Hence, the morning intake of each macronutrient is inversely associated with the total intake of that same macronutrient over the entire day. Since different types of foods contain differing proportions of macronutrients, it stands to reason that ingesting different types of foods at different times of day may influence macronutrient intakes and consequently overall intake.

There is considerable individual variation in the types of foods and their macronutrient compositions eaten in the morning[6]. Since the amount and macronutrient composition of foods eaten at different times of day can influence overall intake, it would be reasonable to expect that people who eat different foods at different times of day would have different levels of overall intake and as a result different weights and levels of body fatness. Indeed, it was demonstrated that people who ate high-carbohydrate breakfasts had significantly lower BMI than people who skipped breakfast or ate a high-protein breakfast[7] and children with greater intakes of ready-to-eat breakfast cereals had significantly lower body weights and BMI[8] and significantly lower fat intakes[9]. In addition, overweight individuals tend to skip breakfast[10–12] and eat a larger proportion of their daily intake in the evening[13,14], while those who eat breakfast frequently tend to have lower body weights and BMI[15,16].

Hence it is important to look systematically at the consumption of varying food types at different times of the day and their relations with overall and macronutrient intakes. The present research attempted to investigate this issue by reanalysing the data on the intakes of free-living individuals that we have acquired with 7 d diet diaries[1,2,4,5,17–29]. The total intakes of thirty-one different food and beverage types occurring during the morning, afternoon and evening were identified and related

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to overall food energy and macronutrient intakes during the entire day.

Materials and methods

Participants

The data were collected from 1009 individuals consisting of 388 males and 621 females. They were recruited as participants for a number of prior studies of intake control in human subjects[1,2,4,5,17–29]. Obviously, both the participants and the experimenter were unaware that the time of day and intake was being studied. The majority of the participants, 536, were paid $30 to participate and also received a detailed nutritional analysis of their intake although 354 participated solely for the detailed nutritional analysis, while 119 were undergraduate students who satisfied a course requirement. The participants had a mean of 34·2 (SD 6·2) years, 69·0 (SD15·9) kg and 1·67 (SD 0·10) m and had a mean BMI of 24·6 (SD 4·6) kg/m^2. In order to participate, the individuals could not be actively dieting, pregnant or lactating, on chronic medication, or alcoholic as ascertained with a demographic questionnaire. The detailed description and analysis of the overall, macronutrient and meal intakes of these participants have been presented in prior publications[4,5] and will not be repeated here. The study was approved by the Georgia State University Institutional Review Board.

Procedure

For a detailed review of the method, reliability and validity of the diet–diary procedure see de Castro[30,31]. The participants were given a small (8 × 18 cm) pocket-sized diary and were instructed to record in as detailed a manner as possible every item that they either ate or drank, the time they ate it, the amount they consumed and how the food was prepared. The participants initially recorded this information for a day and reviewed the records with the experimenter. They then recorded their intake for seven consecutive days. Afterwards, they were contacted to clarify any ambiguities or missing data. For 536 participants, two individuals who ate with the participant were contacted and asked to verify the reported intake. In some cases, difficulty was encountered in remembering exactly what was eaten. However, in no case was the diary report contradicted in either the nature or the amount[30,31].

Data analysis

The foods reported in the diaries were assigned codes by an experienced dietitian from a computer file containing the nutrient compositions of common food items created from the U.S. Department of Agriculture Handbooks no. 8 and 456 of the Nutritive Value of American Foods, from package labels, from personal communications with food industry sources and from the present published literature. The coder was unaware of the experimental hypotheses and the participants' characteristics and did not interact directly with the participants. Total daily intakes of food energy, carbohydrate, fat, protein and dietary energy density (kJ/g) were calculated by summing the contributions of the individual items. Intakes in grams were also calculated for twenty-four different food types: fruits; dairy foods including cheese, butter, yogurt; ice cream-milk or sherbet; candy; soup; seafood; beef; poultry; other meats including pork, veal, lamb; pasta and noodles; pizza; rice; potatoes; legumes; nuts and seeds; other vegetables; bread and crackers; chips and snacks; breakfast cereal; other breakfast foods including pancakes, etc.; eggs; pastry including cookies, pies, cakes; sugar including honey and jam; condiments including sauces and salad dressings; seven different drink types including water, alcoholic drinks, sugared sodas, diet sodas, milk, coffee/tea, fruit juices. The specific food and beverage item types that were chosen for study were selected to encompass a range of different foods and beverages and for practical reasons because they could be easily identified and separated in the computer file of food/beverage items and because they were ingested frequently enough by enough different subjects that meaningful analyses could be performed.

To investigate the influence of morning, afternoon and evening intake of different types of foods on overall intake, the total amounts of food energy, carbohydrate, fat and protein and the gram amounts of the twenty-four food and seven beverage types ingested during three periods during the day 04.00–10.29, 10.30–16.59 and 17.00 hours were calculated. The morning period was specifically selected to capture most intakes that would be termed breakfast but not lunch. Similarly, the afternoon period was selected to capture most of the intakes termed lunch and afternoon snack, while the evening period was chosen to capture most of the intake termed dinner and evening snack. In addition, the percentages of the total gram intake occurring during each period of each of the food and beverage types were calculated.

All analyses were performed within subjects. That is each participant's intake under one condition was compared with the same participant's intake under another condition. As discussed by de Castro[32], this is the most appropriate and valid method for analysing self-report data. To assess the relation between the time of the day of intake and the intake of particular types of foods, multiple linear regression analyses[33] were performed to predict the overall daily intakes on the basis of the proportions of intake ingested during each period and the percentage of the total gram intake occurring during each period of each of the food and beverage item types. Since the amount ingested during a period is highly correlated with the total amount eaten over the day, the proportion of the intake during each period was used instead of the absolute amounts. Since each food and beverage type has a characteristic pattern of intake over the day and often was ingested predominantly during specific periods, the percentage of the total gram intake occurring during each period for each item type was used. These proportions were then used in the multiple regressions predicting the absolute amounts ingested over the entire day for each subject individually. Separate regressions were performed predicting total daily food energy intake, and the overall daily intakes of carbohydrate, fat and protein. In addition, the dietary energy density of the foods ingested during each period was paired with the percentage of the total gram intake occurring during each period for each item type in multiple regressions predicting the absolute amounts ingested over the entire day for each subject individually.

Mean standardised regression coefficients (β coefficients) were then calculated over all participants and for male and female participants separately and compared with zero with a *t* test.

To make the multiple regression results more concrete, days were identified when the proportions of the daily intake of the individual food and beverage types ingested were above or below the mean level for each individual for the morning, afternoon or evening periods. The total amounts eaten on those days of food energy, carbohydrate, fat and protein, and the twenty-four food and seven beverage types were then compared. For example, the total amounts ingested on days in which an individual ate a proportion of their morning intake of breakfast cereals that was greater than the mean level for that individual for the morning were compared with the total amounts ingested on days when the proportion of breakfast cereals in the morning was below the mean level. The analysis was completed for days when the proportion of total intake was above and below the mean for the afternoon and a final analysis compared evenings with above and below the mean proportionate intakes. These analyses were repeated for the intakes of each of the twenty-four food and seven beverage item types. Repeated-measures ANOVA were used to compare the intakes for below and above the mean days for the three periods. All results were significant at $\alpha < 0{\cdot}05$.

Results

The overall, macronutrient and meal intakes for these data have been described in detail in prior publications[4,5].

Time of day of amounts of food and beverage type intake

The proportions of the total gram intake ingested during the morning, afternoon and evening varied considerably among the foods and beverages (Table 1). The highest proportion of intake in the morning for the foods was fruit, ingested by 50 % of the participants and for beverages, coffee and tea, ingested by 64 % of the participants. In the afternoon, the highest proportion of intake for the foods was again fruit, ingested by 67 % of the participants, but diet soda was the highest among the beverages, ingested by 33 % of the participants. In the evening, other vegetable types, ingested by 99 % of the participants, and water, ingested by 74 % of the participants, constituted the highest proportions of intake. Eleven item types were ingested in the morning by very few (< 10 %) of the participants, while only one type (other breakfast foods) was in the evening.

Time of day, proportionate energy intake and total daily intake

The total amount eaten over the entire day was associated with the amounts and characteristics of the food eaten during different times of the day. The mean β coefficients from the

Table 1. Intakes (in g) of the food and beverage types for the morning, afternoon and evening
(Mean values with their standard errors)

	Morning			Afternoon			Evening		
Type	% Total g intake	SEM	*n*	% Total g intake	SEM	*n*	% Total g intake	SEM	*n*
Food									
Fruit	8·344	0·368	502	6·833	0·254	676	4·136	0·181	588
Dairy foods	1·934	0·167	268	1·994	0·075	790	1·667	0·065	791
Ice cream	5·583	1·381	16	3·234	0·252	197	3·758	0·187	433
Candy	3·117	0·409	198	2·216	0·180	501	1·741	0·177	393
Soup	3·225	0·776	14	5·110	0·260	343	4·035	0·173	408
Fish	2·505	0·675	19	2·984	0·142	368	3·220	0·137	465
Beef	2·782	0·285	74	5·110	0·167	750	5·229	0·150	861
Poultry	3·896	0·477	55	3·888	0·147	644	3·808	0·114	749
Other meats	2·414	0·197	308	1·918	0·089	570	1·746	0·077	531
Pasta	3·323	0·544	21	4·236	0·177	412	4·695	0·161	654
Pizza	5·219	1·501	10	4·382	0·237	264	4·890	0·197	411
Rice	3·912	0·835	20	3·169	0·192	306	3·394	0·161	515
Potatoes	2·669	0·175	118	3·995	0·131	674	4·513	0·121	838
Beans	1·493	0·245	12	2·385	0·122	376	2·842	0·103	615
Nuts	1·301	0·151	168	1·032	0·077	396	0·781	0·078	347
Other vegetables	2·209	0·291	107	5·898	0·159	946	7·686	0·177	1003
Bread	3·388	0·140	669	3·488	0·090	965	2·421	0·068	926
Chips and snacks	2·374	0·433	74	1·948	0·100	604	1·592	0·113	585
Cereal	4·753	0·197	613	1·979	0·199	214	1·693	0·252	166
Other breakfast	4·663	0·236	255	2·924	0·251	120	1·458	0·241	65
Eggs	3·526	0·136	394	1·919	0·110	344	1·413	0·091	246
Pastry	4·131	0·206	524	2·730	0·124	588	2·383	0·105	589
Sugar	1·638	0·079	549	0·870	0·065	471	0·669	0·045	422
Condiments	1·281	0·178	128	1·802	0·055	953	2·188	0·065	977
Beverage									
Water	19·021	0·712	475	18·615	0·512	725	18·442	0·498	745
Alcohol	5·007	1·383	8	8·767	0·598	202	14·561	0·621	500
Soda	17·259	1·097	184	19·350	0·603	608	15·118	0·490	595
Diet soda	17·774	1·462	111	21·226	0·881	335	14·816	0·681	271
Milk	18·217	0·576	757	9·162	0·388	602	11·064	0·413	651
Coffee	41·281	0·958	646	16·668	0·524	653	13·096	0·466	552
Fruit juice	16·341	0·589	526	8·690	0·390	449	6·910	0·351	452

multiple regressions predict the total food energy intake over the entire day on the basis of the proportion of the individual total daily food energy intake ingested during the morning (Table 2), afternoon (Table 3) and evening (Table 4) periods and the proportion of the total gram intake for the morning, afternoon or evening ingested of the food and beverage types. The β coefficients were presented only if at least 10 % of the participants ingested a food type during the period. The β coefficients for the proportion of the individual total daily intake ingested during the morning indicated predominantly significant inverse relations with overall intake (Table 2), while for the afternoon some of the β coefficients indicated small significant inverse relations with overall intake (Table 3) and for the evening the β coefficients indicated predominantly significant positive relations with overall intake (Table 4). Hence, the multiple regression analysis indicated that higher proportional energy intake in the morning was associated with lower overall intake, while higher proportional energy intake in the evening was associated with higher energy intake for the entire day; more in the morning and less in the evening associated with lower total daily intake.

Morning food and beverage type intake and total daily intake

Multiple regressions were performed to predict the total daily food energy intake on the basis of the proportion of the individual daily intake ingested during the morning and the proportion of the total gram intake for the morning ingested of the food and beverage types (Table 2). A positive β coefficient implies that ingestion of the item type was associated with greater total intake beyond the influence of the proportionate energy intake during that period, while a negative β coefficient implies that it was associated with lower overall intake. It is clear from the table that most item types have positive β coefficients for those that are significant. For morning intake, in descending order of β coefficient magnitude, ingestion of potatoes, other meats, eggs, condiments, other breakfast foods, dairy foods, other vegetables, fruit juice, sugar, pastry, nuts and bread have significant positive β coefficients and were associated with greater total daily intake. On the other hand, fruit, candy, breakfast cereal, water, soda, diet soda and milk did not have significant β coefficients, while coffee/tea was the only morning type with a significant negative association with overall intake.

To look in a little different way at the relation of morning food and beverage type intake with the total daily energy intake, the individuals' intakes on days when they ate relatively less of the food and beverage type during the morning were compared with the days when the same individuals ate relatively more. The differences between total daily energy intakes on days when the proportions of morning intake of the individual food and beverage types were below or above the mean levels were assessed (Table 2). Approximately 1 MJ more was ingested over the day when morning intake was above the mean for other breakfast foods, dairy foods, other meats, eggs, other vegetables and sugar. Approximately 0·5 MJ more was ingested over the day when morning intake

Table 2. Overall daily energy intake on the basis of the proportions of intake ingested during each period and the percentage of the total gram intake occurring during the morning period of each of the food and beverage item types, together with the total daily energy intake on days when the proportion of intake was below and above the mean for individual subjects for the morning period

(Mean β coefficients or values with their standard errors)

	% Total daily energy intake		% Total morning gram intake			Total daily food energy (kJ)				
						Days below		Days above		
Type	Mean β	SEM	Mean β	SEM	*n*	Mean	SEM	Mean	SEM	Days below above difference
Food										
Fruit	− 0·160*	0·026	0·033	0·024	504	8290	109	8483	130	− 193
Dairy foods	− 0·093*	0·037	0·185*	0·035	267	8136	134	9266†	201	− 1130
Candy	− 0·042	0·037	0·004	0·038	197	8186	172	8357	234	− 172
Other meats	− 0·180*	0·051	0·302*	0·049	308	8512	151	9571†	180	− 1059
Potatoes	− 0·199*	0·084	0·337*	0·084	119	9127	239	10 868†	343	− 1741
Nuts	− 0·142*	0·043	0·087*	0·041	169	8504	184	9010†	259	− 506
Other vegetables	− 0·134*	0·055	0·173*	0·054	109	8458	222	9337†	356	− 879
Bread	− 0·156*	0·025	0·082*	0·024	671	8190	96	8625†	121	− 435
Cereal	− 0·158*	0·028	0·022	0·027	610	8353	100	8529	121	− 176
Other breakfast	− 0·090*	0·046	0·199*	0·043	259	8458	142	9621†	230	− 1163
Eggs	− 0·175*	0·035	0·223*	0·033	395	8470	126	9437†	172	− 967
Pastry	− 0·074*	0·032	0·104*	0·032	522	8311	105	8960†	142	− 649
Sugar	− 0·124*	0·030	0·107*	0·030	555	8290	105	9102†	146	− 812
Condiments	− 0·095	0·059	0·215*	0·053	129	8567	222	9860†	343	− 1293
Beverage										
Water	− 0·137*	0·032	0·029	0·031	480	8341	113	8257	138	84
Soda	0·037	0·068	0·018	0·069	181	8667	197	9366†	259	− 699
Diet soda	− 0·218*	0·049	0·007	0·050	115	7596	209	7537	268	59
Milk	− 0·166*	0·025	0·012	0·025	755	8303	96	8416	105	− 113
Coffee	− 0·209*	0·030	− 0·095*	0·029	646	8366	100	8119†	105	247
Fruit juice	− 0·198*	0·029	0·138*	0·027	527	8169	109	8688†	142	− 519

* β Coefficients are significantly different from zero as assessed with a *t* test ($P<0·05$).

† Intakes on above the mean days are significantly different from intakes on below the mean days as assessed with ANOVA ($P<0·05$).

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Table 3. Overall daily energy intake on the basis of the proportions of intake ingested during each period and the percentage of the total gram intake occurring during the afternoon period of each of the food and beverage item types, together with the total daily energy intake on days when the proportion of intake was below and above the mean for individual subjects for the afternoon period

(Mean β coefficients or values with their standard errors)

	% Total daily energy intake		% Total afternoon gram intake			Total daily food energy (kJ)				
						Days below		Days above		
Type	Mean β	SEM	Mean β	SEM	*n*	Mean	SEM	Mean	SEM	Days below above difference
Food										
Fruit	−0·011	0·020	−0·017	0·020	676	8341	96	8399	126	−59
Dairy foods	−0·056*	0·019	0·083*	0·018	790	8211	84	8839†	109	−628
Ice cream	−0·021	0·038	0·242*	0·038	197	8265	176	9797†	285	−1532
Candy	−0·019	0·021	0·019	0·020	501	8362	100	8663†	138	−301
Soup	−0·021	0·028	−0·005	0·027	343	8236	126	8290	176	−54
Fish	−0·044	0·027	0·055*	0·026	368	8211	126	8483	159	−272
Beef	−0·022	0·019	0·087*	0·019	750	8295	92	8931†	113	−636
Poultry	−0·063*	0·021	0·081*	0·020	644	8240	96	8663†	130	−423
Other meats	−0·044*	0·022	0·085*	0·022	570	8571	105	9077†	151	−506
Pasta	−0·027	0·026	0·009	0·025	412	8265	117	8299	159	−33
Pizza	−0·014	0·032	0·051	0·031	264	8483	151	8659	209	−176
Rice	−0·076*	0·028	0·058*	0·028	306	8014	130	8496†	188	−481
Potatoes	−0·024	0·022	0·116*	0·022	674	8341	96	9035†	126	−695
Beans	−0·072*	0·025	0·100*	0·026	376	8244	121	8730†	163	−485
Nuts	−0·019	0·028	0·098*	0·026	396	8337	121	8939†	167	−603
Other vegetables	−0·042*	0·017	0·019	0·016	946	8228	80	8412†	96	−184
Bread	−0·024	0·016	0·018	0·016	965	8261	80	8512†	92	−251
Chips and snacks	−0·042*	0·021	0·106*	0·200	604	8295	92	8977†	130	−682
Cereal	−0·083*	0·035	−0·048	0·032	214	8445	167	8144	213	301
Other breakfast	0·025	0·051	0·066	0·048	120	8073	213	8801†	343	−728
Eggs	0·019	0·029	−0·010	0·028	344	8357	135	8571	205	−213
Pastry	−0·034	0·023	0·140*	0·022	588	8362	96	9261†	130	−900
Sugar	−0·030	0·024	0·057*	0·023	471	8357	113	8730†	146	−372
Condiments	−0·053*	0·018	0·072*	0·018	953	8165	80	8617†	100	−452
Beverage										
Water	−0·051*	0·020	−0·050*	0·019	725	8391	96	8161†	100	230
Alcohol	−0·059	0·039	0·235*	0·040	202	8650	159	10 052†	243	−1402
Soda	−0·058*	0·021	0·047*	0·022	608	8563	105	8989†	117	−427
Diet soda	−0·007	0·028	−0·038	0·027	335	7780	126	7834	155	−54
Milk	−0·025	0·023	0·055*	0·022	602	8341	100	8659†	130	−318
Coffee	−0·065*	0·021	−0·045*	0·021	653	8320	100	8232	117	88
Fruit juice	−0·029	0·024	0·047*	0·023	449	8203	109	8688†	155	−485

* β Coefficients are significantly different from zero as assessed with a *t* test ($P<0·05$).
† Intakes on above the mean days are significantly different from intakes on below the mean days as assessed with ANOVA ($P<0·05$).

was above the mean for soda, pastry, fruit juice, nuts and bread. On the other hand, there were no significant differences between below and above the mean days for fruit, candy, breakfast cereal, water, diet soda and milk, while above the mean days of coffee/tea intake was significantly associated with lower total intake over the day. These results are extremely similar to the multiple regression results. In fact the correlation between the food and beverage types' β coefficients and the difference between below and above the mean days was 0·92 ($P<0·05$).

Afternoon food and beverage type intake and total daily intake

For afternoon intake in descending order of β coefficient magnitude (Table 3), ingestion of ice cream, alcohol, pastry, potatoes, chips and snacks, beans, nuts, beef, other meats, dairy foods, poultry, condiments, rice, sugar, milk, fish, fruit juice and soda have significant positive β coefficients and were associated with greater total daily intake. On the other hand, fruit, candy, soup, pasta, pizza, other vegetables, bread, breakfast cereal, other breakfast foods, eggs and diet soda did not have significant β coefficients, while coffee/tea and water had significant inverse associations with overall intake.

Afternoon food and beverage type intake was also investigated with a below and above the mean intake analysis (Table 3). Individuals' total daily intakes on days when they ate relatively less of the food and beverage type during the afternoon were compared with the days when the same individuals ate relatively more. The differences between the total daily energy intakes on days when the proportionate afternoon intake of the individual food and beverage types were below or above the mean levels were assessed (Table 3). Approximately 1 MJ more was ingested over the day when afternoon intake was above the mean for ice cream, alcohol and pastry. Approximately a half mega joule more was ingested over the day when afternoon intake was above the mean for most other food and beverage types. On the other hand, there were no significant differences between below and above the mean days for fruit, soup, fish, pasta, pizza, breakfast cereal, eggs, diet soda and coffee/tea, while above the mean days of water intake was

Table 4. Overall daily energy intake on the basis of the proportions of intake ingested during each period and the percentage of the total gram intake occurring during the evening period of each of the food and beverage item types, together with the total daily energy intake on days when the proportion of intake was below and above the mean for individual subjects for the evening period

(Mean β coefficients or values with their standard errors)

	% Total daily energy intake		% Total evening gram intake			Total daily food energy (kJ)				
						Days below		Days above		
Type	Mean β	SEM	Mean β	SEM	*n*	Mean	SEM	Mean	SEM	Days below above difference
Food										
Fruit	0·094*	0·021	0·010	0·020	588	8403	100	8529	126	−126
Dairy foods	0·080*	0·019	0·092*	0·019	791	8173	88	8973†	113	−799
Ice cream	0·039	0·025	0·130*	0·022	433	8592	113	9487†	159	−896
Candy	0·085*	0·025	0·099*	0·023	393	8366	121	9098†	172	−732
Soup	0·088*	0·025	−0·072*	0·023	408	8295	117	8039†	142	255
Fish	0·076*	0·024	0·032	0·022	465	8232	113	8613†	146	−381
Beef	0·048*	0·017	0·095*	0·016	861	8173	88	8943†	105	−770
Poultry	0·052*	0·019	0·004	0·017	749	8316	92	8424	113	−109
Other meats	0·048*	0·022	0·082*	0·020	531	8403	109	9048†	151	−644
Pasta	0·073*	0·020	0·012	0·018	654	8337	96	8475	121	−138
Pizza	0·039	0·026	0·036	0·023	411	8311	121	8579	163	−268
Rice	0·091*	0·022	0·008	0·020	515	8169	105	8370	142	−201
Potatoes	0·057*	0·018	0·040*	0·016	838	8278	88	8705†	100	−427
Beans	0·104*	0·021	−0·005	0·019	615	8324	96	8483†	121	−159
Nuts	0·086*	0·025	0·098*	0·025	347	8441	121	9345†	180	−904
Other vegetables	0·066*	0·017	0·004	0·015	1003	8207	80	8391†	92	−184
Bread	0·077*	0·017	0·002	0·016	926	8261	84	8567†	96	−306
Chips and snacks	0·041*	0·021	0·117*	0·020	585	8433	96	9400†	138	−967
Cereal	0·094*	0·043	−0·021	0·041	166	8244	201	8370	280	−126
Eggs	0·143*	0·039	0·012	0·038	246	8215	155	8571†	197	−356
Pastry	0·042*	0·021	0·162*	0·019	589	8320	100	9404†	146	−1084
Sugar	0·100*	0·025	0·006	0·023	422	8454	117	8751†	155	−297
Condiments	0·065*	0·017	0·078*	0·015	977	8136	80	8676†	96	−540
Beverage										
Water	0·064*	0·020	−0·088*	0·018	745	8408	92	8232	113	176
Alcohol	0·037	0·023	0·198*	0·021	500	8290	109	9814†	163	−1523
Soda	0·067*	0·021	0·057*	0·019	595	8374	105	9086†	130	−711
Diet soda	0·041	0·032	−0·072*	0·029	271	7914	134	7792	193	121
Milk	0·076*	0·021	−0·010	0·019	651	8512	100	8688	121	−176
Coffee	0·109*	0·022	−0·015	0·021	552	8157	105	8286	121	−130
Fruit juice	0·122*	0·024	0·028	0·022	452	8228	113	8793†	146	−565

* β Coefficients are significantly different from zero as assessed with a *t* test ($P<0·05$).
† Intakes on above the mean days are significantly different from intakes on below the mean days as assessed with ANOVA ($P<0·05$).

significantly associated with lower total intake over the day. These results are extremely similar to the multiple regression results. In fact the correlation between the food and beverage types' β coefficients and the difference between below and above the mean days was 0·96 ($P<0·05$).

Evening food and beverage type intake and total daily intake

For evening intake in descending order of β coefficient magnitude (Table 4), ingestion of alcohol, pastry, ice cream, potatoes, chips and snacks, candy, nuts, beef, dairy foods, other meats, condiments, soda and potatoes have significant positive β coefficients and were associated with greater total daily intake. On the other hand, fruit, fish, poultry, pasta, pizza, rice, legumes, other vegetables, bread, breakfast cereal, eggs, sugar, milk, coffee/tea and fruit juice did not have significant β coefficients, while soup, diet soda and water have significant negative associations with overall intake.

Evening food and beverage type intake was also investigated with a below and above the mean intake analysis. Individuals' total daily intakes on days when they ate relatively less of the food and beverage type during the evening were compared with the days when the same individuals ate relatively more. The differences between the total daily energy intakes on days when the proportions of evening intake of the individual food and beverage types were below or above the mean levels were assessed (Table 4). Approximately 1 MJ more was ingested on days when evening intake was above the mean for alcohol, pastry, chips and snacks, nuts, ice cream, dairy foods and beef. Approximately 0·5 MJ more was ingested when evening intake was above the mean for most other food and beverage types. On the other hand, there were no significant differences between below and above the mean days for fruit, poultry, pasta, pizza, rice, breakfast cereal, water, diet soda, milk and coffee/tea, while above the mean days of soup intake was significantly associated with lower total daily intake. These results are extremely similar to the multiple regression results with the correlation between the food and beverage types' β coefficients and the difference between below and above the mean days was 0·97 ($P<0·05$).

Dietary energy density, food and beverage type and total daily intake

The associations of food and beverage types with overall intake may, to some extent, be associated with their dietary energy density. To investigate this, multiple regressions were performed to predict the total daily food energy intake on the basis of the dietary energy density of intake during each period and the proportion of the total gram intake ingested of the food and beverage types (Table 5). For the morning, afternoon and evening periods, the β coefficients for dietary energy density were in general strong, positive and significant. This indicates that higher levels of dietary energy density are associated with higher levels of energy intake regardless of the time of day. The β coefficients for the food and beverage types were primarily non-significant. The few significant β coefficients were all substantially smaller than the β coefficients for the same types when they were paired with proportionate energy intake (Tables 2–4) with the exception of alcohol. These results indicate that the influences of the food and beverage types on overall daily intake may, in large part, be mediated by their contributions to the overall dietary energy density of the intake during the morning, afternoon or evening.

Discussion

There is evidence that the 7 d diet–diary methodology employed in the present analysis is reasonably reliable and valid[34–38] (see de Castro[30,31] for review). It appears, however, to consistently underestimate actual intake[39–42]. So, in the present analysis, not only were the absolute values analysed but also the proportions of intake. These proportions are magnitude independent and thus recording errors are unlikely to be responsible for the observed relations. In addition, underestimation may differ systematically between subjects such that certain participants (e.g. overweight) might tend to underestimate more than others. However, the results were significant for within-subject analyses of the proportions, which correct for the overall and individual underestimated level of intake. Thus, underestimation of intake could not account

Table 5. Overall daily energy intake on the basis of the dietary energy density and the percentage of the total gram intake of each of the food and beverage item types occurring during the morning, afternoon and evening periods

(Mean β coefficients with their standard errors)

	Morning				Afternoon				Evening			
	Daily dietary energy density		% Total morning gram intake		Daily dietary energy density		% Total afternoon gram intake		Daily dietary energy density		% Total evening gram intake	
Type	Mean β	SEM	Mean β	SEM	Mean β	SEM	Mean β	SEM	Mean β	SEM	Mean β	SEM
Food												
Fruit	0·206*	0·030	−0·040	0·030	0·241*	0·018	−0·017	0·018	0·316*	0·019	0·001	0·018
Dairy foods	0·186*	0·042	0·093*	0·041	0·259*	0·019	0·029	0·019	0·361*	0·019	0·012	0·020
Ice cream					0·219*	0·038	0·141*	0·038	0·322*	0·024	0·043	0·024
Candy	0·164*	0·052	−0·002	0·051	0·284*	0·026	0·001	0·026	0·376*	0·029	−0·013	0·031
Soup					0·246*	0·025	0·046	0·024	0·296*	0·026	−0·014	0·025
Fish					0·271*	0·028	0·011	0·026	0·297*	0·022	0·027	0·021
Beef					0·293*	0·021	0·002	0·021	0·320*	0·018	0·300	0·018
Poultry					0·232*	0·019	0·049*	0·019	0·329*	0·018	−0·031	0·017
Other meats	0·214*	0·049	0·096*	0·048	0·256*	0·021	0·019	0·021	0·312*	0·021	0·031	0·020
Pasta					0·251*	0·021	0·031	0·021	0·324*	0·018	0·008	0·018
Pizza					0·273*	0·029	−0·016	0·030	0·324*	0·026	−0·025	0·027
Rice					0·216*	0·027	0·040	0·027	0·353*	0·023	0·013	0·022
Potatoes	0·112	0·080	0·191*	0·085	0·266*	0·019	0·039	0·020	0·322*	0·017	0·004	0·017
Beans					0·265*	0·023	0·082*	0·023	0·330*	0·019	−0·004	0·018
Nuts	0·275*	0·099	−0·082	0·060	0·224*	0·028	0·021	0·027	0·356*	0·029	0·000	0·030
Other vegetables	0·189*	0·053	0·100*	0·048	0·240*	0·017	0·020	0·016	0·329*	0·015	0·010	0·015
Bread	0·250*	0·035	−0·069	0·035	0·305*	0·019	−0·078*	0·020	0·341*	0·018	−0·056*	0·018
Chips and snacks					0·306*	0·026	−0·025	0·027	0·335*	0·023	0·063*	0·025
Cereal	0·193*	0·039	−0·013	0·038	0·195*	0·033	−0·085*	0·031	0·252*	0·041	0·018	0·038
Other breakfast	0·258*	0·047	0·038	0·042	0·186*	0·047	0·083	0·043				
Eggs	0·196*	0·043	0·047	0·042	0·224*	0·026	−0·007	0·025	0·310*	0·029	0·011	0·030
Pastry	0·272*	0·034	−0·034	0·035	0·275*	0·025	0·058*	0·025	0·277*	0·022	0·098*	0·021
Sugar	0·209*	0·032	0·015	0·032	0·268*	0·024	0·004	0·024	0·312*	0·024	−0·004	0·023
Condiments	0·261*	0·065	0·032	0·061	0·273*	0·017	−0·004	0·016	0·313*	0·016	0·030	0·015
Beverage												
Water	0·166*	0·031	0·038	0·032	0·253*	0·021	0·027	0·021	0·331*	0·020	0·014	0·019
Alcohol					0·218*	0·035	0·226*	0·039	0·330*	0·024	0·207*	0·025
Soda	0·254*	0·048	−0·032	0·049	0·211*	0·024	−0·004	0·024	0·312*	0·020	0·047*	0·020
Diet soda	0·252*	0·084	0·157	0·085	0·251*	0·030	−0·017	0·032	0·374*	0·028	−0·011	0·028
Milk	0·195*	0·032	−0·049	0·032	0·236*	0·021	0·011	0·021	0·332*	0·018	−0·017	0·019
Coffee	0·235*	0·035	0·004	0·035	0·266*	0·019	−0·003	0·020	0·348*	0·020	0·051*	0·019
Fruit juice	0·136*	0·036	0·088*	0·037	0·258*	0·022	0·057*	0·021	0·340*	0·023	0·042	0·022

* β Coefficients are significantly different from zero as assessed with a *t* test ($P<0·05$).

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for the present results. Obviously, there are unsystematic errors of measurement. But, the fact that significant relations were found with a technique that includes considerable error suggests that the effects reported may actually be underestimated and that the influence of the time of day of the intakes of various foods and beverages are, in fact, considerably stronger.

In previous studies[4,5] it was demonstrated that the larger the proportion of total food energy intake ingested in the morning the smaller the overall intake, while the larger the proportion of total intake ingested in the late evening the larger the total intake. These results suggested that intake during the morning is associated with lower intake during the remainder of the day, while intake late at night is associated with higher levels of overall daily intakes. The present study supports this basic phenomenon and extends these results. It indicates that the types of foods and beverages ingested during these periods can also make a difference in the total intakes over the entire day. The multiple regressions suggest that the foods and beverages have influences beyond their simple contributions to energy intake.

Interestingly, fruit, soup, breakfast cereal, pasta, pizza, water, coffee/tea and diet soda had either negative or non-significant β coefficients for all periods. Previously, it was shown that, fruit, soup, water, coffee/tea and diet soda ingestion does not appear to add to overall daily intake or evening intake as was the case for most other food types[21,22]. The inverse association or lack of association of these item types with overall intake indicated that they were not associated with greater intake beyond their contribution to overall energy intake. Hence, ingestion of these foods and beverages would be recommended for intake control. Indeed, the consumption of breakfast cereal has been repeatedly shown to be associated with lower fat intake and BMI[8,9,43,44]. In addition, since morning intake of food energy was associated with lower overall intake and breakfast cereal and fruit contributed to this morning energy intake and do not have an association by themselves with overall intake, it suggests that these foods and the non-nutritive beverages are excellent for morning intake and overall intake control. Indeed, Mattes[45] found that when cereal with fruit was used as a replacement meal in a dietary program, there was a decrease in overall intake and a greater reduction in body weight. Also substituting cereal for an evening snack significantly aided in weigh loss[46].

On the other hand, there were a number of foods and beverages that appeared to be associated with heightened overall daily intake no matter when they were ingested. Dairy foods, ice cream, beef, other meats, potatoes, pastry, nuts, chips and snacks, condiments, alcohol and soda, in addition to their contributions to the overall energy intake during a period, were significantly associated with higher total intake over the day. Similarly, it was previously shown that, cheese, ice cream, beef, potatoes, alcohol and soda ingestion appeared to add to overall daily intake or evening intake and did not displace the intake of other foods[21,22]. The results suggest that, in any attempt to restrict intake, these food and beverage types should be avoided. It is interesting to note that most of these food types appear to be high-dietary energy density foods.

The idea that the associations of food types with overall intake may to some extent be associated with the dietary energy density of the type is supported by the findings with the non-nutritive beverages. The non-nutritive beverages investigated in the present study of water, diet soda and coffee/tea were found to be either not significantly associated or negatively associated with overall daily intake no matter when they were ingested. These results are similar to previous findings[21,22]. Since these beverages contribute to the total bulk and weight of intake, but do not contribute food energy, their ingestion lowers the overall dietary energy density of a meal. It has been clearly demonstrated that the higher the dietary energy density of intake, the higher the overall energy intake[24,47–55]. Hence, many of the results reported here for individual food and beverage types may well be mediated by their contributions to dietary energy density.

When dietary energy density was paired with the food and beverage types in the multiple regressions, the food and beverage type β coefficients that were significant when paired with proportionate energy intake became either non-significant or markedly reduced. When pairing a variable with another results in a marked reduction in its association with a dependent variable, it strongly suggests that the original association of the variable resulted from mediation[56]. This clearly suggests that the associations of the food and beverage types with overall daily intake results from their contributions to the dietary energy density of overall intake. Foods that tend to increase dietary energy density result in heightened intake beyond their simple contribution to energy intake, while foods and beverages that are low in energy density either do not or inversely contribute to overall energy intake.

The study has a number of shortcomings. It is well documented that actual intakes are systematically under-reported in dietary diaries. Although, the analyses presented here should be relatively immune to contamination by under-reporting, it is still possible that there exists a complex, non-linear, relationship between under-reporting and time of day or item types, which conceivably could in some way bias the results. Regardless, the fact of under-reporting, at the very least, reduces the external validity of the results. Another issue is selective reporting, where participants have a tendency to include items perceived as healthful and neglect items perceived as forbidden. This selective reporting could have resulted in relative over-reporting of some items and under-reporting of others. In addition, the sample employed consists of a composite of multiple convenience samples that may not be representative of the population.

We are presently in the midst of an epidemic of obesity[57,58]. This epidemic has developed in parallel with a modern trend for children and adolescents to eat very little in the morning and shift the preponderance of their intake till much later in the day[59–61] and for adults to be less likely to eat breakfast[62]. Based upon the present results, it can be speculated that the increase in the rates of obesity may be in part the result of the shift in the time of day of intake. Indeed, overweight and obesity were associated with skipping breakfast[10,11,15,16,63] and eating late in the day[13]. In addition, only 4 % of the people who have been successful in losing a substantial amount of weight and keeping it off for a prolonged period of time are breakfast skippers[64]. This hypothesis suggests that an effective strategy to prevent or treat obesity might be to encourage an intake pattern where relatively large amounts of low-density foods are eaten in

the morning and intake of high-density foods during the evening are avoided.

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