International Journal of Obesity (1997) 21, 407–412
 0307-0565/97 $12.00

Evening eating and subsequent long-term weight change in a national cohort

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OBJECTIVE: To examine the association of proportion of daily energy consumed in the evening with weight change over 10 y of follow-up.
DESIGN: The data used were from the First National Health and Nutrition Examination Survey (NHANES I, 1971–75) Epidemiologic Follow-up Study (NHEFS, 1982–84). The analytic cohort included 2580 men and 4567 women aged 25–74 y at baseline (NHANES I, 1971–75). The proportion of energy consumed in the evening (after 5 pm) was estimated from a 24 h dietary recall obtained at baseline. Weight change was defined as the difference between the follow-up and baseline weights.
RESULTS: Mean ± s.e. of percent energy from evening food intake was 46 ± 0.29 in the analytic cohort. After adjustment for multiple covariates, percent energy from evening food intake and weight change were unrelated in both men and women.
CONCLUSION: Extent of evening eating was not a significant predictor of 10 y weight change in the NHEFS cohort.

Keywords: meal patterns; evening eating; weight change; TEF; NHANES I; NHEFS; obesity; energy intake; energy expenditure

Introduction

Does eating at night lead to weight gain? Evidence exploring this hypothesis in the scientific literature is limited. Halberg[1], in his review on chronobiology of nutrition, reported that subjects consuming a fixed amount of energy for breakfast versus dinner showed differences in the amount of weight change. These data suggest that efficiency of energy utilization shows circadian variability. Findings of Romon *et al*[2] support this notion. Thermic effect of food (TEF) of isocaloric meals differed according to time of day, with TEF due to morning meal being significantly higher than TEF attributed to afternoon or night meals[2]. These observations suggest that dietary patterns where energy intake in the evening or night is higher, may increase the risk of energy storage (weight gain) by decreasing daily energy expenditure. Another popular hypothesis is that large evening meals promote energy storage due to the customary practice of sedentary activities following such meals.

We recently reported the association of self-reported body weight with extent of evening eating in 1802 women[3]. In this cross-sectional study, body mass index and proportion of daily energy consumed in the evening were not related. We undertook the present study to enable a prospective examination of the relation of extent of evening eating with subsequent weight change over ten years of follow-up in a large cohort of men and women.

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Received 7 March 1996; Revised 25 September 1996 and 29 January 1997; accepted 3 February 1997

Methods

The first National Health and Nutrition Examination Survey (NHANES 1) was conducted from 1971–75 by the National Center on Health Statistics (NCHS)[4]. The NHANES I Epidemiologic Follow-up Study (NHEFS) was initiated in 1982 by NCHS and other Public Health Service agencies, including the National Institutes of Health[5]. The aim of NHEFS is to relate mortality and morbidity at follow-up to nutritional, health, and other information collected in NHANES I[5]. Respondents who were 25–74 y of age at the time of initial survey ($n = 14\,407$) were considered eligible for follow-up[5]. The augmentation phase of NHANES I included 3059 adults, for whom 24 h dietary recall was not obtained. We excluded these respondents from the eligible cohort.

Analytic cohort

From the entire NHEFS cohort exclusions were made for: 24 h recalls judged by the interviewer to be unsatisfactory due to physical or mental limitations, negative attitude, and incomplete interviews (205);

atypical intake due to illness on the day of recall (272); recalls obtained from proxies (334), transcription errors in 24 h recalls (45); and recalls of pregnant and lactating women at baseline (125). Some respondents were in more than one exclusion category. These exclusions based on validity of baseline 24 h recall data yielded a cohort of 10 424 individuals. From this initial cohort, exclusions were made for lack of follow-up weight due to known or suspected death, or unknown status ($n = 3257$); unreliable reported weight ($n = 5$); and pregnant at follow-up ($n = 15$). The final analytic cohort thus included 2580 men and 4567 women ($n = 7147$).

A single 24 h dietary recall was administered to each respondent at baseline by a trained dietary interviewer using three-dimensional food models to enable estimation of amount of food consumed[4]. Estimates of nutrient intake were obtained using US Department of Agriculture food composition data for the amounts of food reported consumed in each recall[6]. Information on age, income, education, smoking status, level of physical activity, and health status was obtained at baseline[4].

At baseline in 1971–75, body weight and height were measured using standardized procedures in disposable uniforms and footwear in examination trailers[4]. At follow-up in 1982–84, weight was measured in indoor clothing, without shoes, using a portable scale in subject's home[5], but height was not measured. Because sex, age, body size, and season-adjusted estimated weights of indoor clothing are not available for this cohort, we did not adjust the follow-up weight for weight of indoor clothing. Further, our purpose was to examine the association of evening eating with weight change from baseline and not the extent of absolute weight change over the period of follow-up. Such analyses would be unchanged by subtraction of a constant estimated weight of indoor clothing from the follow-up weight.

Extent of evening eating at baseline

As part of the baseline 24 h dietary recall, subjects were asked to give time of day for each eating occasion. Eating occasions reported before or until 10:59 am were classified as occurring in the morning period; eating occasions reported from 11:00 am–4:59 pm were in the afternoon period; eating occasions from 5:00 pm–7:59 pm were in the evening period; and those reported at or after 8:00 pm were in the night period.

Statistical methods

Weight change was defined as the difference between weight measured at follow-up and baseline. Proportion of daily energy intake from each of the defined time periods (morning, afternoon, evening, and night) was calculated for each respondent. Descriptive statistics for baseline nutrient intake, baseline body mass index (BMI), and weight change were obtained by percent energy from evening and night food intake.

The association of percent energy from evening and night combined (all foods consumed after 5 pm), and night (after 8 pm) food intake at baseline and weight change was examined using sex-specific regression analyses. All regression analyses were run with and without adjustment for variables known to affect body weight. The potential confounders included race (white, non-white), education (<12 y, 12 y, >12 y), smoking status (never, former and current smoker), age at baseline (continuous), length of follow-up (continuous), level of self-reported recreational physical activity at baseline and at follow-up (a lot, moderate, and little), energy intake (continuous), baseline BMI (continuous), alcohol intake (none, low and high), special diet status (yes and no), and parity (0, ≥ 1) (women only). Additionally, because changes in body weight may be affected by the presence of certain medical conditions, a trend variable based on physician-confirmed diagnosis of heart condition, diabetes, hypertension, or thyroid disease, and hospitalization since 1970 for cirrhosis, colitis, chronic bronchitis or cancer was created, using the criteria of Williamson *et al*[7]. The morbidity variable ranged from 0–3, where 0 = no, 1 = 1 positive response, 2 = 2 positive responses, and 3 = 3 or more positive responses.

Statistical software suitable for analyses of complex survey data were used to estimate standard errors for means (SESUDAAN)[8] and linear regression coefficients (SURREGR)[9].

Results

The mean age of men and women in the analytic cohort was 44.6 ± 0.3 and 45.9 ± 0.3 y, respectively, at baseline. The mean follow-up time was 10.6 ± 0.1 y. Men reported consuming $33 \pm 0.5\%$ of total daily energy in the evening period with an additional $13 \pm 0.4\%$ in the night period for a total of approximately 46% reported after 5 pm (Table 1). Comparable levels were reported by women. Men and women in the third tertile of percent energy consumed after 5 pm reported an average of 63% and 65% of total energy from foods consumed after 5 pm, respectively (Table 1).

Energy and macronutrient intake in relation with the extent of after 5 pm eating

With increasing percent of energy consumed after 5 pm, mean dietary energy and alcohol intake increased ($P \leq 0.05$), and mean percent energy from carbohydrate declined (Table 2). No association of

Table 1 Mean ±s.e. of percent of daily energy consumed at various times of the day by tertiles of proportion of energy consumed after 5 pm by men and women at baseline in 1971–74

	Tertiles of % energy consumed after 5 pm			
	All	*First*	*Second*	*Third*
MEN				
n	2580	860	860	860
Percent energy from:				
Morning[a]	21 ± 0.3	28 ± 0.7	22 ± 0.4	13 ± 0.4
Afternoon[b]	33 ± 0.3	47 ± 0.7	33 ± 0.4	23 ± 0.4
Evening[c]	33 ± 0.5	17 ± 0.5	32 ± 0.5	46 ± 0.9
Night[d]	13 ± 0.4	8 ± 0.4	13 ± 0.5	17 ± 0.9
WOMEN				
n	4567	1522	1523	1522
Percent energy from:				
Morning[a]	20 ± 0.3	26 ± 0.5	21 ± 0.4	14 ± 0.3
Afternoon[b]	34 ± 0.3	50 ± 0.6	34 ± 0.4	21 ± 0.4
Evening[c]	34 ± 0.4	17 ± 0.4	35 ± 0.4	49 ± 0.7
Night[d]	11 ± 0.3	7 ± 0.3	10 ± 0.4	16 ± 0.7

Tertiles of percent energy consumed after 5 pm in men: T1 = < 37.8; T2 = 37.8–52.0; T3 = > 52.0. In women T1 = < 37.0; T2 = 37.0–52.8; T3 = > 52.8.
[a]Morning = Foods reported consumed before 11.00 am.
[b]Afternoon = Foods reported consumed from 11:00 am to 4:59 pm.
[c]Evening = Foods reported consumed from 5:00 pm to 7:59 pm.
[d]Night = Foods reported consumed from 8:00 pm to last reported time.

Table 2 Mean ± s.e. of energy and macronutrients by tertiles of proportion of energy consumed after 5 pm by men and women at baseline in 1971–74

	Tertiles of % energy consumed after 5 pm			
	All	*First*	*Second*	*Third*
MEN				
Energy[a] (kcals)	2452 ± 28	2348 ± 53	2482 ± 38	2508 ± 40
Percent energy from:				
Fat	37 ± 0.2	37 ± 0.4	36 ± 0.4	37 ± 0.5
Carbohydrate[a]	42 ± 0.3	43 ± 0.5	43 ± 0.5	40 ± 0.5
Protein	16 ± 0.1	16 ± 0.3	17 ± 0.3	17 ± 0.1
Alcohol[a] (g)	13 ± 0.8	10 ± 1.1	12 ± 1.1	16 ± 1.1
WOMEN				
Energy[a] (kcals)	1543 ± 16	1501 ± 26	1536 ± 20	1584 ± 26
Percent energy from:				
Fat	36 ± 0.2	36 ± 0.3	36 ± 0.3	37 ± 0.4
Carbohydrate[a]	45 ± 0.3	46 ± 0.4	45 ± 0.5	42 ± 0.5
Protein[a]	17 ± 0.2	16 ± 0.2	17 ± 0.2	17 ± 0.3
Alcohol[a] (g)	4 ± 0.3	3 ± 0.3	4 ± 0.2	5 ± 0.6

Tertiles of percent energy consumed after 5 pm in men: T1 = < 37.8; T2 = 37.8–52.0; T3 = > 52.0. In women: T1 = < 37.0; T2 = 37.0–52.8; T3 = > 52.8.
[a]The association with percent energy intake after 5 pm was significant ($P \leq 0.05$). The regression model for energy intake as dependent variable included percent energy intake after 5 pm and age as independent variables. All other models included percent energy intake after 5 pm, age, and total energy intake as independent variables.

percent energy from fat was noted with increasing level of food consumed after 5 pm.

Association of the extent of after 5 pm eating with other factors related to weight change

The mean weight change was 2.1 ± 0.2 and 2.5 ± 0.2 kg in men and women, respectively (Table 3). Percent energy consumed after 5 pm decreased with advancing age (Table 3), but increased with the level of education (Table 4). Whites reported a higher level of after 5 pm eating that did non-whites. Current smokers had higher level of after 5 pm eating relative to never-smokers. Women with a high level of baseline BMI (> 27.2) reported a lower percent energy after 5pm relative to those with BMI of ≤ 27.2. Men with no or low morbidity had higher food intake after 5 pm relative to those with greater morbidity. Percent energy consumed after 5 pm varied little by the level of self-reported recreational physical activity at baseline or follow-up in both men and women.

Association of extent of evening eating with weight change

Table 5 presents the regression coefficient ± s.e. associated with percent energy consumed after 5 pm from unadjusted, age-adjusted and multiple-covariate-adjusted regression models. In men, percent energy from evening food intake and weight change were not related in unadjusted, age-adjusted or multiple-co-

Table 3 Mean ± s.e. of weight change and baseline BMI by tertiles of proportion of energy consumed after 5 pm in men and women

	Tertiles of % energy consumed after 5 pm			
	All	*First*	*Second*	*Third*
MEN				
Weight change[a] (kg)	2.1 ± 0.2	2.2 ± 0.3	1.8 ± 0.3	2.3 ± 0.3
BMI[b] at baseline	25.9 ± 0.1	25.9 ± 0.2	25.8 ± 0.2	26.0 ± 0.2
Age at baseline (y)	44.6 ± 0.3	46.8 ± 0.5	45.3 ± 0.6	42.1 ± 0.4
Years of follow-up	10.6 ± 0.1	10.6 ± 0.1	10.6 ± 0.1	10.6 ± 0.1
TSF[c] (mm)	12.4 ± 0.2	12.3 ± 0.2	12.2 ± 0.3	12.6 ± 0.3
SSF[d] (mm)	16.8 ± 0.3	16.9 ± 0.3	16.6 ± 0.4	17.0 ± 0.4
WOMEN				
Weight change[a] (kg)	2.5 ± 0.2	1.9 ± 0.3	2.3 ± 0.2	3.1 ± 0.2
BMI[b] at baseline	25.2 ± 0.1	25.8 ± 0.2	25.1 ± 0.2	24.8 ± 0.2
Age at baseline (y)	45.9 ± 0.3	48.0 ± 0.4	45.9 ± 0.4	44.2 ± 0.5
Years of follow-up	10.6 ± 0.1	10.6 ± 0.1	10.6 ± 0.1	10.6 ± 0.1
TSF[c] (mm)	23.9 ± 0.2	24.5 ± 0.3	23.9 ± 0.3	23.3 ± 0.3
SSF[d] (mm)	19.3 ± 0.2	20.3 ± 0.4	19.3 ± 0.4	18.6 ± 0.3

Tertiles of percent energy consumed after 5 pm in men: T1 = < 37.8; T2 = 37.8–52.0; T3 = > 52.0. In women: T1 = < 37.0; T2 = 37.0–52.8; T3 = > 52.8.
[a]Weight change = Weight measured at followup minus weight at baseline.
[b]BMI = Body mass index (kg/m^2). Baseline BMI and percent energy from evening food intake were not related. The regression model included baseline BMI as a dependent variable and percent energy from evening food intake, smoking status, energy intake, race, alcohol intake, and level of recreational physical activity at baseline as independent variables.
[c]TSF = Triceps skinfold measured at baseline.
[d]SSF = Subscapular skinfold measured at baseline.

Table 4 Correlation (Pearson's *r*) of covariates with percent energy consumed after 5 pm, and with weight change in men and women

	Men (n = 2580)		*Women (n = 4567)*	
	% energy after 5 pm	*Wt change*	*% energy after 5 pm*	*Wt change*
Age (y)	−0.15	−0.25	−0.12	−0.29
Education (y)	0.17	−0.00*	0.11	0.08
Baseline BMI	−0.00*	−0.25	−0.08	−0.24
Alcohol intake	0.07	−0.02*	0.10	−0.02*
Length of follow-up	−0.01*	−0.04	0.00*	−0.03*
Morbidity	−0.08	−0.11	−0.05	−0.12
Level of physical activity	0.03*	−0.10	−0.02*	−0.08

All correlations except those marked with an asterisk (*) were significant ($P \leq 0.05$).

Table 5 Regression coefficient (Beta ± s.e.) associated with percent energy consumed after 5 pm in men and women[a]

	Beta	*s.e.*	*F*	*P*
MEN				
Unadjusted	0.00969	0.00877	1.21	0.27
Age-adjusted	− 0.00574	0.00911	0.40	0.53
Multiple-covariate-adjusted	− 0.00121	0.00860	0.02	0.88
WOMEN				
Unadjusted	0.03037	0.00830	13.46	0.0008
Age-adjusted	0.01494	0.00806	3.41	0.07
Multiple-covariate-adjusted	0.01350	0.00793	2.89	0.09

Unadjusted regression model: Dependent variable = weight change; independent variable = percent energy from evening food intake.
Age-adjusted regression model: Dependent variable = weight change; independent variables = percent energy from evening food intake, and age.
Multiple-covariate-adjusted regression model : Dependent variable = weight change; independent variables = percent energy from evening food intake, age, race, length of follow-up (y), education, baseline BMI, smoking status, energy intake (kcals), alcohol intake (g), morbidity, recreational level of physical activity, special diet status, and parity (women only).
[a]Above mentioned regression models were also run with percent weight change from baseline as the dependent variable. The relationship of percent eating after 5 pm with weight change relative to baseline body weight was not different from that reported above in the table.

variate-adjusted regression models. In women, a positive association of extent of after 5 pm eating with weight change was noted in unadjusted models, but not after adjustment for age or multiple covariates. Association of night eating (after 8 pm) with weight change was also not significant in men or women (data not shown).

The association of after 5 pm eating with weight change was also examined after stratification for weight loss or weight gain status. No association ($P > 0.05$) was noted in men and women who lost or gained weight over the period of follow-up (data not shown).

To determine whether potential confounders such as baseline BMI, age, cigarette smoking, physical activity, morbidity, and special diet status at baseline modify the association of extent of after 5 pm eating with weight change, stratum-specific regression analyses were performed within each strata of each of these variables. Percent energy from evening food intake and weight change were positively associated in multiple-covariate-adjusted regression models in men never-smokers ($n = 754$, beta for percent energy intake after 5 pm = 0.0370, $P = 0.02$), and those reporting the highest level of recreational exercise at follow-up ($n = 494$, beta for percent energy intake after 5 pm = 0.0437, $P = 0.0027$). In women, the positive association of extent of after 5 pm eating with weight change was significant in those reporting little or no recreational physical exercise at baseline ($n = 2266$, beta for percent energy intake after 5 pm = 0.0334, $P = 0.0141$); highest level of recreational physical activity at follow-up ($n = 593$, beta for percent energy intake after 5 pm = 0.0579, $P = 0.0071$); and morbidity score of 1 ($n = 1555$, beta for percent energy intake after 5 pm = 0.0289, $P = 0.0494$). (Data for stratified analyses not shown).

Discussion

To our knowledge, this is the first study to prospectively examine the relation of time of energy consumption with long-term weight change. In unstratified analyses, the association of evening eating and weight change was not significant in men or women. In accordance with results of our previous study[3], baseline BMI and percent energy consumed after 5 pm were also not related in multiple-covariate-adjusted regression models.

The biologic plausibility of the hypothesis examined in this study is dependent on time of day differences in TEF. The limited evidence on circadian variability of TEF presents a mixed picture. For example, Romon *et al*[2] reported TEF after a night meal to be lowest relative to iso-energetic meals consumed in the morning or afternoon. Zwiauer *et al*[10], however, noted no differences in TEF after a morning versus an afternoon meal. More work, using reproducible methods to account for large intraindividual variability in TEF measurements[11], is needed in this area.

Another hypothesis for increased risk of energy storage is based on differences in level of voluntary energy expenditure after consumption of meals at different times of the day. It is argued that a large meal in the middle of the day (usually followed by several hours of physical activities) will not lead to energy storage, whereas due to the usual practice of sedentary activities following the evening meal, large evening meals increase the risk of energy storage. These statements suggest a different mechanism, dependent on the interaction of exercise and TEF. However, the available evidence on the interaction of exercise and TEF is equivocal[12,13]. Different results, dependent on pre versus post meal exercise, adiposity, level of fitness, duration of exercise, and energy content of the meal, have been reported[12]. In the present study, no consistent pattern of association was observed in men and women stratified by level of baseline or follow-up physical activity. The observed associations may simply be due to chance because of the number of multiple comparisons made.

We also noted a positive association of after 5 pm eating with weight change in male never-smokers only, which suggests an interaction of smoking with TEF. Although metabolic effects of smoking are known to differ by gender, Perkins[14] concluded that smoking had either little effect on TEF or reduced the TEF.

The evidence of the effect of adiposity on thermogenic effect of food is equivocal. Some indicate that TEF is blunted in obese individuals[15,16], others have reported no differences in TEF of obese versus non-obese individuals[17,18]. We examined the association of extent of evening eating with weight change within different strata of baseline BMI. No association was evident in any strata in men or women, suggesting lack of effect of adiposity on the relation of evening eating and weight change.

The estimated mean of 46% of energy intake after 5 pm for this cohort (24 h dietary recall in 1971–1975) is similar to the estimate we reported for women in the 1985–86 CSFII (four non-consecutive days of dietary data)[3]. Few other published estimates are available, but generally our results are consistent with these reports[19].

The source of baseline dietary data for the NHEFS cohort is a 24 h dietary recall. Measurement error is known to be associated with all dietary assessment methods including recalls[20]. Under reporting and misreporting of food intake has been recognized as a problem in dietary survey[20,21]. A differential in the extent of under reporting by the level of adiposity has also been reported in some studies.[21] To improve quality of dietary intake data in future surveys, use of techniques such as double labeled water or other biomarkers to validate estimates of energy intake in a subsample should be considered. Also, replicate dietary measurements can be used to derive variance ratios for dietary variables. However, biomarkers for validating dietary intake or estimates of intra- and interindividual variability of the exposure variable (time of day energy intake) for the NHEFS cohort are not available to allow correction of our estimates of association.

Another possible reason for attenuation of the true association of time of eating with weight change may be a differential ability or willingness to recall foods consumed at different times of day. To our knowledge, no evidence is available to support or contradict this hypothesis. Yet, it is possible that individuals may not remember or choose to recall foods consumed late at night due to undesirability of this eating behavior, thereby leading to an underestimate of the extent of after 5 pm eating. Furthermore, if there is a body weight related differential in estimates of extent of after 5 pm eating, it may also diminish the true association.

The assumption of persistence of dietary patterns over the period of follow-up is inherent in epidemiologic studies that do not include repeated ascertainment of changes in exposure. Repeated measures of dietary intake over the follow-up period are not available for the NHEFS cohort. To test the validity of this assumption, it is useful to examine whether time of day food consumption patterns persist in adults. A comparison of estimates of after 5 pm eating for the NHEFS cohort (46% in 1971–1974) with estimates from CSFII (46%) in 1985–86), does not support the notion of dramatic changes in time of day food consumption patterns of Americans. However, because the extent of after 5 pm eating declined with age in this cohort (Table 3), it is reasonable to assume that as the cohort ages, time of day food consumption patterns will change with retirement. The effect of this possible change in exposure over follow-up would be to further attenuate the true association.

Conclusions

The extent of evening eating and subsequent weight changes were unrelated in the NHEFS cohort. The results of this study point to a need for long-term feeding trials with manipulation of time-of-day distribution of iso-energetic intake in subjects serving as their own controls. Work on the relation of body weight with accuracy of dietary reporting by time of day as well as the extent of intra- and inter-individual variability in estimates of extent of eating by time of day is needed. Further exploration of time of day differences in TEF, controlling for factors that contribute to large variability in measurement of TEF, is also needed.

Acknowledgement

We thank Lisa Licitra Kahle, IMS, Silver Spring, Md, for computing assistance.

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