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The effects of skipping a meal on daily energy intake and diet quality

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Abstract

Objective: To examine whether skipping breakfast or lunch increased the next meal's energy content and changed total daily energy content and the quality of food intake measured by the 2010 Healthy Eating Index (HEI-2010).

Design: Means were compared across intake days and meal patterns. Multivariate individual fixed-effects model was used to account for individual food intake and diet quality preferences.

Setting: National Health and Nutrition Examination Survey, 2007–2016.

Participants: Adults aged 18 years or older who reported 2 d (24-h periods) of dietary intake and were not pregnant or lactating (*n* 23 488).

Results: Adults consumed 193 more kJ at lunch after skipping breakfast and 783 more kJ at dinner after skipping breakfast and lunch. Skipping at least one meal reduced total daily intake between 1053 (breakfast) and 1464 (dinner) kJ and reduced the daily HEI score. Skipping breakfast or skipping lunch reduced the HEI component scores for fruit, whole grains, dairy and empty energy; skipping lunch reduced the component scores for fruit, vegetables, whole grain, dairy, seafood and plant protein, and empty energy. Skipping dinner reduced component scores for vegetables, greens and beans, dairy, protein food, seafood and plant proteins, and empty energy. Skipping one or more meals increased component scores for total vegetables (breakfast), whole grains (dinner), Na (lunch or dinner) and refined grains (breakfast, lunch or dinner).

Conclusions: Skipping meals (particularly dinner) reduces daily energy intake, but the reduction in daily diet quality (particularly when skipping breakfast) may impact health negatively over time.

Keywords
National Health and Nutrition Examination Survey
Dietary intake
Skipping meals
Diet quality
Healthy Eating Index-2010
Eating occasions
Eating patterns

Identifying strategies that can lead to reduced energy intake and weight gain, overweight and obesity among adults in the USA is a public health goal given the large medical and productivity costs of excessive body weight[1,2]. Meal skipping is one behaviour studied as a factor influencing weight outcomes and dietary quality, with most of the research focusing on skipping breakfast. Research on adults indicates that although those who regularly skip breakfast tend to have higher body weights than those who do not[3–6], there is little evidence that skipping breakfast contributes to this difference[5,7–9]. A few studies that have attempted to identify the effect of skipping breakfast among US adults using dietary intake data and within-person changes in meal patterns find that skipping breakfast increases energy content consumed at lunch but reduces total daily energy intake[10,11]. This finding has led some to suggest that skipping breakfast may be one way in which individuals can lose weight[12].

More generally, there is scant research into the effect of skipping lunch or dinner or how skipping meals impacts overall dietary quality. Although Mancino & Kinsey[13] found that the longer an individual went between meals, the more energy content they consumed at the next meal and the lower the quality of that meal, they did not focus on any meal in particular or the effect on overall daily energy intake and the nutritional quality of the day's consumption. The current study extends and adds to the literature by investigating the effect of skipping meals – breakfast, lunch and dinner – on energy intake at subsequent meals (for breakfast and lunch only), total daily dietary intake and overall daily diet quality among US adults using 2 d of dietary intake data from the

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2007–2016 National Health and Nutrition Examination Survey (NHANES).

Data and methods

National Health and Nutrition Examination Survey and the dietary intake component

The NHANES is a continuous survey of the noninstitutionalised US civilian population that collects a wide range of information related to health and nutrition[14–16]. Conducted by the National Center for Health Statistics within the Centers for Disease Control and Prevention, the NHANES is unique in that it combines interviews and physical examinations. Interviews collect data on demographic and socioeconomic characteristics, dietary intake and many other health-related topics, while the examination component consists of medical, dental and physiological measurements, as well as laboratory tests administered by highly trained medical personnel. The survey interviews about 5000 individuals each year, but data are released to the public for analysis in 2-year cycles. The current study combined the five most recent publically available rounds, covering 2007–2016.

Dietary intake was collected for two non-consecutive days (24-h periods, midnight to midnight prior to the interview) via recall in the What We Eat in America component of NHANES. The first day of intake was collected in person, at the time of a physical exam in the survey's Mobile Examination Center, while the second day was collected over the phone during a follow-up interview 3–10 d after the first recall. The intake data were collected using USDA's Automated Multiple-Pass Method, which employs five steps (or passes) designed to achieve complete and accurate food recall[17,18]. Despite this detailed process, the NHANES intake data have been found to suffer from under-reporting[17,19]. However, they are still considered the best data with which to estimate population level and subgroup dietary intake[20]. During the dietary interview, the participant stated what they ate (types and amount of foods), the time of day they started and what eating occasion the food was a part of (e.g. breakfast, snack). Complete nutritional information and food pattern equivalent values were appended to each food reported, which can be used to calculate total energy intake at each meal or the entire day and summary nutritional quality.

Study sample

We limited our sample to adults aged 18 years or older who reported 2 d of dietary intake (n 23 830). After excluding pregnant (n 194) and lactating (n 148) respondents, the final analytic sample included 23 488 respondents. Indicators for being male, married or living with a partner, being non-Hispanic White, non-Hispanic Black, being of Hispanic origin, having less than a high school education, having graduated from high school or obtained a high school equivalency certificate (General Education Development or GED), having completed some college or an Associate's degree and having completed four or more years of college were constructed for each individual. A variable measuring age in years was also included for analysis.

Identifying meals and measuring intake

An eating occasion was defined as any time when any food was consumed in which energy content were greater or equal than 209 kJ; occasions were not counted as eating occasions when only drinks (defined as such using the USDA eight-digit food code or four-digit food category assigned to the item[21]) were consumed since they do not satisfy hunger in the same way as food does. The eliminated meals (about 5 %) are mainly composed by coffee, tea, water, milk, juices and sodas.

Each eating occasion was classified as either a breakfast, lunch, dinner or snack according to the respondent's definition of the eating occasion. Specifically, 'breakfast' and 'desayuno' were considered *breakfast*; 'lunch', 'brunch', 'almuerzo' and 'comida' (if the individual was of Mexican descent) were considered *lunch*; 'dinner', 'supper', 'cena' and 'comida' (if the individual was not of Mexican descent) were considered *dinner* and 'snack', 'merienda', 'entre comida', 'botana', 'bocadillo' and 'tentempie' were considered *snacks*. Breakfast skippers were identified as those who did not consume breakfast on one or both days, lunch skippers were those who did not consume lunch on one or both days and dinner skippers were those who did not consume dinner on one or both days.

We created indicators for whether or not each person skipped each meal each day and counted the total number of snacks and meals consumed on both day 1 and day 2. The total energy content consumed per day was calculated as the sum of all energy content reported, and we also summed up the energy content at each meal and the total energy content from snacks for each individual on each day and the average over both days. In cases where an individual consumed more than one of the same meals (e.g. two or three breakfasts), we use the first reported occasion for that meal when summarising the energy content consumed at that meal. We also calculated total energy content per meal (food and beverages) and total energy content from food, excluding beverages, for both day 1 and day 2 and the average over both days. We followed Mancino *et al.*[22] and classified a meal as food-away-from-home (FAFH) if the majority of energy content in that meal, excluding beverages, came from fast-food or table-service restaurants, cafeterias or taverns. We calculated the ratio of FAFH meals as the sum of meals from FAFH divided by the total meals consumed in the day.

For a robustness check, we defined meals by the time of day, selecting the hours for each meal as those where

at least 5 % of individuals reported consuming that meal at that time[23]. Specifically, *breakfast* was consumption reported between 6.00 and 10.59; *lunch*, between 11.00 and 15.59 and *dinner*, between 16:00 and 21:59 Individuals were identified as skipping breakfast based on the time of day definition if they did not consume foods during breakfast time. Similarly, individuals were identified as skipping lunch if they did not consume any foods during lunchtime, and skipping dinner if they did not consume any foods during dinnertime.

For a second robustness check, we ran our model after excluding meals considered breakfast, lunch or dinner that had less than 837 kJ to test whether our 209 kJ threshold affected our estimates.

Assessing nutritional quality

To assess the nutritional quality, we used the 2010 Healthy Eating Index (HEI-2010) total score and the separate components. The HEI is a measure of diet quality that was developed by the USDA Center for Nutrition for Policy and Promotion to measure people's conformance with the *Dietary Guidelines for Americans*. The original HEI was created by Center for Nutrition for Policy and Promotion in 1995 and then updated to reflect the changes in the *Guidelines* in 2005, 2010 and 2015. The HEI-2010 is a scoring metric that comprises twelve components that sum to a maximum total score of 100[24,25]. It includes nine adequacy components (i.e. for food groups or nutrients that people should consume at least a certain amount of every day), with higher scores reflecting better diet quality: total fruit, whole fruit, total vegetables, greens and beans, whole grains, total dairy, total protein foods, seafood and plant proteins and fatty acids. The other three are moderation components (i.e. for nutrients that should be limited), with higher scores reflecting lower consumption and therefore better diet quality: refined grains, Na and empty energy (i.e. energy from solid fats, alcohol and added sugars). The HEI-2010 applies to the most years of our data, so if individuals were basing their decisions on the *Dietary Guidelines*, this version best captures their adherence to recommendations in our sample.

Statistical analyses

We summarised total energy content, total energy content from food, the proportion of individuals who skipped breakfast, lunch and dinner, the total energy content and energy content from food consumed at these meals for those who consumed the meals, and the total HEI-2010 and the component scores on day 1, day 2 and both days combined. Means of day 1 and day 2 were compared using *t* tests. We then compared demographic characteristics among those who ate breakfast on both days, those who skipped breakfast on one or both days, those who reported consuming all three meals on both days and those who skipped one or more meals on one or both days. Breakfast skippers were compared with non-skippers, and any meal skippers were compared with non-skippers using *t* tests.

To estimate the effect of skipping meals on subsequent meals, total daily intake and total daily HEI-2010 score, we used a first difference model, which is essentially a fixed-effects model with two observations for each individual. We calculated the difference between variables over the 2 d (day 2–day 1) which removes all individual characteristics that do not change between the 2 d (e.g. demographic variables and unobserved food and eating preferences). What remains are variables that vary between the 2 d and the model estimates how changes in day-to-day eating patterns affect the dependent variables. The constant term reflects differences in the means across the 2 d.

The model to estimate the effect of skipping breakfast on energy content consumed at lunch included an indicator for skipping breakfast (as defined by the respondent), the number of snacks consumed prior to lunch, whether lunch was prepared away from home (FAFH) and whether the intake day was a weekend. To estimate the effect of skipping lunch on energy content consumed dinner, we included indicators for skipping breakfast, skipping lunch and skipping both breakfast and lunch, the number of snacks consumed prior to dinner and whether dinner was from FAFH. The model to estimate the effect of skipping meals on measures of total daily intake (total energy content, total food energy content and total HEI-2010 score) included indicators for whether or not the individual skipped breakfast, lunch or dinner on the intake day, as well as separate indicators of whether they skipped multiple meals (breakfast and lunch, breakfast and dinner, lunch and dinner or all three meals), and the number of snacks consumed in the day, the ratio of meals prepared away from home and an indicator for whether the intake day was a weekend. This model also used the respondent-defined meals to identify skipped meals, but we also estimated this model using the alternatively defined meals using the time of day of eating occasions.

We also estimated the effect of skipping each meal (breakfast, lunch and dinner, as defined by the respondent) on the total HEI-2010 score and the 12 component scores with separate models that included only an indicator for whether the individual skipped that meal, the number of snacks consumed in the day, the ratio of FAFH meals and whether the intake day was on a weekend.

All analyses were conducted using the survey-related commands in the statistical software package Stata version 14.2 with the intake day 2 weights applied and SE adjusted to account for the complex survey design.

Results

Summary of intake

Mean energy intake on day 2 was lower than on day 1 (8521 *v.* 8951, $P < 0{\cdot}1$) with a similar pattern when only energy

Table 1 Summary of intake measures from National Health and Nutrition Examination Survey (NHANES), day 1 and day 2, adults aged 18 and older

	Day 1		Day 2		Both days	
	Mean	SE	Mean	SE	Mean	SE
Total energy content	**8950·51**	38·20	**8521·49**	49·84	8736·00	39·34
Energy content from food	**7317·75**	36·48	**7097·47**	44·10	7207·61	34·64
Breakfast						
% who ate	**73·32**	0·56	**78·14**	0·49	75·73	0·47
Total energy content	1841·80	13·15	1861·04	14·90	1851·70	10·07
Energy content from food	1501·23	12·66	1501·26	13·94	1501·24	9·51
Lunch						
% who ate	**79·95**	0·55	**82·57**	0·51	81·26	0·46
Total energy content	**2683·07**	22·19	**2627·30**	22·50	2654·73	18·34
Energy content from food	**2420·67**	20·28	**2372·93**	20·53	2396·41	16·55
Dinner						
% who ate	93·20	0·22	93·42	0·24	93·31	0·19
Total energy content	**3264·43**	20·91	**3141·32**	23·16	3202·80	16·56
Energy content from food	**2907·34**	19·75	**2801·39**	20·95	2854·30	14·54
HEI-2010 (max = 100)	**50·84**	0·28	**51·82**	0·23	51·33	0·24
Adequacy components (max)						
Total vegetables (5)	**3·01**	0·02	**3·06**	0·02	3·04	0·15
Greens and beans (5)	1·32	0·03	1·34	0·02	1·33	0·22
Total fruit (5)	**2·11**	0·03	**2·24**	0·03	2·17	0·25
Whole fruit (5)	**2·11**	0·03	**2·23**	0·03	2·17	0·03
Whole grains (10)	**2·56**	0·05	**2·79**	0·04	2·67	0·04
Total dairy (10)	5·16	0·05	5·19	0·05	5·17	0·04
Total protein foods (5)	**4·22**	0·01	**4·25**	0·01	4·23	0·01
Seafood and plant proteins (5)	2·07	0·03	2·03	0·03	2·05	0·03
Fatty acids (10)	5·02	0·04	4·99	0·04	5·01	0·04
Moderation components (max)						
Na (10)	**4·29**	0·03	**4·09**	0·04	4·19	0·03
Refined grains (10)	6·16	0·04	6·16	0·05	6·16	0·04
Empty energy (20)	**12·82**	0·10	**13·45**	0·09	13·13	0·09
Observations	23 488		23 488		46 976	

HEI, Healthy Eating Index.
In parenthesis, the maximum number of points each element contributes to the HEI-2010. In boldface, if the difference between the mean of day 1 and the mean of day 2 is statistically different from zero ($P < 0.1$). SE account for complex survey design. NHANES dietary intake day 2 weights (wtdr2d) were used to compute nationally representative estimates. Meal energy amounts exclude 0 values among those who do not eat the respective meal.
Source: Authors' calculations using data from the 2007–2016 NHANES and https://epi.grants.cancer.gov/hei/developing.html.

content from beverages is considered (Table 1). Of all three meals, mean energy intake at dinner was highest (3203 kJ), followed by lunch (2655 kJ) and then breakfast (1852 kJ). The energy intake at lunch and dinner was lower on day 2 than day 1 ($P < 0·1$); however, we did not find any statistical difference for breakfast. Similar patterns are observed when looking only at energy content from food, excluding drinks.

On average, 76 % of American adults consumed breakfast, 81 % consumed lunch and 93 % consumed dinner. More people skipped breakfast on day 1 than on day 2 (26·7 *v.* 21·9 %, $P < 0·1$), but those who skipped did not always skip on both days. Specifically, 14·3 % skipped breakfast only on day 1 and 9·5 % skipped breakfast only on day 2, while 12·4 % skip breakfast on both days (not shown). Mean HEI-2010 score was lower on day 1 (50·8) than on day 2 (51·8) with the total vegetables, total fruit, whole fruit, whole grains and empty energy component scores also lower on day 1 ($P < 0·1$). The score for the Na component was higher on day 1 ($P < 0·1$). Of all meals, 76·7 % are considered food-at-home (FAH), and 23·3 % are considered FAFH. More people consume FAH meals on day 2 than on day 1 (78·6 *v.* 74·9, $P < 0·1$). Among breakfast, 85·2 % are considered FAH, while 63·4 % of lunches and 70·0 % of dinners are from FAH (not shown).

Comparing meal skippers to non-skippers

Those who skipped breakfast on at least 1 d were different from those who did not. A larger share (51·5 %) of those who skipped breakfast were male compared with those who did not (47·7 %). Individuals who skipped breakfast were on average younger, single, Hispanic or non-Hispanic Black and had a lower education than those who did not skip breakfast ($P < 0·1$) (Table 2). We found similar demographic characteristics when looking at those who did not skip any main meals (i.e. breakfast, lunch and dinner) on both days *v.* those who skipped one or more main meals on one or more day.

Table 2 Means and SE of demographic characteristics by eating pattern over 2 d, adults aged 18 and older

	Not skip breakfast		Skip breakfast		Not skip any meal		Skip one or more meals	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Male	**47·52**	0·49	**50·57**	0·88	**47·43**	0·64	**49·51**	0·60
Age (years)	**49·53**	0·31	**41·62**	0·37	**49·84**	0·34	**44·29**	0·36
Married or living with partner	**65·66**	0·85	**57·46**	1·22	**68·72**	0·91	**58·16**	1·07
Hispanic	**13·57**	1·08	**15·55**	1·26	**11·10**	0·93	**16·66**	1·32
Non-Hispanic, White	**69·70**	1·53	**62·26**	1·85	**74·52**	1·36	**61·39**	1·85
Non-Hispanic, Black	**9·62**	0·72	**14·69**	1·19	**6·78**	0·51	**14·95**	1·14
Less than high school	**14·60**	0·73	**18·72**	0·95	**11·99**	0·74	**19·19**	0·86
High school graduate or GED	**20·43**	0·63	**25·10**	0·88	**19·09**	0·73	**24·40**	0·76
Some college or AA degree	**30·48**	0·78	**34·00**	0·87	**29·73**	0·93	**33·27**	0·72
College graduate or above	**34·49**	1·16	**22·18**	1·08	**39·19**	1·30	**23·14**	1·04
Observations	14 943		8545		9249		14 239	

GED, General Education Development. All meals are defined as breakfast, lunch and dinner. In boldface, if the difference between the mean of those who skip the meal and the mean of those who do not skip the meal is statistically different from zero ($P < 0.1$). SE account for complex survey design. National Health and Nutrition Examination Survey (NHANES) dietary intake day 2 weights (wtdr2d) were used to compute nationally representative estimates. Due to some missing responses, the total number of observations for married is 22 306 and for level of education is 22 295.
Source: Authors' calculations using data from the 2007–2016 NHANES and https://epi.grants.cancer.gov/hei/developing.html.

Table 3 Coefficients and SE from first difference regressions of energy content at lunch and energy content at dinner on meal skipping indicators and other intake characteristics

	(1)		(2)	
	Energy content at lunch		Energy content at dinner	
	Coefficient	SE	Coefficient	SE
Skip breakfast	193·18***	56·68	113·89*	58·32
Skip lunch			369·48***	51·98
Skip breakfast and lunch			299·25**	123·08
Number of snacks until meal	−72·86*	37·18	−83·51***	21·68
Meal from FAFH	711·13***	40·73	632·39***	43·24
Weekend	153·99***	34·46	4·26	29·42
Constant	8·72	24·55	−53·85*	29·75
Observations	15 664		19 906	
R^2	0·06		0·04	
Calculated full effect				
Skipping breakfast and lunch			782·62***	110·16

FAFH, food-away-from-home.
SE account for complex sampling design. National Health and Nutrition Examination Survey (NHANES) dietary intake day 2 weights (wtdr2d) were used to compute nationally representative estimates. Result (1) is robust when only considering those who eat breakfast 1 d and skip it the other day.
Source: Authors' calculations using data from the 2007–2016 NHANES.
***$P < 0.01$, **$P < 0.05$, *$P < 0.1$.

Effects of skipping meals

We found that adults consumed 193 more kJ at lunch when they skipped breakfast ($P < 0·01$). Adults consumed 114 more kJ at dinner when they only skipped breakfast ($P < 0·1$), 369 more kJ at dinner when they only skipped lunch ($P < 0·01$) and 783 more kJ at dinner when they skipped both breakfast and lunch ($P < 0·01$) (Table 3). We also found that adults consumed more energy content at the meal when the meal was prepared outside the home (711 more kJ at lunch and 632 more kJ at dinner, $P < 0·01$).

The net effect of skipping meals on total daily energy content was negative, ranging from 1053 kJ from skipping breakfast ($P < 0·01$) to 1464 kJ from skipping dinner ($P < 0·01$) (Table 4). Skipping multiple meals reduced daily energy intake by more than the sum of the effect of each meal. When two meals were skipped, intake fell between 2554 kJ ($P < 0·01$) (when breakfast and lunch were skipped) and 3171 kJ ($P < 0·01$) (when lunch and dinner were skipped). When all three meals were skipped, intake fell by 3901 kJ ($P < 0·01$). Average daily energy intake on the weekend was greater, by 494 kJ ($P < 0·01$), while the mean reported energy intake on day 2 was lower, by 359 kJ ($P < 0·01$). Each snack added 832 kJ to the day's intake ($P < 0·01$) and the more meals that were consumed from FAFH the more energy content were consumed in the day ($P < 0·01$).

Table 4 Coefficients and SE from first difference regressions of daily energy content from food, total daily energy content and daily HEI-2010 score on meal skipping indicators and other intake characteristics

	(1)		(2)		(3)	
	Daily energy content (food only)		Total daily energy content (food and drinks)		Daily HEI-2010	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Skip breakfast	−1014·24***	80·34	−1053·26***	101·46	−2·24***	0·39
Skip lunch	−1144·43***	81·61	−1201·25***	86·14	−2·26***	0·37
Skip dinner	−1432·10***	109·35	−1464·15***	125·11	−1·36**	0·53
Skip breakfast and lunch	−326·59*	165·54	−299·19*	171·98	1·19*	0·67
Skip breakfast and dinner	−470·89**	208·12	−501·32*	276·32	0·65	0·95
Skip lunch and dinner	−329·16	323·57	−505·31*	286·57	−1·60	1·61
Skip breakfast, lunch and dinner	960·09	823·73	1,123·47	877·86	−0·47	2·52
Number of snacks in the day	790·22***	29·12	831·95***	30·54	1·07***	0·13
Ratio of FAFH meals	12·91***	1·01	15·69***	1·35	−0·06***	0·01
Weekend	344·26***	48·66	494·24***	55·26	−1·90***	0·22
Constant	−161·82***	42·74	−358·92***	43·52	0·72***	0·19
Observations	23 488		23 488		23 488	
R^2	0·12		0·11		0·04	
Calculated full effect						
Skipping breakfast and lunch	−2485·26***	129·59	−2553·70***	140·67	−3·31***	0·70
Skipping breakfast and dinner	−2917·24***	205·30	−3018·73***	257·01	−2·96***	0·91
Skipping lunch and dinner	−2905·69***	318·49	−3170·71***	275·21	−5·22***	1·49
Skipping breakfast, lunch and dinner	−3757·33***	623·73	−3901·01***	679·45	−6·10***	2·21

HEI, Healthy Eating Index; FAFH, food-away-from-home.

The ratio of FAFH meals $= \frac{\sum \text{FAFH meals}}{\sum \text{all meals}} \times 100$.

SE account for complex survey design. National Health and Nutrition Examination Survey (NHANES) dietary intake day 2 weights (wtdr2d) were used to compute nationally representative estimates. Results are robust when eliminating those who skip dinner.

Source: Authors' calculations using data from the 2007–2016 NHANES.

***$P < 0·01$, **$P < 0·05$, *$P < 0·1$.

Table 5 Summary of results of effect of skipping breakfast, lunch and dinner on total HEI-2010 and the 12 component scores, first difference regression

	(1)		(2)		(3)	
	Skip breakfast		Skip lunch		Skip dinner	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Daily HEI-2010 score	−1·73***	0·35	−1·72***	0·39	−1·10**	0·46
Adequacy components, scores						
Total vegetables	0·10**	0·05	−0·17***	0·04	−0·44***	0·07
Greens and beans	−0·03	0·06	−0·07	0·05	−0·20***	0·07
Total fruit	−0·29***	0·04	−0·14**	0·06	0·06	0·06
Whole fruit	−0·31***	0·05	−0·24***	0·05	−0·05	0·07
Whole grains	−0·83***	0·08	−0·23***	0·08	0·21*	0·11
Total dairy	−0·33***	0·10	−0·33***	0·10	−0·22*	0·12
Total protein foods	0·00	0·04	−0·23***	0·04	−0·31***	0·06
Seafood and plant proteins	0·00	0·06	−0·30***	0·06	−0·21***	0·08
Fatty acids	0·07	0·09	0·07	0·10	0·11	0·14
Moderation components, scores						
Na	0·00	0·09	0·56***	0·09	0·61***	0·14
Refined grains	0·37***	0·10	0·20**	0·10	0·23*	0·13
Empty energy	−0·48***	0·14	−0·82***	0·17	−0·89***	0·21

HEI, Healthy Eating Index.

SE account for complex survey design. National Health and Nutrition Examination Survey (NHANES) dietary intake day 2 weights (wtdr2d) were used to compute nationally representative estimates. Addional controls include number of snacks in the day, the ratio of FAFH meals and whether the intake day was a weekend. Observations: 23 488.

Source: Authors' estimations using data from the 2007–2016 NHANES.

***$P < 0·01$, **$P < 0·05$, *$P < 0·1$.

Skipping meals was found to decrease diet quality as measured by the daily HEI-2010, by about 2·25 points for skipping breakfast or lunch ($P < 0·01$) (about 4·3 % relative to the mean) and 1·36 points for skipping dinner ($P < 0·05$) (2·6 % relative to the mean). Skipping multiple meals did not always increase the effect on the HEI-2010 score, like

Table 6 Coefficients and SE from first difference regressions of daily energy content from food, total daily energy content and daily HEI-2010 score on meal skipping indicators and other intake characteristics, meals defined using time of day

	(1) Daily energy content (food only)		(2) Total daily energy content (food and drinks)		(3) Daily HEI-2010	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Skip breakfast	−695·89***	81·92	−684·67***	99·70	−1·63***	0·34
Skip lunch	−820·30***	106·32	−871·60***	122·04	−1·22***	0·41
Skip dinner	−772·73***	171·00	−631·86***	198·48	−2·44***	0·78
Skip breakfast and lunch	−590·62***	214·49	−668·07***	238·29	0·26	0·73
Skip breakfast and dinner	−555·26**	245·88	−903·61***	246·48	1·02	1·01
Skip lunch and dinner	−734·94	943·86	−1089·26	870·10	−4·22	2·75
Skip breakfast, lunch and dinner	1243·72	989·58	1924·99**	934·42	1·20	3·57
Number of snacks in the day	628·43***	30·86	663·21***	31·71	0·82***	0·13
Ratio of FAFH meals	11·92***	1·04	14·69***	1·36	−0·06***	0·01
Weekend	264·81***	46·48	410·14***	53·60	−2·04***	0·22
Constant	−147·63***	42·39	−343·12***	43·25	0·75***	0·18
Observations	23 488		23 488		23 488	
R^2	0·09		0·09		0·04	
Calculated full effect						
Skipping breakfast and lunch	−2106·82***	178·05	−2224·35***	185·56	−2·59***	0·69
Skipping breakfast and dinner	−2023·88***	241·66	−2220·14***	251·01	−3·04***	0·76
Skipping lunch and dinner	−2327·98***	858·81	−2592·72***	744·83	−7·88***	2·70
Skipping breakfast, lunch and dinner	−2926·03***	451·04	−2924·08***	475·19	−7·01***	2·36

HEI, Healthy Eating Index; FAFH, food-away-from-home.

The ratio of FAFH meals $= \frac{\sum \text{FAFH meals}}{\sum \text{all meals}} \times 100$.

SE account for complex survey design. National Health and Nutrition Examination Survey (NHANES) dietary intake day 2 weights (wtdr2d) were used to compute nationally representative estimates.

Source: Authors' calculations using data from the 2007–2016 NHANES.

***$P < 0·01$, **$P < 0·05$, *$P < 0·1$.

in the case of skipping lunch and dinner, which further lowered the HEI-2010 score by 1·60 points in addition to the separate effects of skipping lunch and dinner.

Skipping breakfast, lunch and dinner affected diet quality differently. Skipping breakfast decreased the component scores for total fruit, whole fruit, whole grains, total dairy and empty energy ($P < 0·01$) and increased the scores for total vegetables ($P < 0·05$) and refined grains ($P < 0·01$) (Table 5). Skipping lunch also lowered the component scores for total fruit ($P < 0·05$), whole fruit, whole grains, total dairy and empty energy ($P < 0·01$) and also lowered the total vegetable and seafood and plant protein component scores ($P < 0·01$), while increasing the scores for Na ($P < 0·01$) and refined grains ($P < 0·05$). Skipping dinner decreased the component scores for total vegetables, greens and beans ($P < 0·01$), total dairy ($P < 0·1$), total protein foods, seafood and plant proteins, and empty energy ($P < 0·01$) and increased the scores for whole grains ($P < 0·1$), Na ($P < 0·01$) and refined grains ($P < 0·1$).

When we estimated the effect of skipping meals using the time of day to define meals, we found that the effects are similar to when meals are defined by the respondents, but the point estimates are smaller (Table 6). Our results were also robust to excluding meals with less than 837 kJ (about 22·3 % of all reported meals); we find larger effects in total energy intake but smaller effects on daily HEI (Table 7).

Discussion

In the current study, we use the dietary intake data from five rounds of NHANES to examine whether meal skipping impacted consumption at subsequent meals, total daily energy intake and daily dietary quality. Most previous studies looking at the effects of skipping breakfast compared individuals who skip breakfast to individuals who do not[9]. However, this approach has the potential to yield biased estimates because choosing to skip breakfast is not exogenous and is likely correlated with socioeconomic characteristics and other health-related behaviours that also influence dietary intake. For example, it is possible that breakfast eaters engage in other healthy behaviours, such as reduced snacking, lower total fat intake and the consumption of a healthy diet, all of which will lead to a higher nutritional quality[11]. We relied on variation in eating patterns across two non-sequential days of reported dietary intake to identify the effect of meal skipping and used a first difference model which controlled for all observed and unobserved individual characteristics. In addition to controlling for whether or not each meal is consumed on each of the days, we also accounted for changes in snacking and how many meals were obtained from FAFH on each day. In sum, the variation among the nearly 32 % of individuals who skipped at least one meal on one, but not both, days

Table 7 Coefficients and SE from first difference regressions of daily energy content from food, total daily energy content and daily HEI-2010 score on meal skipping indicators and other intake characteristics, using a 837 kJ threshold

	(1)		(2)		(3)	
	Daily energy content (food only)		Total daily energy content (food and drinks)		Daily HEI-2010	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Skip breakfast	−1286·43***	62·29	−1305·97***	68·45	−0·01	0·30
Skip lunch	−1478·11***	71·84	−1520·29***	85·24	−0·79**	0·39
Skip dinner	−1741·16***	98·59	−1721·41***	117·88	−0·42	0·59
Skip breakfast and lunch	−160·08	103·64	−146·43	115·23	−0·02	0·47
Skip breakfast and dinner	−229·35*	129·44	−305·89*	165·07	−0·55	0·78
Skip lunch and dinner	−345·79*	189·38	−675·96***	207·78	−1·18	1·16
Skip breakfast, lunch and dinner	473·68*	276·78	701·93**	318·99	0·08	1·66
Number of snacks in the day	1365·66***	40·33	1432·11***	42·14	0·38**	0·18
Ratio of FAFH meals	10·05***	0·92	12·69***	1·22	−0·07***	0·01
Weekend	242·07***	40·01	385·35***	49·43	−2·10***	0·23
Constant	−180·17***	36·30	−377·17***	36·64	0·73***	0·18
Observations	23 488		23 488		23 488	
R^2	0·24		0·17		0·03	
Calculated full effect						
Skipping breakfast and lunch	−2924·62***	86·49	−2972·68***	99·54	−0·82	0·53
Skipping breakfast and dinner	−3256·94***	114·73	−3333·26***	140·90	−0·98	0·63
Skipping lunch and dinner	−3565·05***	178·57	−3917·66***	185·63	−2·38**	0·93
Skipping breakfast, lunch and dinner	−4767·23***	169·04	−4974·02***	189·03	−2·88***	1·04

HEI, Healthy Eating Index; FAFH, food-away-from-home.

The ratio of FAFH meals $= \frac{\sum \text{FAFH meals}}{\sum \text{all meals}} \times 100$.

SE account for complex survey design. National Health and Nutrition Examination Survey (NHANES) dietary intake day 2 weights (wtdr2d) were used to compute nationally representative estimates.

Source: Authors' calculations using data from the 2007–2016 NHANES.

***$P < 0·01$, **$P < 0·05$, *$P < 0·1$.

of intake provides means to identify the effect of skipping a meal on daily intake.

We found that skipping a meal leads to greater energy intake at subsequent meals: skipping breakfast led individuals to eat more energy content at lunch, and skipping lunch led individuals to consume more energy content at dinner. However, we find that individuals who skipped a meal did not fully compensate later in the day as we found that the net effect on total daily energy intake was negative. Interestingly though, skipping a meal had a negative effect on diet quality. This may be due to the fact that certain healthful foods are more likely to be consumed at certain meals (such as dairy and whole grains at breakfast, and vegetables and protein at dinner) or that greater hunger causes people to choose different foods at meals following a skipped meal[13]. Thus, while skipping meals may reduce energy intake and could help reduce weight over time, the quality of the food consumed declines, which may impact health negatively over time. These findings are consistent with Mancino & Kinsey[13], where longer intervals between meals contribute to one's consuming more energy content and with lower diet quality.

We found that of all three meals, skipping dinner had a larger impact on daily energy intake and smaller effect on HEI. Thus, if individuals are skipping meals as a strategy to reduce total daily energy intake to lose weight, skipping dinner may have the least impact on diet quality.

Previous research has documented that mean reported energy intake is higher on day 1 as compared with day 2 in the NHANES data[22], and our results were consistent. Research has shown that the nutritional quality of FAH is higher than that of FAFH meals and that individuals consume more when eating FAFH than when they eat FAH[22]. Our findings with respect to FAFH were consistent with these findings.

Although our findings are consistent with the scientific literature on the effects of skipping breakfast, to our knowledge, this is the first paper that estimates the effects of skipping meals on energy intake and quality of intake using multiple days of intake in order to account for unobserved individual characteristics that are likely correlated with energy intake and diet quality and the likelihood of skipping meals.

A potential limitation of this work is that we only use 2 d of dietary intake. Thus, it is possible that we are capturing eating patterns that are not common (e.g. eating patterns during holidays). Moreover, we are not able to determine whether there is compensation for meal skipping on subsequent days when dietary intake data were not collected or whether overeating earlier contributed to subsequent meal skipping. Although we used a fixed-effects estimation to tease out unobservable individual- and household-level effects of meal skipping on energy intake and nutritional quality, some varying, unobservable disturbances may still be correlated with the explanatory variables. For example, an individual could have skipped breakfast 1 d because

they had a feast the previous night. Similarly, we cannot determine whether those who skip a meal did it on purpose (intermittently fast) or due to other reasons (such as shift workers) which means we are not able to estimate whether the effects of intentional meal skipping differ from the effects of meal skipping for other reasons. Our results therefore estimate the effect of meal skipping regardless of why the meal was skipped. It is important to note that because the first part of our analysis classifies each eating occasion as either a breakfast, lunch, dinner or snack according to the respondent's definition of the eating occasion (regardless of the time of day), we do capture meal skipping among shift workers or other individuals who eat meals on an unusual schedule. Given that the results from our robustness check, where we defined meals by the time of day, are similar, suggesting that the different meal schedules of shift workers do not influence our results.

Measurement error may also have affected our estimates, but we did explore their robustness using two ways to define meals. Our results were consistent using both definitions of meals, the respondent-named occasions and meals defined by eating time. Following Murakami & Livingstone[26], we did not consider an eating occasion to be a meal or a snack if it provides less than 209 kJ of energy to avoid giving undue weight to eating occasions that included small quantities of foods. These eating occasions were still included when calculating total daily energy and daily HEI-2010 score, and results may vary if these occasions were treated differently. The 209 kJ threshold eliminated a small share of all eating occasions that were reported to be breakfast, lunch or dinner (about 2 %). Thus, the 209 kJ threshold eliminated eating occasions that are unlikely to reduce hunger and contribute very little to total daily intake. At the same time, this threshold was less likely to exclude small, but reasonable and healthful meals. We also conducted a robustness check for this threshold by running our model when excluding meals considered breakfast, lunch or dinner that have at least 837 kJ. This higher threshold excluded a much larger share of all reported meals (22·3 %), but our results did not vary qualitatively and quantitatively, changed only slightly.

Finally, snacking behaviour is interesting but it is out of the scope of this paper. We focused on the main three meals (breakfast, lunch and dinner) as they are recommended across dietary guidelines. The recommendations for whether to snack, and if so, how often per day varies. However, we control for snack consumption (the number of snacks consumed in the day) in all the analysis as they affect hunger in subsequent meals.

Conclusions

If skipping meals produces a deficit in daily energy intake, then the health benefits derived from consuming a lower daily energy intake may be substantially greater than consuming three meals per day. However, energy intake is only one component of healthy dietary habits and we find that meal skipping lowered daily diet quality. The fact that breakfast, lunch and dinner generally include food components that are part of a healthy diet that are less commonly consumed in snacks should be considered when evaluating the benefits of skipping meals for weight loss or health reasons.

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