ORIGINAL RESEARCH

CURRENT DEVELOPMENTS IN NUTRITION

Eating Behavior and Qualitative Assessments

Psychometric Testing of a Food Timing Questionnaire and Food Timing Screener

Prachi Chakradeo,[1] Heather E Rasmussen,[2] Garth R Swanson,[1] Barbara Swanson,[3] Louis F Fogg,[3] Faraz Bishehsari,[1] Helen J Burgess,[4] and Ali Keshavarzian[1]

[1]Division of Gastroenterology, Hepatology and Nutrition, Department of Medicine, Rush University Medical Center, Chicago, IL, USA; [2]Department of Clinical Nutrition, Rush University Medical Center, Chicago, IL, USA; [3]College of Nursing, Rush University Medical Center, Chicago, IL, USA; and [4]Department of Behavioral Sciences, Rush University Medical Center, Chicago, IL, USA

ABSTRACT

Background: Circadian rhythms coordinate multiple biological processes, and time of eating is an important entrainer of peripheral circadian clocks, including those in the gastrointestinal tract and liver. Whereas time of eating can be assessed through valid and reliable tools designed to measure nutrient intake (24-h recalls), currently there is no easily administered, valid, and reliable tool designed to specifically assess both time of food intake and sleep.

Objectives: The objective of this study was to test the validity and reliability of 2 questionnaires developed to measure food and sleep-wake timing, the Food Timing Questionnaire (FTQ) and Food Timing Screener (FTS), and the agreement between these 2 tools.

Methods: The content validity of these tools was assessed by an expert panel of 10 registered dietitian nutritionists. Adult volunteers ($n = 61$) completed both tools to assess internal consistency and test-retest reliability. Criterion-related validity was determined through the association of FTQ and FTS with 2 valid instruments, the Automated Self-Administered 24-hour recall (ASA24®) Dietary Assessment tool and the Munich Chronotype Questionnaire. Agreement between the FTQ and FTS was tested by calculating the Pearson's correlations for both food and sleep-wake timing.

Results: The content validity indexes for both tools were >0.80, and internal consistency and test-retest reliability coefficients were >0.50 for all meals and sleep-wake times. Correlation coefficients were >0.40 between both tools and criterion measures of food intake and sleep except for snacks. Correlations between the FTQ and FTS for all eating events and sleep were >0.60 except for snack 1.

Conclusions: Both the FTQ and FTS are valid and reliable instruments for meal timing and sleep. However, further psychometric testing in a more expansive and diverse sample will improve the ability of these tools to accurately assess food timing and sleep and their impact on health outcomes. *Curr Dev Nutr* 2022;6:nzab148.

Keywords: validity, reliability, food timing, sleep timing, circadian rhythms, healthy adults, dietary intake

Manuscript received August 24, 2021. Initial review completed November 29, 2021. Revision accepted December 8, 2021. Published online December 16, 2021.
Supported by a Golden Lamp Society dissertation scholarship from the Rush University College of Nursing (to PC). The funders had no role in the design, implementation, analysis, or interpretation of the data.
Author disclosures: The authors report no conflicts of interest.
Supplemental Figures 1 and 2 and Supplemental Tables 1–3 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/cdn/.

Present address for PC: AbbVie, Inc., 1 N Waukegan, North Chicago, IL 60044, USA.
Present address for HER: Department of Nutrition & Health Sciences, University of Nebraska–Lincoln, 1700 N 35th St, Lincoln, NE 68583, USA.
Present address for HJB: Department of Psychiatry, 1500 E Medical Center Drive, University of Michigan, Ann Arbor, MI 48109, USA.
PC and HER contributed equally to this work.
Address correspondence to HER (e-mail: heather.rasmussen@unl.edu).

Abbreviations used: ASA24®, Automated Self-Administered 24-hour recall; CVI, content validity index; FTQ, Food Timing Questionnaire; FTS, Food Timing Screener; ICC, intraclass correlation coefficient; I-CVI, item content validity index; MCTQ, Munich Chronotype Questionnaire; RDN, registered dietitian nutritionist; RUMC, Rush University Medical Center; S-CVI, scale content validity index; S-CVI/Ave, scale content validity index average.

Introduction

Energy intake as reported by eating event has remained mainly consistent in the United States between 1970 and 2010, with slight decreases in energy from meals and increases in energy from snacks (1). Over this same time span, a shift in breakfast and lunch to a later clock time has contributed to a reduced duration of the ingestive period (1). Using data from the NHANES, researchers reported that dinner and after-dinner snack in combination contributes substantially to daily energy intake (2). In addition to eating late at night, skipping meals and

inconsistent meal patterns between types of days are dietary intake patterns that may be considered examples of "irregular eating." Contributing to these meal pattern changes is the increasing number of people who have irregular work hours, which adds to these irregular eating times (3).

Emerging evidence suggests that irregular eating times adversely affect metabolism and contribute to obesity, cardiovascular disease, and type 2 diabetes mellitus (4–6) through disruption of circadian rhythms. The term "circadian" derives from the Latin phrase "circa diem," which means "about a day." Whereas the master, or central, clock located in the suprachiasmatic nucleus is entrained, or synchronized, primarily by the external light-dark cycle (7), clock genes present in peripheral cells—including the intestine, pancreas, liver, and adipose tissue (8, 9)—are entrained by environmental factors such as food intake (10). Accordingly, food intake is the primary zeitgeber, or event that provides stimuli to reset an organism's biological clock, that entrains peripheral circadian rhythms in the intestine and liver (11, 12). Nutrient composition (13), nutrient quantity (14), and time of eating (15) are all thought to entrain the intestinal/hepatic circadian system and thus partially regulate function, nutrition, absorption, and metabolism within the gastrointestinal tract. Specific to timing, irregular eating times, including eating close to the biological night when sleep normally occurs, have been shown to induce circadian misalignment, or a mismatch, between the central and gastrointestinal peripheral clocks (12, 16, 17). This in turn has been associated with proinflammatory states (18, 19) and implicated in regulating blood glucose, energy intake, and body weight (5, 20, 18, 19). In addition, when sleep alone is not aligned with circadian cues, circadian misalignment can result and contribute to alterations of metabolism and health (21). Although the current study did not aim to assess the impact of food or sleep timing on these aforementioned health outcomes, accurately capturing these lifestyle factors is an important first step for future investigations into this relation.

Despite this emerging evidence to support the relation between food and sleep timing and health outcomes, our understanding has been limited owing to the lack of validated tools to assess time of eating. Although a number of smart phone applications have been developed that could potentially capture the timing of eating events (22–26), none have been adequately validated. And, although food records and 24-h recalls can also capture time of eating, these tools have several shortcomings, including the time required to complete them and the inability to specifically capture variations in food intake driven by work or social schedule unless multiple days or types of days are documented. In addition, although the current study is not the first to explore use of a food timing questionnaire to identify meal timing or patterns (27), ours is, as far as we know, the first short screening tool specifically designed to identify diet-induced intestinal/hepatic circadian disruption through the simultaneous measurement of time of eating for all days of the week and on different types of days and the relation between food and sleep timing. The aim of the present study was to fill this unmet need by validating 2 brief assessment tools, the Food Timing Questionnaire (FTQ) and a shorter Food Timing Screener (FTS), using a valid measure of dietary intake [Automated Self-Administered 24-hour recall (ASA24®)] (28) and sleep [Munich Chronotype Questionnaire (MCTQ)] (29) in a sample of adults. Validation of these tools will provide support for accurate assessment of these measures for future studies designed to assess the impact on health outcomes affected by circadian rhythms.

Methods

We developed 2 structured questionnaires that measure usual time of eating, the FTQ and FTS, to be used both in practice and in research where time of eating is assessed. These tools were designed to be both easy to understand and quick to complete by individuals of all education levels and backgrounds. We then evaluated their psychometric rigor by assessing content validity, internal consistency, test-retest reliability, and criterion-related validity.

Study population

To test the content validity of the FTQ and FTS, a sample of 10 registered dietitian nutritionists (RDNs) with >2 y of clinical experience as an RDN was used. To test internal consistency, test-retest reliability, and criterion-related validity, healthy volunteers were recruited from Rush University Medical Center (RUMC). Volunteers were excluded if they met any of the following criteria: *1*) were unable to give informed consent; *2*) were from a vulnerable population, including participants <18 y old, currently pregnant, and prisoners; *3*) were shift workers; and *4*) had traveled across >2 time zones in the past week. The study was approved by the RUMC Institutional Review Board, and procedures followed were in accordance with the ethical standards of the Helsinki Declaration of 1975 as revised in 1983.

Procedures

Items on the initial FTQ and FTS were developed by experts in both chronobiology and nutrition. Constructs were conceptualized and modified by these experts based on content expertise, clinical experience, and the anticipated application of the tool. Tools were informally pilot tested with both clinicians and non-experts before deeming the tools ready for formal review by content experts.

Ten RDNs (content experts) were sampled to test the content validity of the FTQ and FTS. A link to an online survey was sent to the content experts after they consented to participate by email. The content experts were asked to evaluate each item on the FTQ and FTS for both relevance and clarity on a 4-point scale. Comments related to each FTQ and FTS section were solicited to assist in guiding changes to the tools. A reminder email was sent to all experts 10 d after the original email. The survey was completed in 2 rounds, and all responses were confidential with no personal identifiers collected.

For internal consistency, test-retest reliability, and criterion-related validity, healthy volunteers were recruited through word-of-mouth. Interested, self-selected volunteers contacted the researchers in person, by phone, or through email. All eligible volunteers were sent study details by email, and those who were interested in participating consented electronically through REDCap®. Participants then completed a demographics questionnaire, the FTQ, FTS, and MCTQ. Forty-eight hours after completing the first set of questionnaires (time point 1), the participants electronically completed a second FTQ and FTS (time point 2). The participants were then directed to complete the ASA24® dietary assessment tool for 7 consecutive days to capture both free days and work days.

FTQ

The FTQ (**Supplemental Figure 1**) is a self-report questionnaire that assesses an individual's usual eating and sleep habits on all 7 d of the

week through soliciting responses to 6 questions for each of the 7 d of the week. Individuals can select school/work day or free time/day off for each day, herein called work days and free days, respectively. Respondents report, in 1 sitting, the time of eating for 3 meals (breakfast, lunch, and dinner) and ≤3 snacks (snack 1, snack 2, and snack 3), the times of awakening and falling asleep, whether s/he awakens from sleep to eat, and the largest eating event of the day (self-defined most food to identify the relation of energy intake to time of day in the absence of direct reporting of energy intake) for all 7 d of the week. The FTQ inquires about sleep-wake time to be able to identify the relation between food intake and sleep timing.

FTS

The FTS (**Supplemental Figure 2**) is a brief self-report screener that assesses an individual's usual eating and sleep habits through 6 questions pertaining to all days of the week but with the response option dichotomized into 2 types of days: school/work days and free days/days off. Respondents report, in 1 sitting, the time of eating for 3 meals (breakfast, lunch, and dinner) and ≤3 snacks (snack 1, snack 2, and snack 3), the times of awakening and falling asleep, whether s/he awakens from sleep to eat, and the largest eating event of the day (self-defined most food to identify the relation of energy intake to time of day in the absence of direct reporting of energy intake) on each type of day. The FTS was designed to be a concise form of the FTQ to be used independently when time to complete the full FTQ is limited. As with the FTQ, sleep-wake time is included to be able to identify the relation between food intake and sleep timing.

MCTQ

The MCTQ is a self-administered, validated questionnaire (29–31) that measures individual chronotype. It contains a total of 14 questions pertaining to sleep timing, accompanied by pictures describing sleep-related activities such as bedtime, length of time to fall asleep, time of awakening, and use of an alarm clock. All questions are asked separately for workdays/schooldays and for free days (weekend/vacation). The validity of the MCTQ has been supported by positive correlations between MCTQ-measured chronotype and dim light melatonin onset (30) and associations between mid-sleep on free days corrected for sleep-debt accumulated through weekdays (MSFsc) and dim light melatonin onset (30, 32). The MCTQ was used to validate the sleep-wake time questions on the FTQ and FTS. Sleep timing was identified using the MCTQ response options "I actually get ready to fall asleep at __ o'clock" and "I wake up at __ o'clock."

ASA24® recalls

The ASA24® is a valid and reliable (33) web-based tool developed by the National Cancer Institute to capture 24-h dietary intake (28, 34). Participants report each food item that they consumed in the last 24 h using the Automated Multiple-Pass Method, a reference standard adapted from the USDA (35). The ASA24® guides the respondent through multiple steps of recalls that include reporting each meal or snack or any other time that foods or beverages were consumed, a comprehensive list of foods and drinks consumed, and finally a detail step that includes quantity of food consumed, any forgotten foods, and a final review. Respondents are asked to self-define meals and snacks, as well as document the times of all eating events. The criterion validity of the ASA24® recalls is supported by high agreement (~80%) with traditional interviewer-administered recalls (36) and comparable energy intake estimates between ASA24® recalls and the interview-administered Automated Multiple-Pass Method in healthy men and women (37). A total of 7 consecutive ASA24® recalls were used to validate the time of eating events and the largest meal on the FTQ and FTS. Participants were excluded if not all 7 recalls were completed.

Statistical analysis

Based on psychometric studies done in the field of nutrition, the correlations between different FFQs or between FFQs and recalls tend to be in the range of 0.3–0.6 (extracted from https://epi.grants.cancer.gov/cgi-bin/dacv/index.pl). Using 0.3 as the correlation coefficient, it was determined that a sample size of 60 would yield a power of 0.80 given a 1-tailed α of 0.05.

Using 4-point Likert scales, content validity indexes (CVIs) were calculated to assess the relevance and clarity of both the individual items on the FTQ and FTS and the overall scales. For relevance, the scale was as follows: 1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, 4 = very relevant. For clarity, the scale was as follows: 1 = not clear, 2 = somewhat clear, 3 = quite clear, 4 = very clear. For each item, the item-CVI (I-CVI) was computed as the number of experts giving a rating of either 1 and 2 or 3 and 4 (thus dichotomizing the ordinal scale into relevant and not relevant, and clear and not clear), divided by the total number of experts (38, 39). The scale CVI (S-CVI) was calculated by dividing the total number of questions that were scored as 3 or 4 by the total number of questions. The S-CVI/Ave was calculated by taking the average of the S-CVIs. The I-CVI threshold was defined as ≥0.78 and S-CVI/Ave was defined as ≥0.9 (40–42).

To assess internal consistency of the FTQ, intraclass correlation coefficients (ICCs) for the timing of eating events across all self-reported work days, as well as free days, were calculated. The internal consistency of the FTS was not tested because this tool only has 1 work day and 1 free day. To assess test-retest reliability, Pearson's correlations were calculated for the timings for breakfast, lunch, dinner, and snacks at the 2 time points, 48 h apart, for both the FTQ and FTS. Work days and free days were analyzed separately.

Criterion-related validity of the FTQ was assessed by calculating Pearson's correlations between reported usual times of breakfast, lunch, dinner, snack 1, and snack 2 intake for all work and free days as measured by the first administered FTQ and the 7 ASA24® recalls. Additional snacks were not reported because of low overall consumption. The reported times of each eating event on the ASA24® recalls were averaged for work days and free days to compare them with the times of eating on the first administered FTS. Agreement between sleep-wake timings was assessed by calculating Pearson's correlations for the sleep-wake timings on the FTQ/FTS and the MCTQ; the reported times on the FTQ were averaged for work days and free days to compare them with the timings on the MCTQ. Cohen's κ values were calculated to assess agreement on the largest meals between the FTQ/FTS and ASA24® recalls, with the former (both FTQ and FTS) self-defined by the participant and the latter defined by the meal with the highest caloric content. Agreement between the first administered FTQ and FTS was assessed by calculating Pearson's correlations for all meal, snack 1 and 2, and sleep timings on the FTS with an average of these same timings over the self-reported work days and free days on the FTQ. Because only

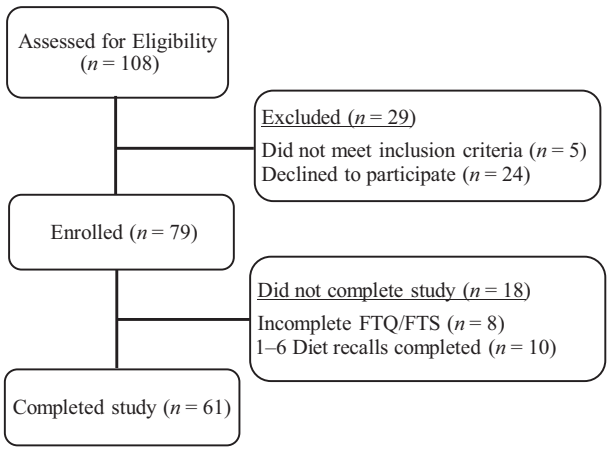

FIGURE 1 Flow diagram depicting participant enrollment and attrition. Study completion was defined as those who fully completed seven 24-h recalls, 2 FTQs, and 1 FTS. FTQ, Food Timing Questionnaire; FTS, Food Timing Screener.

3 participants reported waking up at night to eat on the FTQ and FTS, these data were not included in the analyses.

Results

Content validity

A total of 9 out of 10 experts responded to the survey for a 90% response rate. All I-CVI relevance scores for each item on the FTQ were >0.80, whereas those for clarity were >0.40. The S-CVI/Ave for relevance was 0.90 and for clarity was 0.68. All I-CVI relevance scores for each item on the FTS were >0.80, whereas those for clarity were >0.63. The S-CVI/Ave for relevance was 0.94 and for clarity was 0.80.

Because I-CVI and S-CVI/Ave for relevance of items on both the FTQ and FTS met the thresholds, all items on both tools were deemed relevant. To increase the clarity of both tools, the instructions and questions on the FTQ and FTS were revised based on expert comments. Nine of the 10 (90%) experts then evaluated the revised FTQ for clarity, and the subsequent I-CVI and S-CVI/Ave scores were both 1.0. Because the FTS revisions were minimal based on the initial CVI and expert comments, the experts were not asked to re-evaluate this tool.

Reliability and criterion-related validity

To test FTQ internal consistency, as well as test-retest reliability and criterion-related validity of both tools, a total of 79 participants were enrolled of whom 61 completed the study (**Figure 1**). The sample was 72.1% female, with a mean ± SD age of 34.9 ± 11.2 y and BMI of 26.8 ± 5.4 kg/m^2. Of the sample, 63.9% were employed full time, with a majority (67.2%) reporting 5 work/school days and 2 free days. **Table 1** shows participant characteristics.

Internal consistency.

For the FTQ, the mean ICC on work days for all events was 0.84, with all ICCs >0.70 (**Supplemental Table 1**). On average, the ICCs on free days were somewhat lower than those on work days; the mean ICC on free days for all events was 0.69, with 75% of ICCs >0.60. The lowest ICC (0.27) was for snack 1 on free days. All ICCs were statistically significant at the 0.05 level except for snack 1 on free days.

TABLE 1 Demographics of study participants[1]

Characteristic	Value
Age, y	34.9 ± 11.24
Gender	
Male	17 (27.9)
Female	44 (72.1)
BMI, kg/m^2	26.82 ± 5.37
Race	
Native American	1 (1.6)
Asian	14 (23.0)
African American	12 (19.7)
White	34 (55.7)
Ethnicity	
Hispanic	12 (19.7)
Not Hispanic	49 (80.3)
Education	
High school dropout	2 (3.3)
High school graduate/GED	8 (13.1)
Associates degree	6 (9.8)
Bachelor's degree	15 (24.6)
Graduate/professional degree	30 (49.2)
Employment status	
Full time	39 (63.9)
Part time	5 (8.2)
Retired	3 (4.9)
Student	10 (16.4)
Homemaker	2 (3.3)
Unemployed	2 (3.3)

[1] $n = 61$. Values are mean ± SD or n (%). GED, general educational development.

Test-retest reliability.

The mean Pearson's correlation coefficient for all eating events between the 2 time points was 0.75 and 0.66 for the FTQ and FTS, respectively, with 70% of correlations >0.70 for both the FTQ and FTS (**Table 2**). On average, the Pearson's correlations on free days were lower than those on work days for both the FTQ and FTS. All test-retest correlations for the FTQ were significant, and all correlations except for snack 1 on the FTS were significant at the 0.05 level ($r = 0.09$, $P = 0.62$).

Criterion-related validity.

Breakfast, lunch, and dinner times on the FTQ and FTS were significantly correlated to the reported eating events on the ASA24® recalls (**Figure 2**). A majority of the correlations for meal timing were >0.40 except for breakfast on free days for both the FTQ and FTS, as well as dinner on the FTQ for work days and lunch on the FTS for free days. Overall, correlation coefficients for meals were either similar or higher for the FTS compared with the FTQ in relation to the ASA24® dietary recalls. Snack times between the ASA24® recalls and both the FTQ and FTS were not significantly correlated. There was poor agreement for the largest meal reported on the FTQ (**Supplemental Table 2**) and FTS (Cohen κ on work day: 0.23 and on free day: 0.19) compared with the ASA24® dietary recalls.

Sleep-wake times on the FTQ and FTS were compared with those on the MCTQ. All correlations for awakening and sleep times were significant, with mean correlations of 0.90 and 0.58 for awakening and sleep

TABLE 2 Test-retest reliability of the FTQ and FTS on 2 types of days[1]

	FTQ		FTS	
Event	Work day	Free day	Work day	Free day
Breakfast	0.884	0.927	0.758	0.759
Snack 1	0.784	0.485	0.731	0.090
Lunch	0.928	0.817	0.835	0.639
Snack 2	0.721	0.346	0.769	0.647
Dinner	0.893	0.647	0.786	0.546
Awaken	0.967	0.947	0.938	0.866
Fall asleep	0.709	0.733	0.641	0.712

[1] $P < 0.05$ for all correlations except FTS snack 1 on free days, $P = 0.62$. FTQ, Food Timing Questionnaire; FTS, Food Timing Screener.

times on the FTQ, and mean correlations of 0.58 and 0.56 for awakening and sleep times on the FTS, respectively (**Supplemental Table 3**).

FTQ and FTS agreement

In addition, the FTQ was compared with the FTS for food and sleep-wake timings (**Table 3**). Time of food intake and sleep were significantly correlated for sleep/awakening and all eating events except for snack 1 on weekends.

Discussion

Time of eating has emerged as an additional important and modifiable factor that may affect health, with irregular eating patterns, or eating at what may be considered the wrong time, associated with metabolic and neuropsychological disorders (17, 43). Despite recent evidence to support this association, simple tools to accurately assess when individuals usually eat do not exist. Our findings suggest that, overall, both the FTQ and FTS are reliable and valid tools to assess not only usual time of meal intake, but also simultaneously usual sleep-wake time. In addition, our findings indicate that the FTQ and FTS are stable with repeat administration in respect to breakfast, lunch, and dinner, but are more limited when assessing both timing of specific snacks and the largest meal.

Within type of day, timing of eating events was largely consistent, as seen by high ICCs for overall eating events. This finding is supported in a sample comparing time of eating within work days (44, 45). Although still significant, ICCs were slightly lower for eating events on free days, and specifically, consumption of the first snack (snack 1) was not consistent within free days. This is aligned with current literature, indicating that food intake on free days is influenced by external factors that are not consistent from day to day (45). Accordingly, it is likely that this variability in eating time on free days also contributed to lower test-retest reliability and criterion validity for snacks because individuals are less likely to be able to consistently identify a set time for usual eating events when intake is highly variable. However, meal timing on both the FTQ and FTS was highly stable.

Whereas intake within types of days, especially work days, is relatively stable, the time at which an individual eats varies between work days and free days (44–46), requiring validation for both types of days. Overall, both the FTQ and FTS were able to capture meal timing for both types of days, with the highest correlation for breakfast and lunch on work days. This is likely largely driven by rigidity of the work schedule, an important factor that also drives sleep schedule and thus circadian rhythms (47). Whereas the relations between meal times on the FTQ/FTS and 24-h recalls were significant for all meals, less relation was seen for dinner on work days and breakfast on free days. It is likely that lower consistency in food timing on free days

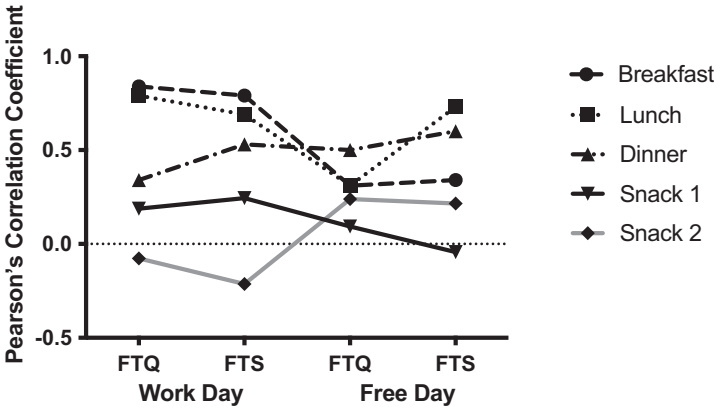

FIGURE 2 Correlations between the FTQ/FTS and seven 24-h recalls [Automated Self-Administered 24-hour recall (ASA24®)] on work days and free days for breakfast, lunch, dinner, snack 1, and snack 2. All meal times were significantly correlated at $P < 0.05$, whereas no significant relation was found for snack times between tools. FTQ, Food Timing Questionnaire; FTS, Food Timing Screener.

TABLE 3 Agreement between timing of eating events and sleep on the Food Timing Questionnaire and Food Timing Screener[1]

Event	Work day	Free day
Breakfast	0.845	0.761
Snack 1	0.681	0.418
Lunch	0.923	0.637
Snack 2	0.827	0.843
Dinner	0.842	0.630
Awaken	0.934	0.809
Fall asleep	0.903	0.683

[1] $P < 0.05$ for all correlations (r) except snack 1 on free days, $P = 0.059$.

contributed to the lower correlations on these days between the 2 assessment methods. Similarly, inconsistent snack intake may be driving the lack of relation between snack times on the FTQ/FTS and 24-h recalls on both types of days. In addition, the provided guidance on the FTQ/FTS indicating a broad definition of a snack, any food or drink except for plain water, may have increased the difficulty in determining time of snack intake. Although this is a clear limitation of these tools, the majority (78%) of energy intake originates from meal consumption in the United States (2). In addition, the contribution of snack intake to overall diet quality is unclear, with limited evidence suggesting that, although snacks may indeed contribute to increased diet quality, meals may play a larger role in diet quality than snacks in certain adult populations (48, 49). Evidence supporting differences in snack nutrient composition and timing by age (50, 51) should be taken into consideration before applying this tool to other populations, especially if administered without a coinciding assessment of nutrient composition.

One interesting finding was the similar ability of the FTS to capture time of eating and sleep when compared with the FTQ. In addition to exhibiting stability over time, correlation coefficients for meal timing between the 24-h recalls and the FTS were either similar or higher compared with the FTQ. It is likely that the high ICCs on the FTQ allow for summary data to be collected (average time of eating on work days and free days) and support use of the FTS. Although completion of the FTQ allowed for a detailed understanding of food intake for individual days and did not require significant time, certain clinical or research situations may call for further brevity. Our findings support requiring only 1 response option for food intake by type of day, despite the potential for variability in timing, especially on free days.

Although both tools were found to be valid and reliable to capture meal timing, especially during the weekdays, neither is able to capture the largest meal of the day. The definition of the "largest meal" was not included in the tool instructions, because response guidance based on either energy content or volume would not have provided clarity. A limited ability to identify the energy density of foods has been seen elsewhere (52) and likely contributes to the difficulty in self-identifying the largest meal as defined by energy intake in the current study. This question was included because the quantity of energy intake may influence circadian rhythms (14), and a majority of individuals consume a substantial proportion of their energy late in the day (2), with this late consumption disruptive to circadian rhythms and related health outcomes (5, 53). However, it is possible that the ability to capture the eating event at which the most energy is consumed is not possible in such a brief format and rather should be collected through utilization of 24-h recalls if time allows.

Our study has several strengths. To our knowledge, this is the first study to demonstrate psychometric maturity for measures of food timing. Multiple studies have shown that time of eating is critical for metabolic homeostasis (5, 6, 54) and many signaling pathways responsible for normal cellular function. Irregular eating patterns have also been associated with intestinal circadian disruption, which can be a predisposing factor for disease, including promoting carcinogenesis (55, 56), obesity, and metabolic syndrome (57). Validation of these tools allows for future use of these tools to explicate the health outcomes of this timing. Second, content experts were RDNs trained in dietary assessment. Third, a criterion measure of food intake, the 24-h recall, was used for validation of time of eating, and this was done for 7 d to capture both weekdays and weekend days; in addition, we confirmed that the week of dietary reporting reflected participants' usual intake. Lastly, both the FTQ and FTS can be used to capture meal and sleep-wake timing, thus enabling researchers to look at the relation between sleep and food consumption rhythms.

The study does have several limitations. The study sample was primarily highly educated, white females and thus not representative of the general population. The ICC was calculated across all days within type of day; thus, a low ICC may reflect an inconsistent eating pattern across work days or free days rather than indicating that the tool is not reliable. Whereas 53% of individuals in the United States reported snack intake after dinner, only ~20% of our small sample consumed a snack at this time (data not shown); because of this low frequency, the relation of what would be snack 3 intakes between tools is uncertain. We used ASA24® to administer seven 24-h recalls over 1 wk, which may not have been an adequate reflection of usual time of eating. We used the ASA24® as a criterion measure, but ASA24® or the Automated Multiple-Pass Method used in NHANES has been validated for nutrient intake but not specifically time of intake. In addition, despite allowing for identification of food timing, both the FTQ and FTS do not allow for collection of nutrient intake. Because it is known that specific nutrients can also influence circadian rhythms (14), ideally a more comprehensive tool should be used to fully determine the impact of food intake, in terms of both nutrients and timing, on circadian rhythms. Although this can be accomplished through a 24-h recall, especially with the recent release of the ASA24® that includes a sleep module, multiple 24-h recalls would need to be completed to accurately identify both factors; completion of 1 or more 24-h dietary recalls is not often feasible in certain clinical and research situations because of responder burden. Despite the brevity of the FTQ and FTS (~8 and ~5 min to complete, respectively) as seen in our current administration among >400 participants in a clinical setting, the exact amount of time needed to complete these tools was not assessed in the current study. Because the FTQ and FTS are self-report instruments, they are subject to common method bias; future studies with direct observation of time of eating would need to be done to overcome this limitation. Lastly, if a participant did not indicate an eating time for an eating event, this was counted as missing data because we were not able to differentiate between skipped eating events and missing data.

Future directions for the FTQ and FTS include additional cognitive testing on non-experts, including those with a diversity of backgrounds; modifying the definitions of snacks and the largest meal; as well as

consideration of physical activity timing assessment to incorporate an additional lifestyle measure thought to influence circadian rhythms (58). In addition, future studies including FTQ/FTS administration and assessment of biological outcomes would be needed to identify the true utility of the FTQ and FTS to predict these outcomes or be used as a tool for intervention.

In conclusion, both the FTQ and FTS are valid and reliable instruments for meal timing and sleep-wake timing. These tools are unique in that both the FTQ and FTS can be used to capture both of these 2 key modifiable lifestyle factors that affect health outcomes and can be incorporated into studies to advance the field of food timing and circadian rhythms. In addition, these easy-to-administer and validated questionnaires could accurately assess meal timing to identify those with irregular meal patterns to modify risk for those susceptible to metabolic and inflammatory disorders. However, further psychometric testing in a more expansive and diverse sample and subsequent modification may improve the ability of these tools to accurately assess food, especially snack, and sleep-wake timing.

Acknowledgments

The authors' responsibilities were as follows—HER, AK, and FB: designed the questionnaires; HER, AK, and LFF: developed the study design; BS, GRS, and HJB: assisted in study design development; PC: conducted the study as part of her PhD dissertation; PC, HER, and LFF: analyzed the data; PC and HER: wrote the first draft of the manuscript; PC, HER, GRS, BS, LFF, HJB, and AK: had primary responsibility for the final content; and all authors: read and approved the final manuscript.

Data Availability

Data described in the article, code book, and analytic code will be made available upon request pending application and approval.

References

1. Kant AK, Graubard BI. 40-year trends in meal and snack eating behaviors of American adults. J Acad Nutr Diet 2015;115(1):50–63.
2. Kant AK. Eating patterns of US adults: meals, snacks, and time of eating. Physiol Behav 2018;193:270–8.
3. Lowden A, Moreno C, Holmbäck U, Lennernäs M, Tucker P. Eating and shift work – effects on habits, metabolism, and performance. Scand J Work Environ Health 2010;36(2):150–62.
4. Garaulet M, Gómez-Abellán P, Alburquerque-Béjar JJ, Lee Y-C, Ordovás JM, Scheer F. Timing of food intake predicts weight loss effectiveness. Int J Obes 2013;37(4):604–11.
5. Bandín C, Scheer FAJL, Luque AJ, Ávila-Gandía V, Zamora S, Madrid JA, Gómez-Abellán P, Garaulet M. Meal timing affects glucose tolerance, substrate oxidation and circadian-related variables: a randomized, crossover trial. Int J Obes 2015;39(5):828–33.
6. Arble DM, Bass J, Laposky AD, Vitaterna MH, Turek FW. Circadian timing of food intake contributes to weight gain. Obesity 2009;17(11):2100–2.
7. Moore RY. Neural control of the pineal gland. Behav Brain Res 1995;73(1–2):125–30.
8. Balsalobre A. Clock genes in mammalian peripheral tissues. Cell Tissue Res 2002;309(1):193–9.
9. Schibler U, Ripperger J, Brown SA. Peripheral circadian oscillators in mammals: time and food. J Biol Rhythms 2003;18(3):250–60.
10. Davidson AJ, Poole AS, Yamazaki S, Menaker M. Is the food-entrainable circadian oscillator in the digestive system? Genes Brain Behav 2003;2(1):32–9.
11. Froy O, Chapnik N, Miskin R. Mouse intestinal cryptdins exhibit circadian oscillation. FASEB J 2005;19(13):1920–2.
12. Stokkan K-A, Yamazaki S, Tei H, Sakaki Y, Menaker M. Entrainment of the circadian clock in the liver by feeding. Science 2001;291(5503):490–3.
13. Froy O. The relationship between nutrition and circadian rhythms in mammals. Front Neuroendocrinol 2007;28(2–3):61–71.
14. Oosterman JE, Kalsbeek A, la Fleur SE, Belsham DD. Impact of nutrients on circadian rhythmicity. Am J Physiol Regul Integr Comp Physiol 2015;308(5):R337–50.
15. Mendoza J. Circadian clocks: setting time by food. J Neuroendocrinol 2007;19(2):127–37.
16. Yoshida C, Shikata N, Seki S, Koyama N, Noguchi Y. Early nocturnal meal skipping alters the peripheral clock and increases lipogenesis in mice. Nutr Metab 2012;9(1):78.
17. Yoon J-A, Han D-H, Noh J-Y, Kim M-H, Son GH, Kim K, Kim C-J, Pak YK, Cho S. Meal time shift disturbs circadian rhythmicity along with metabolic and behavioral alterations in mice. PLoS One 2012;7(8):e44053.
18. Lopez-Minguez J, Gómez-Abellán P, Garaulet M. Timing of breakfast, lunch, and dinner. Effects on obesity and metabolic risk. Nutrients 2019;11(11):2624.
19. McHill AW, Phillips AJK, Czeisler CA, Keating L, Yee K, Barger LK, Garaulet M, Scheer FAJL, Klerman EB. Later circadian timing of food intake is associated with increased body fat. Am J Clin Nutr 2017;106(5):1213–19.
20. Reutrakul S, Van Cauter E. Interactions between sleep, circadian function, and glucose metabolism: implications for risk and severity of diabetes. Ann N Y Acad Sci 2014;1311(1):151–73.
21. Foster RG. Sleep, circadian rhythms and health. Interface Focus 2020;10(3):20190098.
22. Lee W, Chae YM, Kim S, Ho SH, Choi I. Evaluation of a mobile phone-based diet game for weight control. J Telemed Telecare 2010;16(5):270–5.
23. Gill S, Panda S. A smartphone app reveals erratic diurnal eating patterns in humans that can be modulated for health benefits. Cell Metab 2015;22(5):789–98.
24. Mattila E, Lappalainen R, Pärkkä J, Salminen J, Korhonen I. Use of a mobile phone diary for observing weight management and related behaviours. J Telemed Telecare 2010;16(5):260–4.
25. Tsai CC, Lee G, Raab F, Norman GJ, Sohn T, Griswold WG, Patrick K. Usability and feasibility of PmEB: a mobile phone application for monitoring real time caloric balance. Mob Netw Appl 2007;12(2–3):173–84.
26. Carter MC, Burley VJ, Nykjaer C, Cade JE. Adherence to a smartphone application for weight loss compared to website and paper diary: pilot randomized controlled trial. J Med Internet Res 2013;15(4):e32.
27. Bertéus Forslund H, Lindroos AK, Sjöström L, Lissner L. Meal patterns and obesity in Swedish women—a simple instrument describing usual meal types, frequency and temporal distribution. Eur J Clin Nutr 2002;56(8):740–7.
28. Subar AF, Kirkpatrick SI, Mittl B, Zimmerman TP, Thompson FE, Bingley C, Willis G, Islam NG, Baranowski T, McNutt S, et al. The Automated Self-Administered 24-hour dietary recall (ASA24): a resource for researchers, clinicians, and educators from the National Cancer Institute. J Acad Nutr Diet 2012;112(8):1134–7.
29. Di Milia L, Adan A, Natale V, Randler C. Reviewing the psychometric properties of contemporary circadian typology measures. Chronobiol Int 2013;30(10):1261–71.
30. Kantermann T, Sung H, Burgess HJ. Comparing the Morningness-Eveningness Questionnaire and Munich ChronoType Questionnaire to the dim light melatonin onset. J Biol Rhythms 2015;30(5):449–53.
31. Zavada A, Gordijn MCM, Beersma DGM, Daan S, Roenneberg T. Comparison of the Munich Chronotype Questionnaire with the Horne-Östberg's Morningness-Eveningness score. Chronobiol Int 2005;22(2):267–78.
32. Kitamura S, Hida A, Aritake S, Higuchi S, Enomoto M, Kato M, Vetter C, Roenneberg T, Mishima K. Validity of the Japanese version of the Munich Chronotype Questionnaire. Chronobiol Int 2014;31(7):845–50.

33. Kirkpatrick SI, Subar AF, Douglass D, Zimmerman TP, Thompson FE, Kahle LL, George SM, Dodd KW, Potischman N. Performance of the Automated Self-Administered 24-hour Recall relative to a measure of true intakes and to an interviewer-administered 24-h recall. Am J Clin Nutr 2014;100(1): 233–40.
34. Zimmerman TP, Hull SG, McNutt S, Mittl B, Islam N, Guenther PM, Thompson FE, Potischman NA, Subar AF. Challenges in converting an interviewer-administered food probe database to self-administration in the National Cancer Institute Automated Self-Administered 24-Hour Recall (ASA24). J Food Compos Anal 2009;22:S48–51.
35. Moshfegh AJ, Rhodes DG, Baer DJ, Murayi T, Clemens JC, Rumpler WV, Paul DR, Sebastian RS, Kuczynski KJ, Ingwersen LA, et al. The US Department of Agriculture Automated Multiple-Pass Method reduces bias in the collection of energy intakes. Am J Clin Nutr 2008;88(2):324–32.
36. Kirkpatrick SI, Potischman N, Dodd KW, Douglass D, Zimmerman TP, Kahle LL, Thompson FE, George SM, Subar AF. The use of digital images in 24-hour recalls may lead to less misestimation of portion size compared with traditional interviewer-administered recalls. J Nutr 2016;146(12):2567–73.
37. Thompson FE, Dixit-Joshi S, Potischman N, Dodd KW, Kirkpatrick SI, Kushi LH, Alexander GL, Coleman LA, Zimmerman TP, Sundaram ME, et al. Comparison of interviewer-administered and Automated Self-Administered 24-Hour dietary recalls in 3 diverse integrated health systems. Am J Epidemiol 2015;181(12):970–8.
38. Grant JS, Davis LL. Selection and use of content experts for instrument development. Res Nurs Health 1997;20(3):269–74.
39. Waltz CF, Bausell BR. Nursing research: design statistics and computer analysis. Philadelphia, PA: FA Davis Company; 1981.
40. Polit DF, Beck CT, Owen SV. Is the CVI an acceptable indicator of content validity? Appraisal and recommendations. Res Nurs Health 2007;30(4): 459–67.
41. Lynn MR. Determination and quantification of content validity. Nurs Res 1986;35(6):382–6.
42. Waltz CF. Measurement in nursing and health research. New York: Springer Publishing Company; 2005.
43. Yoshida J, Eguchi E, Nagaoka K, Ito T, Ogino K. Association of night eating habits with metabolic syndrome and its components: a longitudinal study. BMC Public Health 2018;18(1):1366.
44. Houser HB, Bebb HT. Individual variation in intake of nutrients by day, month, and season and relation to meal patterns: implications for dietary survey methodology. In: Committee on Food Consumption Patterns, Food and Nutrition Board, National Research Council, editors. Assessing changing food consumption patterns. Washington (DC): National Academy Press; 1981. p. 155–79.
45. Thompson FE, Larkin FA, Brown MB. Weekend-weekday differences in reported dietary intake: the nationwide food consumption survey, 1977–78. Nutr Res 1986;6(6):647–62.
46. Larkin FA, Metzner HL, Guire KE. Comparison of three consecutive-day and three random-day records of dietary intake. J Am Diet Assoc 1991;91(12):1538–42.
47. Boivin DB, Boudreau P. Impacts of shift work on sleep and circadian rhythms. Pathol Biol 2014;62(5):292–301.
48. Murakami K, Livingstone MBE. Associations between meal and snack frequency and diet quality in US adults: National Health and Nutrition Examination Survey 2003-2012. J Acad Nutr Diet 2016;116(7):1101–13.
49. Leech RM, Livingstone KM, Worsley A, Timperio A, McNaughton SA. Meal frequency but not snack frequency is associated with micronutrient intakes and overall diet quality in Australian men and women. J Nutr 2016;146(10):2027–34.
50. Krok-Schoen JL, Jonnalagadda SS, Luo M, Kelly OJ, Taylor CA. Nutrient intakes from meals and snacks differ with age in middle-aged and older Americans. Nutrients 2019;11(6):1301.
51. Wang D, Van der Horst K, Jacquier EF, Afeiche MC, Eldridge AL. Snacking patterns in children: a comparison between Australia, China, Mexico, and the US. Nutrients 2018;10(2):198.
52. Peng M, Cahayadi J, Geng X, Eidels A. Mixed messages: assessing interactions between portion-size and energy-density perceptions in different weight and sex groups. Appetite 2020;144:104462.
53. Rangaraj VR, Siddula A, Burgess HJ, Pannain S, Knutson KL. Association between timing of energy intake and insulin sensitivity: a cross-sectional study. Nutrients 2020;12(2):503.
54. Wehrens SMT, Christou S, Isherwood C, Middleton B, Gibbs MA, Archer SN, Skene DJ, Johnston JD. Meal timing regulates the human circadian system. Curr Biol 2017;27(12):1768–75.e3.
55. Gery S, Koeffler HP. Circadian rhythms and cancer. Cell Cycle 2010;9(6):1097–103.
56. Izumi H, Wang K, Morimoto Y, Sasaguri Y, Kohno K. Circadian disruption and cancer risk: a new concept of stromal niche. Int J Oncol 2014;44(2):364–70.
57. Johnston JD, Ordovás JM, Scheer FA, Turek FW. Circadian rhythms, metabolism, and chrononutrition in rodents and humans. Adv Nutr 2016;7(2):399–406.
58. Gabriel BM, Zierath JR. Circadian rhythms and exercise—re-setting the clock in metabolic disease. Nat Rev Endocrinol 2019;15(4):197–206.