Temporal eating patterns: associations with nutrient intakes, diet quality, and measures of adiposity

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ABSTRACT

Background: Some evidence suggests that higher energy intake (EI) later in the day is associated with poor diet quality and obesity. However, EI at one eating occasion (EO) is also dependent on EI at surrounding EOs. Studies that examine the distribution of EOs across the day are rare.

Objective: The aim of this study was to examine associations between temporal eating patterns, nutrient intakes, diet quality, and measures of adiposity in a representative sample of Australian adults.

Design: Dietary data from two 24-h recalls collected during the cross-sectional 2011–2012 Australian National Nutrition and Physical Activity Survey were analyzed (n = 4544 adults, aged ≥19 y). Temporal eating patterns, based on the distribution of EOs across the day, were determined by using latent class analysis. Diet quality estimated adherence to healthy eating recommendations and was assessed by using the 2013 Dietary Guidelines Index (DGI). Multivariate regression models assessed associations between temporal eating patterns, nutrient intakes, diet quality, and adiposity (body mass index, waist circumference, weight status, and central weight status). Models were adjusted for potential confounders and energy misreporting.

Results: Three patterns, labeled "conventional," "later lunch," and "grazing," were identified. Compared with a "conventional" or "later lunch" pattern, men and women with a "grazing" pattern had lower DGI scores and higher intakes of discretionary (noncore) foods ($P < 0.05$). Among women, the "grazing" pattern was associated with overweight or obesity (OR: 1.57; 95% CI: 1.15, 2.13) and central overweight or obesity (OR: 1.73; 95% CI: 1.19, 2.50). These associations were attenuated after the exclusion of energy misreporters and adjustment for total EI.

Conclusions: This study found that a "grazing" temporal eating pattern was modestly but significantly associated with poorer diet quality and adiposity among women, after adjustment for covariates and energy misreporting. Future research should consider the impact of energy misreporting on the relation between temporal eating patterns and adiposity. This secondary analysis was registered at anzctr.org.au as ACTRN12617001029381. *Am J Clin Nutr* 2017;106:1121–30.

Keywords: diet quality, eating occasion, latent class analysis, meal timing, obesity

INTRODUCTION

Chrono-nutrition is an emerging field of research that refers to the temporal variations in the patterning and distribution of food and beverage intake or eating occasions (EOs), including meals and snacks, across the day (1). Animal studies have shown that deviations from habitual eating patterns negatively affect metabolic and physiologic functions that are also regulated by circadian clock systems in the suprachiasmatic nuclei and peripheral tissues (2, 3). For example, eating during the normal sleep cycle (4) or consuming a high-fat meal at the end of a wake cycle (5) negatively affected cardiometabolic health variables in mice.

In humans, nightshift work has been linked to an increased risk of cardiometabolic diseases (6, 7). There is also evidence to suggest that weight gain in shift workers may be related to poor diet quality (8, 9). However, little research has examined temporal eating patterns in relation to dietary intakes and health outcomes in non–shift-work populations (10). Several epidemiologic studies have reported a positive association between evening energy intakes (EIs) and daily total EIs (11, 12) and obesity (10, 13). The later timing of an EO has also been associated with higher total EIs (14) and less successful weight loss (15). The causal effects of a later temporal eating pattern are not clear. Intervention studies in this area vary with respect to the populations, temporal eating patterns, and risk factors examined (16). Furthermore, most studies that examined temporal eating patterns focused on the timing of EOs at isolated time periods of the day, and this approach disregards EOs at other times

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Abbreviations used: ABS, Australian Bureau of Statistics; DGI, Dietary Guidelines Index; EE, energy expenditure; EI, energy intake; EO, eating occasion; LCA, latent class analysis; NNPAS, National Nutrition and Physical Activity Survey; PA, physical activity; PAL, physical activity level; WC, waist circumference.

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of the day (10). The need for research that examines temporal eating patterns in the context of both EO timing and frequency across the day was also highlighted in a recent scientific statement from the American Heart Association (16).

Studies that examine the temporal patterning of EOs across the day are rare (17). Two studies found distinct temporal eating patterns across the day when applying a data-driven analytic approach, including cluster analysis (17) and latent class analysis (LCA) (18). These methods were used to discover unknown patterns in the data on the basis of an observed set of indicators (e.g., time of EO consumption). Examples of patterns found by using these methods include a "conventional" pattern, where meals and snacks were evenly spaced and consumed at conventional times in the United States and Australia, and a pattern characterized by a higher eating frequency with less definitive meal occasions (17, 18). These patterns were associated with differences in sociodemographic and health characteristics (17, 18) and diet quality (17).

The identification of temporal eating patterns associated with diet quality and obesity has important implications. These include providing insight into how the interplay between time and dietary intakes may promote obesity and how current population-based dietary advice for weight management could be improved (19). Therefore, the aim of this study was to examine whether temporal eating patterns, determined by using an LCA approach, are related to nutrient intakes, diet quality, and measures of adiposity in Australian adults.

METHODS

Sample and study design

This study was a secondary analysis of data from the nationally representative 2011–2012 Australian National Nutrition and Physical Activity Survey (NNPAS) and was registered at anzctr.org.au as ACTRN12617001029381. This cross-sectional survey was conducted by the Australian Bureau of Statistics (ABS). Details of the study design and data collection methods have been described elsewhere (20). Briefly, 12,153 persons aged ≥2 y (of whom 9341 were adults aged ≥19 y) were sampled from private households by using a multistage, probability sampling design (**Supplemental Figure 1**). The initial response rate (77%) and person-specific weights, adjusted for probability of selection and nonresponse bias, were used to provide estimates relating to the whole population. The Census and Statistics Act 1905 provided ethics approval for the ABS to conduct the household interview components of health surveys (20).

Anthropometric measurements

Measurement of height (centimeters), weight (kilograms), and waist circumference (WC; centimeters) were taken to 1 decimal point by trained ABS staff during a household interview by using a portable stadiometer, digital scales, and a metal tape measure, respectively. Anthropometric measurements were voluntary and excluded pregnant women. BMI (kg/m^2) was calculated, and overweight or obesity was defined as having a BMI ≥25 (21). Central overweight or obesity was defined as WC ≥94 cm in men and ≥80 cm in women (22).

Dietary assessment

Methods to assess respondents' dietary intake have been described previously (20). In brief, dietary intake was collected during two 24-h recalls, which were based on the validated USDA automated multiple 5-pass method (23, 24). The dietary recalls were conducted across all days of the week (except for Sunday, unless requested by the participant). The second recall was completed by 6053 (65%) of the initial adult respondents on a different day ∼3–10 d after the first recall (average = ∼9 d) (25). During each recall, respondents identified the time when each EO commenced and the EO type (i.e., breakfast, lunch, dinner, snack, beverage-only, etc.).

EOs

For the purpose of the analysis, an EO was defined as any occasion at which food or drink was ingested and provided a minimum energy content of 210 kJ (50 kcal) and was separated in time from the surrounding EOs by 15 min. This definition of EO has been shown to predict variance in total EI and measures of adiposity more strongly than applying EO definitions with no energy criterion (26, 27) or differing time intervals (16, 27). The EI from EOs within each hour of the day was examined and averaged across the 2 d of dietary recalls. To determine the temporal pattern of EOs across the day, binary variables were created to indicate whether or not an EO had occurred for each hour of the day.

Food and nutrient intakes

Energy and nutrient intakes from all foods and beverages were calculated by using the Australian Supplement and Nutrient Database 2011–2013 (28). Mean estimates of energy, food, and nutrient intakes and diet quality scores were obtained by averaging dietary information across the 2 d of recall. Intakes of foods in the Australian Guidelines to Healthy Eating were assessed (29). These included intakes (servings per day) of the 5 core food groups (vegetables, fruit, grain foods, dairy and alternatives, and lean meat and alternatives) and intakes of discretionary foods [noncore foods that are high in saturated fat, added sugars, or both; e.g., sugary drinks, sweetened biscuits (e.g., cookies), cakes, pastries, and processed meats]. Dietary intakes of carbohydrates (grams), total sugars (grams), total fat (grams), SFAs (grams), MUFAs (grams), PUFAs (grams), protein (grams), dietary fiber (grams), folate (micrograms), β-carotene (micrograms), iodine (milligrams), sodium (milligrams), potassium (milligrams), calcium (milligrams), and iron (milligrams) for each participant were averaged across the 2 dietary recall days. These nutrients are identified in the Australian Dietary Guidelines and Nutrient Reference Values to play an important role in preventing or promoting diet-related conditions with a high burden of disease (30, 31). Sodium intakes included sodium naturally present in foods and added during processing but did not include salt added at the table or during cooking, because estimated intakes on discretionary salt use were not collected in the NNPAS. All nutrient intakes adjusted for total EI with the use of the residual method by regressing nutrient intakes on total EIs (32, 33).

Diet quality

Overall diet quality was assessed by using a food-based diet quality index, the 2013 version of the Dietary Guidelines Index (DGI). The DGI has shown convergent (34) and predictive (35, 36) validity and has been described in detail previously (34–37). Briefly, DGI scores are the sum of 13 dietary components, each scored out of 10 possible points, reflecting proportional compliance for meeting an Australian Dietary Guideline and include meeting recommendations for food variety, salt use, and intakes of the 5 core food groups, fluids, discretionary foods, SFAs, unsaturated fat, added sugars, and alcohol. The possible total score range is 0–130, with higher scores indicating better diet quality.

Energy misreporting

Energy misreporting was assessed in this study to address previous research that indicates that energy misreporting may bias the relation between temporal eating patterns and obesity (13) and that those who underreport EIs also underreport their EO frequency (38, 39). The methods used to determine energy misreporting have been described in detail previously (37). Briefly, energy misreporting was assessed by using the ratio of reported total EI to predicted total energy expenditure (EE; EI:EE) (40). EE was calculated by using the validated sex- and age-specific equations suitable for use in populations with a range of weight statuses published in the US Dietary Reference Intakes (41). Because the NNPAS assessed transport- and leisure-related physical activity (PA) only and did not include a measure of occupational PA or an objective measure of overall PA, a low-active PA level (PAL; e.g., PAL $\geq$1.4 and $<$1.6) was assumed, which is consistent with previous research (40, 42). This assumption is based on objectively measured population-level PA data that show that most adults spend waking hours being either sedentary or in light activity (43, 44). Participants were identified as plausible reporters, underreporters, or overreporters of EI on the basis of published calculations for the $\pm$1 SD cutoff for EI:EE, which incorporates the CV in total EIs and predicted total EE of NNPAS participants and the number of dietary recall days used (40, 45).

Covariates

Information on respondents' sociodemographic characteristics and health behaviors was collected in the household survey (20). Educational level was categorized as low (completed some high school or less), medium (completed high school or completed some high school or received a certificate or diploma), or high (having a tertiary qualification). Country of birth was categorized by the ABS as follows: Australia, other mainly English-speaking countries (e.g., countries where English is the main or official language spoken), and all other countries. Smoking status was self-reported and categorized as current smoker, ex-smoker, and never smoked. Frequency and duration of moderate and vigorous PA during leisure-time and for transport in the last week were assessed in the NNPAS by using questions from the Active Australia Survey (46). Participants were categorized by the ABS as meeting or not meeting current Australian PA guidelines of 150 min and 5 sessions/wk (47). Participants self-reported the total minutes spent in sedentary behavior, defined as time spent sitting or lying down at work, or during transport or leisure activities in the past week (20). Weekly sedentary time was divided by 7 to derive daily sedentary time (minutes). Participants reported their total sleep duration on the night before the survey in minutes. Daily sleep time was converted to hours by dividing estimates by 60. Participants also indicated whether they were currently following a diet for weight loss or for health reasons (yes or no).

Analytic sample

Participants were included in the analysis if they provided 2 d of dietary recall and were not pregnant, breastfeeding, or had undertaken shift-work in the past 4 mo (n = 5366; Supplemental Figure 1). Participants were excluded if they reported no EI during either of the 24-h recalls (n = 8) or did not report the time at which an EO commenced (n = 116). Of the remaining 5242 participants, 665 (13%) had missing data for adiposity measures and 33 ($<$1%) were missing data for covariates (PA and sedentary time), which left a final sample of 2127 men and 2417 women for the present analysis.

Statistical analysis

Temporal eating patterns

LCA, conducted in M-Plus version 7.31 (Muthen & Muthen), was used to identify distinct temporal eating patterns in men and women. The LCA procedures and a description of the resulting patterns have been described in detail previously (18). In brief, binary variables that indicate whether or not an EO (minimum energy content of $\geq$210 kJ) had occurred within each hour of the day were used as the input variables for the LCA. A model with 2 latent classes was tested first, and additional classes were added until the optimal number of latent classes was identified. Final class numbers were determined by the evaluation of model fit indexes (e.g., Akaike information criterion and Bayesian information criterion), likelihood ratio tests comparing k with k^{-1} class models, and pattern interpretability (48). After these procedures, a 3-class solution was identified as the most appropriate fit for the data (18). The reliability of the 3-class solution was then examined by repeating the LCA procedures with the use of 1 recall day of dietary intake, and similar temporal eating patterns were found when comparing results with the use of 1 compared with 2 d of dietary intake (18).

Descriptive analysis

Analyses that examined temporal eating patterns were conducted in Stata 14 (StataCorp). Person weights and replicate weights were applied to compute point estimates and SEs to account for the probability of selection and the clustered survey design, respectively (20). Descriptive statistics for sample characteristics are presented as weighted means (95% CIs) or as weighted percentages. After examining the distribution of the data, BMI, energy and nutrient intakes, daily total sedentary time, and EI:EE were log-transformed to improve normality. Weighted geometric means (95% CIs) were used for all log-transformed variables. The F test (for continuous data) and the adjusted Pearson's chi-square test (for categorical data) were used to determine differences in sample characteristics by latent class of temporal eating patterns.

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TABLE 1
Sociodemographic and health behavior characteristics of Australian men and women, by latent class of temporal eating patterns[1]

	Men (n = 2127)				Women (n = 2417)			
	Conventional (n = 956)	Later lunch (n = 710)	Grazing (n = 461)	P	Conventional (n = 1016)	Later lunch (n = 820)	Grazing (n = 581)	P
Age, y	50 (49, 51)[a]	47 (45, 49)[b]	41 (39, 43)[c]	<0.05	50 (49, 51)[a]	50 (48, 51)[a]	45 (43, 47)[b]	<0.01
Educational level, %				<0.01				<0.001
Low	25	16	17		35	26	25	
Medium	53	53	54		41	46	38	
High	22	31	29		24	28	37	
Country of birth, %				<0.05				<0.001
Australia	71	71	61		71	74	59	
Mainly English-speaking countries	13	11	14		12	12	12	
All other countries	17	18	25		17	15	29	
Smoking status, %				<0.01				NS
Nonsmoker	40	51	42		59	57	59	
Ex-smoker	40	35	33		27	31	26	
Current smoker	19	14	25		14	12	15	
Currently following a diet, %	13	10	9	NS	15	17	20	NS
Meets physical activity guidelines,[2] %	43	51	48	<0.05	42	44	46	NS
Daily sedentary time,[3] h	4.9 (4.6, 5.2)[a]	5.5 (5.2, 5.8)[b]	5.2 (4.7, 5.7)	<0.01	4.2 (3.9, 4.5)	4.4 (4.0, 4.7)	4.6 (4.2, 5.1)	NS
Daily sleep time, h	7.9 (7.7, 8.0)	7.9 (7.7, 8.1)	7.8 (7.5, 8.0)	NS	8.1 (8.0, 8.3)[a]	8.0 (7.9, 8.1)	7.8 (7.6, 8.1)[b]	<0.05
Daily total EI,[3] MJ	8.7 (8.5, 9.1)[a]	9.1 (8.9, 9.4)[b]	10.1 (9.7, 10.5)[c]	<0.05	6.7 (6.5, 6.9)[a]	7.1 (6.9, 7.3)[b]	7.3 (7.1, 7.6)[b]	<0.01
EI:EE[3]	0.83 (0.80, 0.85)[a]	0.85 (0.83, 0.88)[a]	0.92 (0.88, 0.96)[b]	<0.01	0.85 (082, 0.88)[a]	0.90 (0.87, 0.92)[b]	0.90 (0.87, 0.94)[b]	<0.05
Energy misreporting status,[4] %				<0.001				<0.05
Plausible reporters	67	66	67		66	73	65	
Underreporters	28	27	20		27	20	23	
Overreporters	5	7	13		7	7	11	
BMI,[3] kg/m^2	27.7 (27.3, 28.1)[a]	27.2 (26.7, 27.6)[b]	26.7 (26.0, 27.4)[b]	<0.05	26.4 (25.9, 27.0)	26.3 (25.8, 26.8)	26.6 (26.0, 27.2)	NS
Overweight/obese,[5] %	75	69	65	<0.05	54	56	57	NS
Waist circumference, cm	99.1 (97.9, 100.3)	97.7 (96.4, 98.9)	95.5 (93.6, 97.3)		88.2 (86.6, 89.7)	86.8 (85.6, 88.1)	87.8 (86.2, 89.4)	NS
Centrally overweight/obese,[6] %	64	61	54	<0.05	65	67	69	NS

[1] Values are weighted means (95% CIs) or weighted percentages unless otherwise stated. Different superscript letters indicate significant pairwise differences between latent classes for continuous variables by using an F test with Bonferroni correction. Differences between classes for categorical variables were assessed by using the design-adjusted Pearson's chi-square test. EE, energy expenditure; EI, energy intake.

[2] Whether met physical activity guidelines of 150 min and 5 sessions/wk.

[3] Values are geometric means (95% CIs).

[4] Defined by using the ±1 SD cutoff for EI:EE of <0.68 for underreporters and >1.32 for overreporters.

[5] Defined as a BMI ≥25.

[6] Defined as a waist circumference ≥94 cm for men and ≥80 cm for women.

Associations for temporal eating patterns with nutrient intakes, diet quality, and adiposity

Linear regression was used to adjust for differences in sample characteristics between latent classes. Adjusted means (95% CIs) for intakes of energy, nutrients, and food groups and diet quality scores were estimated for each latent class. Multiple linear regression (for continuous outcomes) and logistic regression (for binary outcomes) were used to test for associations between temporal eating patterns by using the "conventional" pattern as the reference and the following measures of adiposity: BMI and WC (continuous) and overweight or obesity and central overweight or obesity status (binary). Four models were tested. Model 1 was an unadjusted model, whereas model 2 adjusted for age (continuous), educational level (categorical), country of birth (categorical), meeting PA guidelines (yes or no), daily sedentary time (continuous), sleep time (continuous) smoking status (categorical), daily energy-adjusted alcohol intake (grams per day; continuous), dieting (binary), and DGI-2013 scores (continuous). These covariates were selected on the basis of their hypothesized relation with both dependent and independent variables and the published literature. To assess the effect of energy misreporting on the association between temporal eating patterns and adiposity, model 3 additionally adjusted for EI:EE (continuous), an approach used in previous studies (26, 40, 49). To examine total EI in relation to reported associations between temporal eating patterns and adiposity, model 4 additionally adjusted for total EI after excluding energy misreporters (n = 694 men and n = 791 women) (50). Because total EI and EI:EE are strongly and positively related, energy misreporters were excluded in model 4 to additionally adjust for EI. All of the models were checked for multicollinearity and appropriate model fit by using regression diagnostics. For all of the analyses, $P < 0.05$ was considered significant.

RESULTS

Characteristics of temporal eating patterns

The latent classes of temporal eating patterns for Australian men and women participants in the NNPAS 2011–2012 have been described previously (18). In brief, 3 latent classes, herein referred to as temporal eating patterns, were identified for both men and women and were similar. The labels given to each pattern are based on the conditional probabilities for EOs occurring at certain times of the day, relative to the other classes. The first pattern, labeled "conventional" (42% men, 40% women), was characterized by EOs occurring at conventional meal times in Australia (e.g., lunch at 1200 and dinner at 1800) and between conventional meal times at 1000 and 1500 (i.e., between-meal snacks). The second pattern, labeled "later lunch" (34% men, 34% women), was distinguished by a lunch EO that occurred 1 h later than the "conventional" pattern. The third pattern, labeled "grazing" (24% men, 26% women), was characterized by more frequent EOs and lower conditional probabilities (e.g., <0.7) of an EO occurring at conventional meal times. A later timing of the first EO and higher conditional probabilities for EOs occurring later in the day (e.g., after 2000) were also observed for the "grazing" pattern when compared with the "conventional" and "later lunch" patterns.

Table 1 presents the sociodemographic and health behavior characteristics of men and women by latent class of temporal eating patterns. There were significant differences ($P < 0.05$) between temporal eating patterns for age, educational level, country of birth, smoking status (men only), meeting PA guidelines, daily sedentary time (men only), daily sleep time (women only), total EIs, EI:EE, and WC (men only). Men with a "conventional" temporal eating pattern had a significantly higher BMI and a higher proportion were classified as overweight or

TABLE 2
Daily energy and energy-adjusted nutrient intakes by latent class of temporal eating patterns among Australian men and women[1]

	Men (n = 2127)			Women (n = 2417)		
Nutrient	Conventional (n = 956)	Later lunch (n = 710)	Grazing (n = 461)	Conventional (n = 1016)	Later lunch (n = 820)	Grazing (n = 581)
Energy, MJ	9.1 (9.1, 9.2)	9.2 (9.1, 9.3)	9.3 (9.1, 9.4)	7.0 (6.9, 7.0)[a]	7.0 (6.9, 7.0)[a]	7.1 (7.0, 7.2)[b]
Carbohydrate, g	231 (226, 236)	230 (225, 235)	230 (224, 237)	173 (170, 176)	173 (169, 176)	177 (172, 181)
Total sugars, g	93 (88, 98)	93 (89, 97)	100 (94, 107)	76 (73, 79)	76 (73, 79)	80 (76, 84)
Protein, g	98 (96, 101)	97 (95, 99)	94 (91, 97)	74 (73, 75)[a]	74 (72, 76)[a]	69 (67, 71)[b]
Total fat, g	72 (70, 74)[a]	73 (71, 75)	74 (72, 77)[b]	57 (56, 58)	57 (56, 58)	57 (56, 59)
SFAs, g	26 (25, 27)[a]	27 (26, 28)	28 (27, 29)[b]	20 (20, 21)	20 (19, 21)	21 (20, 22)
MUFAs, g	28 (27, 29)	28 (27, 29)	28 (28, 29)	21 (21, 22)	22 (21, 22)	22 (21, 23)
PUFAs, g	11 (10, 11)	11 (10, 11)	10 (10, 11)	9 (8, 9)	9 (9, 9)	9 (8, 9)
Fiber, g	23 (22, 24)	23 (22, 24)	21 (20, 23)	20 (19, 20)[a]	19 (19, 20)	19 (18, 19)[b]
Folate equivalents, μg	607 (583, 633)	622 (596, 648)	590 (550, 633)	493 (474, 512)	476 (454, 500)	465 (440, 492)
Vitamin C, mg	85 (79, 92)	84 (77, 92)	87 (79, 96)	73 (68, 78)	73 (67, 77)	68 (62, 74)
β-Carotene, μg	2151 (1992, 2322)	2191 (1975, 2430)	2165 (1901, 2466)	2143 (1966, 2337)	2129 (1937, 2340)	1953 (1735, 2199)
Calcium, mg	733 (699, 768)	746 (721, 771)	744 (704, 787)	668 (647, 691)	642 (612, 674)	655 (622, 690)
Iron, mg	12 (11, 12)	12 (11, 12)	12 (11, 12)	9 (9, 9)[a]	9 (9, 9)	8 (8, 9)[b]
Iodine, mg	167 (161, 174)	172 (166, 178)	167 (159, 177)	138 (134, 142)	136 (130, 142)	135 (129, 141)
Sodium, mg	2385 (2296, 2477)	2429 (2350, 2510)	2426 (2308, 2551)	1837 (1777, 1899)	1865 (1809, 1923)[a]	1765 (1697, 1835)[b]
Potassium, mg	3023 (2935, 3114)	3008 (2932, 3086)	2953 (2865, 3043)	2508 (2462, 2555)	2507 (2450, 2565)	2463 (2384, 2546)

[1] Values are geometric means (95% CIs) adjusted for age (years), educational level, country of birth, physical activity guidelines met (yes or no), daily sedentary time (minutes), smoking status, and the ratio of energy intake to energy expenditure. Different superscript letters indicate significant t test pairwise comparisons, with adjustment for multiple comparisons, between latent classes ($P < 0.05$).

obese compared with the "later lunch" and "grazing" patterns ($P < 0.05$).

Temporal eating patterns associated with energy-adjusted nutrient intakes and diet quality

Tables 2 and **3** present energy-adjusted nutrient intakes, diet quality scores, and selected food group intakes by temporal eating patterns for men and women. After adjustment for multiple covariates, men with a "grazing" pattern had significantly higher intakes of fat and saturated fat than those with the "conventional" pattern. Women with a "grazing" pattern also had significantly higher total EIs and lower energy-adjusted intakes of protein than did women with a "conventional" or "later lunch" pattern. Fiber and iron intakes were also significantly lower in women with a "grazing" pattern than in women with a "conventional" pattern. Diet quality scores and selected food groups were associated with temporal eating patterns. The lowest diet quality scores and the highest intakes of discretionary foods were observed in both sexes with a "grazing" pattern. Men with a "grazing" pattern also had lower intakes of grain foods than did those with a "later lunch" pattern.

Associations between temporal eating patterns and adiposity

The associations between temporal eating patterns and BMI and overweight or obesity (BMI ≥25) for men and women are presented in **Table 4**. In the unadjusted model, a significant inverse association was found between the "grazing" pattern and BMI and overweight or obesity among men only. These associations were attenuated after adjustment for the covariates included in model 2. After additional adjustment for EI:EE, significant positive associations between the "grazing" pattern and BMI and overweight or obesity were found among women only. No significant associations were found between temporal eating patterns and BMI or overweight or obesity after the exclusion of energy misreporters and adjustment for total EI.

Results of the regression analyses for the associations between temporal eating patterns and WC and central overweight or obesity (men: WC ≥94 cm; women: WC ≥80 cm) are shown in **Table 5**. In the unadjusted model, a significant inverse association was found between the "grazing" pattern and WC and central overweight or obesity among men only ($P < 0.01$). However, these associations disappeared after adjustment for covariates (model 2). After additional adjustment for EI:EE, a significant positive association between the "grazing" pattern and central overweight or obesity was found among women ($P < 0.01$). This association was attenuated after the exclusion of energy misreporters and adjustment for total EI.

DISCUSSION

To our knowledge, this is one of the first studies among adults to examine associations for daily temporal eating patterns with energy-adjusted nutrient intakes, diet quality, and adiposity (17). A "grazing" pattern, identified by using LCA and characterized by more frequent EOs found in our earlier study (18), was associated with lower diet quality and higher intakes of discretionary foods in both men and women. Among women, this pattern was associated with overweight or obesity and central

TABLE 3
Diet quality scores and intakes of selected food groups by latent class of temporal eating patterns among Australian men and women[1]

	Men (n = 2127)			Women (n = 2417)		
	Conventional (n = 956)	Later lunch (n = 710)	Grazing (n = 461)	Conventional (n = 1016)	Later lunch (n = 820)	Grazing (n = 581)
Dietary Guidelines Index (range: 0–130)[2]	79.4 (77.9, 81.0)	80.5 (79.1, 82.0)[a]	78.0 (76.5, 79.6)[b]	82.7 (81.5, 84.1)[a]	80.9 (79.2, 82.5)[b]	79.8 (77.8, 81.2)[b]
Daily servings from core food groups (recommended daily standard serving range for adults aged 19–70 y)						
Vegetables (5–6)	2.9 (2.7, 3.1)	2.9 (2.7, 3.1)	2.7 (2.5, 2.9)	2.7 (2.6, 2.9)	2.8 (2.6, 3.0)	2.5 (2.3, 2.7)
Fruit (2–2)	1.6 (1.4, 1.8)	1.6 (1.4, 1.8)	1.7 (1.6, 1.9)	1.5 (1.4, 1.6)	1.4 (1.3, 1.5)	1.5 (1.3, 1.7)
Grain foods (4–6)	3.9 (3.7, 4.0)	4.1 (3.9, 4.3)[a]	3.7 (3.4, 4.0)[b]	2.8 (2.6, 2.9)	2.7 (2.6, 2.9)	2.7 (2.5, 2.8)
Lean meat/alternatives (2–3)	2.2 (2.1, 2.4)	2.2 (2.0, 2.3)	2.2 (2.0, 2.3)	1.7 (1.6, 1.7)	1.7 (1.6, 1.9)	1.7 (1.5, 1.8)
Dairy/alternatives (2–4)	1.5 (1.4, 1.6)	1.5 (1.4, 1.6)	1.6 (1.4, 1.7)	1.4 (1.4, 1.5)	1.3 (1.2, 1.4)	1.3 (1.3, 1.5)
Daily servings of noncore foods[3]						
Discretionary foods[4]	6.0 (5.7, 6.3)[a]	6.0 (5.8, 6.3)[a]	6.7 (6.3, 7.0)[b]	4.1 (3.9, 4.3)[a]	4.2 (4.0, 4.4)	4.5 (4.2, 4.8)[b]

[1] Values are mean estimates (95% CIs) adjusted for age (years), educational level, country of birth, physical activity guidelines met (yes or no), daily sedentary time (minutes), smoking status, and the ratio of energy intake to energy expenditure. Different superscript letters indicate significant t test pairwise comparisons, with adjustment for multiple comparisons, between latent classes ($P < 0.05$).
[2] The Dietary Guidelines Index represents a total diet quality score with higher scores indicating better overall diet quality.
[3] Noncore foods are recommended to be consumed only sometimes or in small amounts.
[4] 1 serving = 600 kJ.

TABLE 4
Associations between temporal eating patterns and BMI and overweight or obesity among Australian men and women[1]

	BMI (kg/m^2)[2,3]				Overweight/obesity[4,5]			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Men (n = 2127)								
Conventional (reference; n = 956)	—	—	—	—	1.00	1.00	1.00	1.00
Later lunch (n = 710)	−0.02 (−0.04, −0.00)*	−0.01 (−0.03, 0.01)	−0.01 (−0.02, 0.01)	−0.00 (−0.03, 0.02)	0.77 (0.58, 1.01)	0.82 (0.61, 1.09)	0.84 (0.61, 1.15)	0.92 (0.62, 1.36)
Grazing (n = 461)	−0.04 (−0.07, −0.00)*	−0.01 (−0.04, 0.01)	0.01 (−0.02, 0.03)	0.00 (−0.03, 0.03)	0.63 (0.43, 0.92)*	0.79 (0.54, 1.17)	1.02 (0.68, 1.53)	0.95 (0.60, 1.49)
Women (n = 2417)								
Conventional (reference; n = 1016)	—	—	—	—	1.00	1.00	1.00	1.00
Later lunch (n = 820)	−0.00 (−0.03, 0.02)	−0.00 (−0.03, 0.02)	0.01 (−0.02, 0.03)	0.00 (−0.02, 0.03)	1.08 (0.82, 1.42)	1.07 (0.80, 1.44)	1.17 (0.88, 1.58)	1.09 (0.78, 1.53)
Grazing (n = 581)	0.01 (−0.03, 0.02)	0.02 (−0.01, 0.05)	0.03 (0.00, 0.05)*	0.02 (−0.01, 0.06)	1.13 (0.83, 1.55)	1.33 (0.98, 1.81)	1.57 (1.15, 2.13)**	1.45 (0.99, 2.14)

[1] Associations were examined by using Wald tests of associations for linear (continuous outcome = BMI) and logistic (binary outcome = overweight/obesity) regression. Model 1 was the crude analysis; model 2 adjusted for age (years; continuous), sedentary time (minutes per day; continuous), alcohol (grams per day; continuous), educational level (low, medium, or high), country of birth (Australia, other mainly English-speaking countries, or all other countries), physical activity guidelines met (yes or no), smoking status (never smoked, past smoker, or current smoker), dieting (yes or no), sleep time (hours per day; continuous) and Dietary Guidelines Index–2013 scores; model 3 adjusted as for model 2 and additionally adjusted for energy misreporting (ratio of energy intake to energy expenditure); model 4 adjusted as for model 2 and additionally adjusted for total energy intake after excluding energy misreporters with ratios of energy intake to energy expenditure of <0.68 or >1.32 (n = 1433 men and n = 1636 women). *P < 0.05, **P < 0.01.

[2] Dependent variables were log-transformed to improve normality. The format for interpretation of the β-coefficient estimates is therefore 100 × (coefficient), corresponding to the percentage change for a 1-unit increase in the independent variable (while holding all other variables constant).

[3] Values are β-coefficients (95% CIs).

[4] Defined as a BMI ≥25.

[5] Values are ORs (95% CIs).

overweight or obesity, after adjustment for covariates and EI:EE. Although these associations were modest, the findings support the use of a novel data-driven approach to capture temporal eating patterns. This approach is conceptually important, because it considers potentially meaningful interactions between the timing and frequency of EOs across the entire day.

Studies that examined temporal eating patterns on the basis of the timing of EOs across the day are rare. By using cluster analysis, Eicher-Miller et al. (17) observed 4 temporal eating patterns in a representative sample of 9326 US adults on the basis of the timing and frequency of participant EOs and EIs. The authors found a pattern characterized by less definitive but frequently peaked intakes of energy, similar to the "grazing" pattern found in the present study, which was significantly associated with 2.6- to 5.9-units lower Healthy Eating Index-2005 scores and obesity. The bivariate association with obesity, however, might also be explained by the higher representation of night-shift workers found in that cluster. Nonetheless, the findings from this study are in line with our observed association between a "grazing" pattern, lower DGI scores, and adiposity. Although the observed differences in DGI scores of 1–3 units is modest, previous research suggests that even small differences in diet quality scores are associated with obesity (34, 35, 51, 52). However, these findings are based mainly on cross-sectional studies and more prospective research is needed to confirm these associations.

Only a few studies have examined the relation between temporal eating patterns and intakes of energy or nutrients in adults (12, 14, 53, 54). However, it is difficult to compare the present results with these studies because they examined the timing of EOs, EI, or macronutrient intakes at varying time periods of the day that differ from ours. Later timing of the last meal (14) and having a higher proportion of total EI later in the day (e.g., evening or night) (12, 53, 54) have been associated with higher overall EI, higher alcohol intakes (12), and lower percentage of energy from carbohydrates (12). In contrast, higher EIs in the morning have been associated with lower overall EIs (54). The "grazing" pattern observed in the present study was characterized by a higher frequency of EO consumption after 2000, and among women, was significantly associated with higher total EIs but lower energy-adjusted intakes of protein, fiber, and iron when compared with a "conventional" pattern. Although differences in total nutrient intakes were small, a cumulative effect on health of small differences across a range of nutrients cannot be discounted (55).

Evidence suggests that temporal eating patterns have changed in recent times, with trends toward increasing EI later in the day (56) and an increase in reported frequency of all EOs and snacks (57). However, the consequences of these changes on obesity are not clear. Studies have reported a progressive lowering of insulin sensitivity and glucose tolerance into the evening, which explains how a later temporal eating pattern may promote weight gain (58–60). Two cross-sectional studies have found a positive association between evening EI and BMI (13, 61). In addition, in a crossover trial in 6 healthy lean volunteers that controlled for total EI and macronutrient intake (59), higher glucose concentrations and diminished insulin sensitivity were observed in participants who consumed a large evening meal that was high in energy (∼59% total EI) and carbohydrates, but low in fiber, compared with those who consumed that same meal in the

TABLE 5
Associations between temporal eating patterns and waist circumference and central overweight or obesity among Australian men and women[1]

	Waist circumference (cm)[2,3]				Central overweight/obesity[4,5]			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Men (n = 2127)								
Conventional (reference; n = 956)	—	—	—	—	1.00	1.00	1.00	1.00
Later lunch (n = 710)	−1.42 (−2.89, 0.04)	−0.34 (−1.80, 1.12)	−0.15 (−1.60, 1.31)	−0.05 (−1.81, 1.72)	0.87 (0.67, 1.14)	1.01 (0.75, 1.35)	1.04 (0.67, 1.45)	0.99 (0.68, 1.51)
Grazing (n = 461)	−3.64 (−6.07, −1.21)**	−0.94 (−3.00, 1.13)	0.41 (−1.67, 2.49)	−0.15 (−2.21, −1.91)	0.65 (0.49, 0.87)**	0.98 (0.72, 1.32)	1.04 (0.71, 1.52)	1.01 (0.68, 1.51)
Women (n = 2417)								
Conventional (reference; n = 1016)	—	—	—	—	1.00	1.00	1.00	1.00
Later lunch (n = 820)	−1.34 (−3.21, 0.53)	−1.39 (−3.11, 0.33)	−0.92 (−2.56, 0.71)	−0.72 (−2.41, 0.97)	1.10 (0.81, 1.51)	1.10 (0.78, 1.53)	1.20 (0.86, 1.68)	1.29 (0.88, 1.88)
Grazing (n = 581)	−0.38 (−2.54, 1.78)	0.76 (−1.19, 2.70)	1.42 (−0.41, 3.25)	0.94 (−1.26, 3.13)	1.18 (0.84, 1.66)	1.47 (1.00, 2.16)	1.73 (1.19, 2.50)**	1.54 (0.99, 2.40)

[1] Associations were examined by using Wald tests of associations for linear (continuous outcome = waist circumference) and logistic (binary outcome = central overweight/obesity) regression. Model 1 was the crude analysis; model 2 adjusted for age (years; continuous), sedentary time (minutes per day; continuous), alcohol (grams per day; continuous), educational level (low, medium, or high), country of birth (Australia, other mainly English-speaking countries, or all other countries), physical activity guidelines met (yes or no), smoking status (never smoked, past smoker, or current smoker), dieting (yes or no), sleep time (hours per day; continuous) and Dietary Guidelines Index–2013 scores; model 3 adjusted as for model 2 and additionally adjusted for energy misreporting (ratio of energy intake to energy expenditure); model 4 adjusted as for model 2 and additionally adjusted for total energy intake after excluding energy misreporters with ratios of energy intake to energy expenditure of <0.68 or >1.32 (n = 1433 men and n = 1636 women). **P < 0.01.

[2] Defined as waist circumference ≥94 cm for men and ≥80 cm for women.

[3] Values are β-coefficients (95% CIs).

[4] Defined as a BMI ≥25.

[5] Values are ORs (95% CIs).

morning. However, it is unlikely that people would consume more than half of their daily EI at one meal. Consequently, studies that reflect everyday eating patterns are also needed to inform the development of "meals-based" advice and strategies that promote healthy eating and reduce the burden of obesity.

Not all studies have found an association between timing of the last EO (14) or evening EI (12) and adiposity. The inconsistent findings among observational studies may be attributed to differences in how the timing and distribution of EI or EOs were assessed. For example, studies have examined the proportion of total EI across stratified time periods (e.g., morning, midday, or evening) (13), the proportion of EI consumed after 1700 (12), and the ratio of evening to morning EI (61). However, because individuals have multiple EOs across the day and the EIs at these EOs are likely correlated, novel approaches, such as the use of LCA or cluster analysis [e.g., the approaches used in this study and in the study by Eicher-Miller et al. (17)] are needed to better understand the relation between temporal eating patterns and obesity.

In the present study, the adjusted associations between the "grazing" pattern and overweight or obesity and central overweight or obesity among women were attenuated after adjustment for total EI and the exclusion of energy misreporters. Similarly, Wang et al. (13) found that the association between evening EI and overweight or obesity disappeared after excluding energy misreporters. However, these findings should be interpreted with caution, because evidence suggests that the exclusion of energy misreporters may introduce selection bias (62). Indeed, post hoc analysis of our data found that energy-misreporting status was significantly associated with weight status (χ^2 = 32.22, P = 0.0002) and 29% of overweight or women compared with 17% of healthy-weight women were classified as energy underreporters. Therefore, the attenuation of results after excluding energy misreporters may reflect loss of power due to the disproportionate exclusion of women who were overweight or obese. Cross-sectional and longitudinal studies that consider the impact of energy misreporting on the relation between temporal eating patterns, dietary intakes, and obesity are warranted.

Strengths of this study include the large, nationally representative sample and the novel methodology used to examine temporal eating patterns on the basis of information on dietary intake from two 24-h recalls. This study also examined associations with adiposity outcomes on the basis of objective anthropometric measurements and adjusted for multiple important confounders and EI:EE.

Limitations of this study should also be considered. For example, temporal eating patterns were determined by using 2 d of dietary recall and may not capture within-person variation in temporal eating patterns over time. Although individual dietary intakes have been shown to vary day to day (63), further research is needed to understand how temporal eating patterns vary over time. Adjustment for intraindividual variability (a type of random error) in dietary intakes may also increase the precision of estimates (33). Temporal eating patterns were determined with the use of an exploratory, data-driven technique, and the findings may therefore not be generalizable to populations from other countries. Finally, total predicted EE estimates that were used to determine EI:EE assumed a low-active PAL. Future research should use objective measures of PA or consider measuring EE by using the gold-standard method of doubly labeled water in a subsample of participants.

In conclusion, distinct temporal eating patterns, determined by using an LCA approach, were associated with modest but significant differences in overall diet quality and measures of adiposity. Men and women with a "grazing" temporal eating pattern had poorer DGI scores and higher intakes of discretionary foods than did individuals with either a "conventional" or "later lunch" pattern. Among women, the "grazing" pattern was also positively associated with overweight or obesity and central overweight or obesity, after adjustment for EI:EE. Although associations with adiposity were attenuated after the exclusion of energy misreporters and adjustment for total EI, this finding may be explained by the introduction of selection bias. Future research that considers the impact of energy misreporting on the relation between temporal eating patterns and adiposity is warranted.

The authors' responsibilities were as follows—RML, SAM, AT, KML, and AW: designed the research; RML: analyzed the data, wrote the manuscript, and had primary responsibility for its final content; KML: prepared the diet quality variables for analysis; and all authors: read and approved the final manuscript. None of the authors reported a conflict of interest related to the study.

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