



**ORIGINAL RESEARCH:
EMPIRICAL RESEARCH - QUANTITATIVE**

Snacking among shiftwork nurses related to non-optimal dietary intake

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Abstract

Aims: To compare nurses' non-optimal eating behaviours across different shifts, to examine whether non-day shifts were related to deviation from optimal dietary behaviours compared with day shifts and whether such deviation was related to non-optimal macronutrient intake.

Design: This is a 4-day intensive longitudinal study.

Methods: A convenience sample of hospital nurses was recruited in Taiwan. From September 2018 through January 2019, 120 participants completed 4-days of 24-h dietary recalls. One-way ANOVA and Kruskal-Wallis *H* test were used to compare differences in energy and macronutrient intake and frequency of meals and snacking, respectively. Generalized linear regressions examined (1) the associations between shiftwork schedules and non-optimal eating behaviours and (2) associations between non-optimal eating and high energy contribution of non-optimal macronutrients.

Results: Nurses consumed less energy on evening and night shifts compared with day shifts. However, energy intake from snacking was higher on evening and night shifts relative to day shifts. Nurses consumed less meals but had higher snacking frequency on non-day shifts. In addition, high energy intake from snacking was positively associated with high energy intake from saturated fat.

Conclusions: Nurses were more likely to have non-optimal eating behaviours on non-day shifts, which may contribute to an increased intake of saturated fat; thus, increasing their risk of chronic diseases. Strategies to improve non-day shift nurses' non-optimal eating behaviours may be beneficial to their health.

Impact: Shiftwork is known to affect nurses' eating behaviours; however, which shift is associated with unhealthy eating remains inconclusive. Despite lower energy intakes, nurses had higher intake by snacking on evening and night shifts. High snacking intake was associated with a high intake of saturated fat. Hospitals can increase the availability of healthy foods on evening or night shifts, which may improve non-day shift nurses' non-optimal eating behaviours.

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KEYWORDS

circadian rhythms, health care workers, junk food intake, medical personnel, non-optimal eating behaviours, nurse or nursing, shift schedules, shift work, snack food and sugar-sweetened beverage consumption

1 | INTRODUCTION

To provide the 24/7 services or increase the productivity, several industries have extended their daily operational time from 8 to 24 h by employing shift work (Tucker & Folkard, 2012). Approximately, 16%–20% of the working population is engaged in shift work around the world (Eurofound, 2017; U.S. Bureau of Labor Statistics, 2019). Shift work refers to working during non-traditional business hours (i.e., 06:00pm to 06:00am) (International Agency for Research on Cancer, 2007), which may be misaligned with workers' biological clocks and further impede their health (Bedrosian et al., 2016).

Several studies have suggested that shift workers were at a higher risk of chronic diseases such as cardiovascular diseases (Torquati et al., 2018; Vyas et al., 2012; Wang et al., 2018) or type 2 diabetes (Gan et al., 2015; Gao et al., 2020; Li et al., 2019). This is exemplified in the dose-response relationship between shift work and cardiovascular diseases (Torquati et al., 2018) and type 2 diabetes (Li et al., 2019). Energy imbalance, particularly from non-optimal eating behaviours, maybe one of the pathways by which shift work increases the likelihood of chronic diseases (Bonnell et al., 2017; Kaneko et al., 2021; St-Onge et al., 2017).

Shift work is unavoidable for nurses. Prior research has suggested that working on rotating night shifts may increase nurses' risk of type 2 diabetes, particularly for those who have unhealthy lifestyles such as low-diet quality (Shan et al., 2018). Examining nurses' non-optimal eating behaviours may not only help to improve nurses' eating behaviours but also overall health.

2 | BACKGROUND

Optimal eating behaviours are defined as having the following situations less than 3 times weekly: skipping breakfast, having dinner in 2h before bedtime, and having snacks after dinner (Kaneko et al., 2020). Previous studies have linked non-optimal eating behaviours to a higher incidence of myocardial infarction, stroke, and heart failure (Kaneko et al., 2021). Recent review documents that consistent high-energy meals (i.e., rich in saturated fat and sugars) cause both physiological dysregulation and dysfunction (e.g., endothelial dysfunction) during the postprandial period and further contribute to the incidence of cardiovascular diseases (Dimina & Mariotti, 2019). Other studies have suggested skipping meals (Kaneko et al., 2021; St-Onge et al., 2017) and increased sugar-sweetened beverages (SSBs) consumption (Richelsen, 2013) may contribute to metabolic dysfunction and further increase the risk of cardiovascular diseases (Poirier et al., 2006; Richelsen, 2013; Yu et al., 2016).

Previous studies have documented that shift work is associated with non-optimal eating behaviours (Cain et al., 2015; de Assis et al., 2003; Hemio et al., 2020; Hemio et al., 2015; Lin et al., 2021; Souza et al., 2019). Night shifts are related to higher energy intake (Fradkin et al., 2019; Hulsegge et al., 2016), markedly from carbohydrates (Fradkin et al., 2019), fat, saturated fat (Hemio et al., 2015; Hemio et al., 2020), energy-dense foods (Lin et al., 2021; Souza et al., 2019), SSBs (Lin et al., 2021), and snack foods (Cain et al., 2015; de Assis et al., 2003). It was also common practice for meal skipping and unconventionally timed food consumption (Souza et al., 2019). A recent review focusing on nurses' nutrition patterns suggests that nurses working on night shifts have some poor nutritional habits such as more frequent snacking, late dinner, irregular meal patterns, or poor diet quality (Peplonska et al., 2019). However, evidence regarding evening shifts has been relatively lacking.

Recent reviews summarize no significant differences in energy intake (EI) between shift and fixed-day workers (Bonham et al., 2016; Souza et al., 2019), or between non-night and night shift workers (Cayanan et al., 2019). A recent study indicates similarity in the eating and snacking patterns between shift and fixed-day shift workers, however, variable snacking patterns across different shifts (Hulsegge et al., 2020). This also suggests shift work may impact non-optimal eating behaviours (e.g., snacking).

To provide the round the clock services for patients, nurses need to work shift schedules, particularly for those working in the hospital. Prior research has suggested that working on rotating night shifts combined with an unhealthy lifestyle may exacerbate the adverse effects on nurses' metabolic health (Shan et al., 2018). However, the majority of studies mainly compare shift and fixed-day nurses' eating behaviours (Han et al., 2016; Peplonska et al., 2019; Yoshizaki et al., 2016; Yoshizaki et al., 2018). Research examining nurses' non-optimal eating across different shifts remains limited.

3 | THE STUDY

3.1 | Aims

Based on available evidence to date, the specific aims of this study are to (1) compare nurse's non-optimal eating behaviours across different shifts and (2) examine whether non-day shifts (i.e., evening and night shifts) were related to deviation from optimal dietary behaviours compared with day shifts. (3) If so, whether such deviation was related to non-optimal macronutrient intake (i.e., saturated fat and sugar).

the total frequency of meals and snacking was calculated by adding reported meals and snacking frequency. According to the reported meal types, EI from snacking, defined as foods and SSBs consumed outside of main meals (Bellisle, 2014; Hess et al., 2016), was also calculated.

During the post-study visit, the research team collected participants' registry-based work schedule for the past 30 days and provided incentives (i.e. approximately USD 30 in cash) after completion of the post-survey (e.g. any sick leave or shift changes due to personal reasons during the study period).

3.5 | Ethical considerations

The study protocol was approved by the Institutional Review Board (IRB) at the National Taiwan University Hospital (No. 201712216RIND). Written informed consent was obtained from all participants.

3.6 | Data analysis

We employed STATA 14.0 (Statacorp) for data analyses. Descriptive statistics such as the mean, standard deviation, median, interquartile range (IQR), count, and percentage summarize participants' personal and work characteristics, their EI and macronutrient intake, frequency of meals and snacking and high-energy meal consumption.

For the first aim, we conducted a one-way analysis of variance (ANOVA) to examine differences in EI and macronutrient intake across different shift work schedules. If the test result was significant ($p < .05$), we conducted a post hoc Tukey's HSD test for respective outcomes. Because EI from snacking and frequency of meals and snacking was not normally distributed, we used the Kruskal-Wallis H test to examine the median differences across different shifts. If the test result was significant ($p < .05$), we performed a Dunn's test with Bonferroni adjustment for pairwise comparison (Dinno, 2015). The Chi-squared test was used to compare high EI from meals or snacking across different shift schedules. Multiple generalized linear regressions were used to examine (1) the associations between shift work schedules and high EI from meals or snacking (the second aim) and (2) the associations of high EI from snacking with high EI of saturated fat and sugar (the third aim). To select the most parsimonious model for analysis, backward selection methods were used. The significant level was set at 0.05. Only significant covariates (i.e. personal and work characteristics) were included in the final models.

3.6.1 | Sensitivity analysis

Recent reviews summarize that rotating shift workers have a greater likelihood of increased body mass index (Chang & Jen, 2020). However, other studies document that fixed night shift workers are at increased risk of dyslipidemia compared with rotating shift workers

(Dutheil et al., 2020). This suggests that EI and macronutrient intake may vary between fixed- and rotating shift workers. To ensure that our main findings were not confounded by shift patterns, we further examined participants' EI and macronutrient intake across different shifts stratified by work shift patterns (i.e., fixed- or rotating).

3.7 | Validity and reliability/rigour

3.7.1 | Shift work schedules

Participants' shift work schedules were derived from their registry-based work schedules collected during the baseline visit. All participants were 8-h workers. Based on their shift start time, there were three different types of shift timings: day (work began between 07:00 and 09:00am), evening (work began between 02:00 and 04:00pm), and night shifts (work began between 10:00pm and midnight) (McMenamin, 2007).

3.7.2 | Estimated energy requirement

Estimated energy requirement (EER) referred to the amount of energy needed to balance the energy intake and expenditure (Sasaki, 2008). Therefore, we measured total daily energy expenditure (TDEE) to estimate participant's EER. TDEE was the sum of sleep energy expenditure (SEE), total physical activity energy expenditure (PAEE), and contribution of the thermic effect of food (TEF). Of which, SEE was equivalent to 30% of daily resting energy expenditure (REE); PAEE was the product of physical activity level (PAL), duration (hour) and weight (kg); TEF was equivalent to approximately 8% of the daily total of EI (Wai, 2012).

Given that registered nurses (RNs) spent more than 4 h standing and moving medical carts to prepare and dispense medications at least twice during their typical shifts, the PAL for this occupation was considered light to moderate intensity (Chappel et al., 2017). Among the Taiwanese population, the average PAL for light and moderate-intensity occupations was 1.7 and 2.3, respectively (Wai, 2012). As a result, we averaged the light- and moderate-intensity occupational PAL and obtained 2.0 metabolic equivalent (MET) for nurses' occupational PAL. The average PAL for sedentary behaviours (e.g. watching television) was 1.2 MET among the Taiwanese population (Wai, 2012). Therefore, we used 1.2 MET for participants' after-hour PAL. The final formula for participants' EER was as follows (Wai, 2012):

$$\begin{aligned} \text{EER} &= \text{TDEE} = \text{SEE} + \text{total PAEE} + \text{TEF} \\ &= (0.3 * \text{REE}) + (2.0 * 8 * \text{weight} + 1.2 * 8 * \text{weight}) + 0.08 * \text{TDEE} \\ &= (0.3 * \text{BMR} * \text{weight} + 3.2 * 8 * \text{weight}) / (1 - 0.08) \end{aligned}$$

where REE was the product of weight (kg) and basal metabolic rate (BMR); total PAEE was the sum of occupational PAL (2.0 MET) and after-hour PAL (1.2 MET) (Wai, 2012). The detailed information about

TDEE calculation was presented in Table S1. Each participant's daily EI and EI contribution of macronutrients were evaluated by calculating the respective percentage of EER.

3.7.3 | Non-optimal eating behaviours and macronutrient intake

Daily frequency of meals and snacking, EI from meals as well as EI from snacking were employed to assess if participants had non-optimal eating behaviours during a sampled day. According to the healthy meal recommendation, the distribution of EI by three meals was as follows: 28.0%–32.3% for breakfast, 28.7%–36.9% for lunch, and 31.7%–40.7% for dinner (Health Promotion Administration, Ministry of Health and Welfare, 2018). However, there is still limited evidence for the definition of a high-energy meal. As a result, we arbitrarily defined any meal with an energy content greater than 60% of EER (i.e. approximately 1.5 to 2 times higher than a recommended meal) as indicating a high EI from meals on that day. As for EI from snacking, no recommended percentage of EER has been provided by the Health Promotion Administration, Ministry of Health and Welfare (2018). A recommendation of 9% or lower in light meals was provided in Swedish recommendations (Bergström et al., 1993). We used 27% as a cut-off point for high-energy intake from snacking because it is three times that of the recommended 9%, and it represented the 75 percentiles of snacking intake in this group of participants.

Non-optimal macronutrient intake was measured by participants' contribution of EI to EER coming from saturated fat and sugar. The World Health Organization also recommends that EI from saturated fat and added sugar should account for less than 10% of total daily EI (World Health Organization, 2020). Furthermore, prior research suggests that greater than 10% of EI coming from saturated fat has been associated with cardiovascular diseases (Hooper et al., 2020). Therefore, EI greater than 10% of EER from saturated fat and sugar were, respectively, defined as high EI from saturated fat and high EI from sugar.

3.7.4 | Personal and work characteristics

The following personal characteristics collected on the baseline survey were employed to describe the study sample: age, sex, educational attainment, marital status, and health-related characteristics, including body mass index derived from self-reported weights and heights, and health conditions (e.g. medical history of diabetes). Working characteristics included job tenure, level of hospital employment, working units, and work shift patterns (i.e. fixed or rotating shifts).

4 | RESULTS

A total of 120 participants were included in the final analysis. Overall, the participants' average age was 27.5 (SD: 4.6) years. The

majority were females (95.0%), had obtained a bachelor's degree or higher (80.8%), were non-obese (i.e., BMI < 27) (74.1%), and did not have any chronic disease (70.8%). The average job tenure as a registered nurse was 5.2 (SD: 4.4) years. Most worked in the acute care wards (e.g. medical, or surgical wards), and nearly half (48.3%) were rotating shift workers (Table 1).

As presented in the upper panel of Table 2, nurses' EI (%) contributed by fat ($F = 4.04$, $p = .020$), carbohydrates ($F = 5.14$, $p = .007$) and sugar ($F = 3.15$, $p = .046$) were significantly different across each shift. According to the post hoc Tukey's HSD test conducted, we noticed that EI (%) from fat was significantly higher on day shifts relative to night shifts ($p = .035$). Energy intakes (%) from carbohydrates ($p = .006$) and sugar ($p = .046$) were significantly higher on day shifts relative to evening shifts. On average, total daily EI (kcal) on day, evening and night shifts were 1878.9 (SD: 510.4), 1540.1 (SD: 623.7), and 1674.6 (SD: 556.5), respectively. The EI (%) of EER were significantly lower on evening ($p = .008$) or night shifts ($p = .044$) compared with their counterparts on day shifts. In contrast, their EI (%) from snacking on evening (median: 19.9, IQR: 9.9–33.8, $p < .001$) or night shifts (median: 20.5, IQR: 0.1–35.3, $p = .012$) were significantly higher than their day shift counterparts' (median: 5.6, IQR: 0.0–17.6).

The middle panel of Table 2 indicates that less meals were consumed on evening (median: 2.0, IQR: 1.0–2.0, $p < .001$) and night (median: 2.0, IQR: 1.5–3.0, $p < .001$) shifts compared with day shifts (median: 3.0, IQR: 2.0–3.0). In contrast, snacking was more frequent on evening (median: 1.0, IQR: 1.0–2.0, $p < .001$) and night (median: 1.0, IQR: 1.0–2.0, $p = .004$) shifts compared with day shifts (median: 1.0, IQR: 0.0–1.0). Additionally, high EI from snacking were more prevalent among evening (35.1%) and night (37.5%) shift workers relative to day shift workers (9.8%, $p = .003$) (Table 2).

Table 3 presented associations between shift work and non-optimal eating behaviours. After adjusting for covariates, compared with day shifts, the likelihood of having high EI from snacking were increased in the evening (OR = 4.9, 95 CI [1.6, 15.5]) and night shifts (OR = 6.0, 95 CI [1.8, 19.8]).

Associations between high EI from snacking and non-optimal macronutrient intake were presented in Table 4. High EI from snacking was positively associated with high EI from saturated fat (OR = 4.0, 95% CI [1.4, 10.9]).

4.1 | Sensitivity analysis

Results of the sensitivity analysis were presented in Table S2. After stratifying by work shift patterns (i.e., fixed and rotating shifts), differences in EI and macronutrient intake across different shifts were similar. However, among fixed shiftwork nurses, there were no significant differences in EI and macronutrient intake across each shift. In contrast, among rotating shiftwork nurses, EI (%) of EER ($p = .012$) and EI (%) from fat ($p = .023$) were lower on night shifts compared with day shifts. Energy intake (%) contributed by carbohydrates were lower on evening ($p = .015$) or night ($p = .038$) shifts relative to

TABLE 1 Participants' characteristics (N = 120)

Variables	n (%)	Mean (SD)	Range
Demographics			
Age (in years)		27.5 (4.6)	21–42
Female	114 (95.0)		
Educational attainment			
Associate degree/ Junior college	23 (19.2)		
Bachelor's/Master's/ Doctorate degree	97 (80.8)		
Marital status			
Married/cohabitation	21 (17.5)		
Single	99 (82.5)		
Health-related characteristics			
BMI ^a (kg/m ²)		22.3 (4.6)	16.2–41.0
Underweight	13 (10.8)		
Normal	76 (63.3)		
Overweight or obese	31 (25.8)		
Having at least one chronic condition ^b	35 (29.2)		
Work characteristics			
Working as a registered nurse (in years)		5.2 (4.4)	0.9–20.2
Level of hospital employment			
Medical centers	79 (65.8)		
Regional/District hospitals	41 (34.2)		
Working units			
Intensive care units	28 (23.3)		
Emergency room	10 (8.3)		
Operation room	4 (3.3)		
Acute care wards ^c	78 (65.0)		
Shift work schedules			
Day	51 (42.5)		
Evening	37 (30.8)		
Night	32 (26.7)		
Work shift patterns			
Fixed shifts	62 (51.7)		
Rotating shifts	58 (48.3)		

Abbreviations: BMI, body mass index; SD, standard deviation.

^aThe definitions of underweight, normal, overweight and obese are BMI < 18.5, BMI ≥ 18.5 and BMI < 24, BMI ≥ 24 and BMI < 27, and BMI ≥ 27 kg/m², respectively.

^bChronic conditions: Diabetes (type 1 or type 2) or high blood sugar, heart diseases (e.g. coronary artery disease, angina, congestive heart failure), hypertension, stroke, high cholesterol/hyperlipidemia, thyroid problems (e.g., hyperthyroidism, hypothyroidism), kidney diseases (e.g. chronic renal failure), cancer or a malignant tumour (excluding minor skin cancer), digestive problems (such as ulcer, colitis or gallbladder disease), mental illnesses (e.g. depression, anxiety) and sleep problems (e.g. insomnia).

^cAcute care wards included surgical, medical, paediatric, gynaecological, orthopaedic and psychiatric wards.

day shifts. Energy intake from snacking was higher on non-day shifts compared with day shifts, particularly on evening shifts (Table S2).

5 | DISCUSSION

Our results suggested that nurses consumed less energy from fat on night shifts and less carbohydrates and sugar on evening shifts. On evening and night shifts, nurses had a lower total daily EI compared with day shifts but consumed greater EI from snacking. However, after stratifying by shift patterns, EI and macronutrient intake across each shift were insignificantly different, particularly among fixed shiftwork nurses. Nurses consumed less meals and demonstrated more frequent snacking on evening and night shifts. In addition, working on evening and night shifts was significantly associated with an increased likelihood of having high EI from snacking. High EI from snacking was positively associated with high EI of saturated fat.

Contrary to previous studies (Fradkin et al., 2019; Hulsegge et al., 2016; Peplonska et al., 2019), our study found that EI from fat on night shifts, carbohydrates on evening shifts, and total daily EI on the evening and night shifts were lower compared with day shifts. Prior research suggested that relative to day workers, shift workers skipped more meals at lunch and breakfast (Gupta et al., 2019; Souza et al., 2019). Most shiftwork nurses consumed less meals per day (Han et al., 2016), which may contribute to their inadequate nutrient intake (Sudo & Ohtsuka, 2001). Similarly, our present analyses suggested that on evening or night shifts, workers consumed less meals, which may lead to a reduction in their EI from fat and carbohydrates as well as their total daily EI.

In addition to reduced meal consumption, other studies suggested that compared with day workers, shift workers had poorer appetites (Tepas, 1990), which may also result in reduced EI and inappropriate macronutrient intake on non-day shifts.

Furthermore, time availability either for food preparation (Bonnell et al., 2017) or for food consumption (Persson & Martensson, 2006; Waterhouse et al., 2003) may influence shift workers' food choices. Workers tended to choose foods that were easy and quick to prepare but often of poor nutritional quality (Bonnell et al., 2017), which may also be one of the reasons for a lower EI from fat and carbohydrates on non-day shifts.

In sensitivity analysis in which we sought to examine whether differences in EI and macronutrient intake across different shifts would differ depending on shift patterns, our results showed that particularly among rotating shiftwork nurses, EI from fat and carbohydrates as well as total daily EI were reduced on non-day shifts. However, no significant differences were noted among fixed shiftwork nurses, suggesting that shift patterns may moderate the adverse effects of non-day shifts on nurses' eating behaviours. Another opportunity is that the small sample size in our sensitivity analysis limits the statistical power to detect the differences across each shift.

In line with prior research (Bonnell et al., 2017; Cain et al., 2015; de Assis et al., 2003; Lin et al., 2021; Souza et al., 2019), our findings showed that EI from snacking in the evening and night shifts

TABLE 2 Macronutrient and energy intake across different shifts among nurses (N = 120)

	Day	Evening	Night	ANOVA test ^a		
	(n = 51)	(n = 37)	(n = 32)	F	p	Tukey's HSD test ^b
	Mean (SD)	Mean (SD)	Mean (SD)			
Macronutrient intake						
Protein (%) ^c	15.6 (6.3)	13.0 (6.0)	13.6 (6.0)	2.25	.110	–
Fat (%) ^c	32.9 (10.9)	26.9 (15.0)	25.9 (11.1)	4.04	.020	D > N (p = .035)
Saturated fat (%) ^c	10.9 (3.7)	9.1 (5.6)	8.8 (4.3)	2.81	.065	–
Carbohydrate (%) ^c	50.2 (13.6)	39.6 (18.6)	43.4 (15.4)	5.14	.007	D > E (p = .006)
Sugar (%) ^c	9.0 (6.3)	5.9 (4.7)	8.6 (6.6)	3.15	.046	D > E (p = .046)
Energy intake						
Total daily EI (kcal)	1878.9 (510.4)	1540.1 (623.7)	1674.6 (556.5)	4.07	.020	D > E (p = .016)
Total daily EI (%) ^d	98.3 (25.5)	79.3 (35.3)	82.4 (26.5)	5.45	.005	D > E (p = .008), D > N (p = .044)
	Median (IQR)	Median (IQR)	Median (IQR)	Kruskal–Wallis H Test ^e		Dunn's test ^f
				χ^2	p	
Non-optimal eating behaviours and macronutrients intakes						
Meals or snacking frequency						
Meals	3.0 (2.0–3.0)	2.0 (1.0–2.0)	2.0 (1.5–3.0)	26.59	<.001	D > E (p < .001), D > N (p < .001)
Snacking	1.0 (0.0–1.0)	1.0 (1.0–2.0)	1.0 (1.0–2.0)	9.79	.008	D < E (p < .001), D < N (p = .004)
Sum of meals and snacking	3.0 (3.0–4.0)	3.0 (2.0–4.0)	3.0 (3.0–4.0)	4.53	.104	–
EIs from snacking (kcal)	116 (0.0–350.7)	418.6 (165.2–711.0)	446.7 (1.6660.9)	14.69	<.001	D < E (p < .001), D < N (p = .009)
EIs from snacking (%) ^d	5.6 (0.0–17.6)	19.9 (9.9–33.8)	20.5 (0.1–35.3)	14.58	<.001	D < E (p < .001), D < N (p = .012)
	n (%)	n (%)	n (%)	Chi-square Test ^g		
				χ^2	p	
High EI from meals ^h	5 (9.8)	5 (13.5)	3 (9.4)	0.40	.869 ⁱ	
High EI from snacking ^d	5 (9.8)	13 (35.1)	12 (37.5)	10.97	.003 ⁱ	
High EI from saturated fat ^j	28 (54.9)	13 (35.1)	11 (34.4)	4.84	.089 ^j	
High EI from sugar ^k	16 (31.4)	9 (24.3)	8 (25.0)	0.67	.715 ^l	

Abbreviations: ANOVA, analysis of variance; HSD, honestly significant difference; EI, energy intake; IQR, interquartile range.

^aThe degrees of freedom (df) of the F statistics were 2 (df₁) and 117 (df₂).

^bOne-way ANOVA with post hoc Tukey HSD test was employed to compare the differences in energy intake across different shifts among participants.

^cThe percentage of energy intake from each macronutrient was calculated based on the following algorithm: (Energy intake from a macronutrient/Daily estimated energy requirement)*100.

^dThe percentage of energy intake was calculated based on the following algorithm: (Energy intake/Daily estimated energy requirement)*100.

^eKruskal–Wallis H test was employed to compare the differences in EI from snacking and meal or snacking frequencies across different shifts among participants. The degrees of freedom (df) of the H (chi-square) test statistics were 2.

^fIf Kruskal–Wallis H test was significant, Dunn's test with Bonferroni adjustment (Dinno, 2015) was employed for pairwise comparisons between two shifts among participants.

^gThe degrees of freedom (df) of the chi-square test statistics were 2.

^hHigh EI from meals: >60% of daily estimated energy requirement.

ⁱThe p value was based on the Fisher's exact test.

^jHigh EI from saturated fat: >10% of daily estimated energy requirement.

^kHigh EI from sugar: >10% of daily estimated energy requirement.

^lHigh EI from snacking: >27% of daily estimated energy requirement.

Bold values indicate statistically significant results.

TABLE 3 Associations between shift work and non-optimal eating behaviours among nurses ($N = 120$)

Shift work schedule ^d	High EI from meals ^{a,b}	High EI from snacking ^{a,c}
	OR (95% CI)	OR (95% CI)
D	Ref.	Ref.
E	1.5 (0.4, 5.8)	4.9 (1.6, 15.5)**
N	1.1 (0.2, 5.1)	6.0 (1.8, 19.8)**

Abbreviations: D, day shifts; E, evening shifts; EI, energy intake; N, night shifts; OR, odds ratio; Ref., reference group.

^aThe percentage of energy intake was calculated based on the following algorithm: (Energy intake/Daily estimated energy requirement)*100.

^bHigh EI from meals: >60% of daily estimated energy requirement.

^cHigh EI from snacking: >27% of daily estimated energy requirement.

^dRespective models were adjusted by age (in years) and shift patterns (i.e., fixed or rotating shift).

* $p < .05$; ** $p < .01$; *** $p < .001$.

Bold values indicate statistically significant results.

were higher compared with day shifts. There were two possible explanations for our findings: First, working during night-time may disrupt workers' circadian rhythm and perturb appetite hormones (e.g. decreased leptin or increased ghrelin) (Bedrosian et al., 2016), which may change their food preferences and increase snacking behaviours (Broussard et al., 2016; Cain et al., 2015; James et al., 2017).

Second, we noted that the majority of workers skipped meals and increased the frequency of snacking on evening or night shifts in this study. A previous review summarized that shift workers skipped more meals, particularly at breakfast and lunch, and increased their energy intake at night (Souza et al., 2019). Most food outlets were closed and only snacks or SSBs were available during the nighttime. Subsequently, another possible mechanism for the participants' increased EI from snacking on evening and night shifts may have been due to reduced meal intake and less availability of healthy foods on evening or night shifts.

In the literature, there remains controversy over the effects of snacking. Snacking could be either beneficial for the adjustment of energy intake or be detrimental to energy balance and further contribute to obesity (Bellisle, 2014). In this study, we observed that increased EI from snacking was positively associated with their higher intakes of saturated fat. Previous studies suggested that reduced saturated fat and SSB intake were associated with a lower incidence of cardiovascular disease (Hooper et al., 2020; Yu et al., 2016) and metabolic syndrome (Julibert et al., 2019). Therefore, promotion of reduced EI from snacking in shift workers and improvement of diet quality on non-day shifts would likely be beneficial for lowering shiftwork nurses' risk of chronic diseases.

5.1 | Clinical implications

Our present analyses suggested that more than one out of three participants had high EI from snacking when they worked on evening

TABLE 4 Associations between high energy intake from snacking and non-optimal macronutrient intake among nurses ($N = 120$)

High EI from snacking ^{d,e,f}	High EI from saturated fat ^{a,b}	High EI from sugar ^{a,c}
	OR (95% CI)	OR (95% CI)
No	Ref.	Ref.
Yes	4.0 (1.4, 10.9)**	2.1 (0.8, 5.5)

Abbreviations: EI, energy intake; OR, odds ratio; Ref., reference group.

^aThe percentage of energy intake from saturated fat or sugar was calculated based on the following algorithm: (Energy intake from saturated fat or sugar /Daily estimated energy requirement)*100.

^bHigh EI from saturated fat: >10% of daily estimated energy requirement.

^cHigh EI from sugar: >10% of daily estimated energy requirement.

^dThe percentage of energy intake from snacking was calculated based on the following algorithm: (Total daily energy intake from foods or SSBs/Daily estimated energy requirement)*100.

^eHigh EI from snacking: >27% of daily estimated energy requirement.

^fRespective models were adjusted by age (in years), shift work schedules (i.e. day, evening, night shifts), and shift patterns (i.e. fixed or rotating shift).

* $p < .05$; ** $p < .01$; *** $p < .001$.

Bold values indicate statistically significant results.

and night shifts. This corresponds with a predominance of snacks or SSBs contributing to workers' energy consumption on evening and night shifts. One of the public health implications of this study is a consideration for prioritization for the provision of a healthy eating environment to reduce workers' high-energy meal intake, particularly for non-day shiftwork nurses.

Furthermore, previous studies suggested that time and accessibility were other factors influencing shift workers' food choices and dietary intake (Bonnell et al., 2017). Workload has been linked to meal substitution using SSBs (Lin et al., 2019). Stress and time constraints in the workplace may increase workers' consumption of low-nutrient foods (Leung et al., 2018). Strategies to reduce stress and workload may also benefit shiftwork nurses' health.

5.2 | Strengths and limitations

There are several strengths of this study. First, the majority of studies compared non-optimal eating behaviours between fixed-night shift and fixed-day workers (Bonnell et al., 2017; Cain et al., 2015; Souza et al., 2019). In the present study, we compared participants' EI and macronutrient intake and non-optimal eating behaviours across different shifts schedules. The current study extends the literature by explaining the effect of different shift schedules on nurses' unhealthy eating behaviours, particularly on evening and night shifts.

Second, most prior research did not describe the timing of dietary data collection or adjust dietary collection periods based on workers' sleep-wake patterns and shift schedules (Bonham

et al., 2016; Cayanan et al., 2019), which may not truly reflect the workers' dietary intakes on evening or night shifts (e.g. food consumption after midnight on evening shifts not accounted). In our present study, each 24-h dietary recall was adjusted based on the participant's own sleep-wake patterns and shift schedules to more precisely document dietary intakes on different shifts.

Third, we excluded days with special events from dietary sampling and derived participants' EI and non-optimal eating behaviours on the first workday during a consecutive shift. This avoids capture of participants' unhabitual dietary intake on workdays and the interference of lagged effects from previous work shifts. Additionally, participants' EI and diet quality were standardized based on the individual's daily recommended EI, which considers the heterogeneity of BMR, thus reducing the potential of information bias.

The current study was limited in several ways. First, the convenience sampling method may introduce selection bias and limit the generalizability of this study. To increase the external validity, we recruited participants from different levels of hospitals (e.g. medical centres, regional hospitals) across four areas in Taiwan. Secondly, 24-h dietary recalls were self-reported, which may be affected by recall bias. To reduce this potential, participants were requested to photograph all of their dietary intakes, and researchers would contact the participants if any records did not match. However, it should be noted that these measures were self-reported as well. Third, the Hawthorne effect (Wickström & Bendix, 2000) and the healthy work effect (McMichael, 1976) could not be ignored in this study. Participants knew their dietary intakes were monitored, which might change their eating behaviours. It is possible that the shift-work nurses' non-optimal eating behaviours were underestimated. Furthermore, the majority of our participants were from a healthy population. Those who could not adjust to shift work may have chosen not to work in hospital settings. We only included one 24-h dietary recall in our present analyses. Therefore, causality between shift work and non-optimal eating behaviours could not be inferred based on our findings.

Emerging research has suggested that shift workers may redistribute their EI when working on non-day shifts (Flanagan et al., 2020). Previous studies have revealed that higher EI during nighttime was significantly associated with obesity (Raynor et al., 2018), hyperglycemia (Song et al., 2021) and increased risk of cardiovascular disease (Almoosawi et al., 2013). However, the upper limit of high EI from meals or snacking remains unclear in the literature. The definition of non-optimal eating behaviours (i.e. high EI from meals and high EI from snacking) were arbitrarily defined in this study. Therefore, additional studies investigating the most optimal energy distribution for workers on different shift schedules, including parameters around maximal EI and contributions from meals and snacks may help to form dietary guidelines for shift workers to better promote their long-term health outcomes. Additionally, breaks for meals and snacks during shifts may affect nurses' eating behaviours (e.g. the number of eating occasions or food choices) (Waterhouse et al., 2003). Considering time availability for meals and snacks may also be warranted in promoting nurses' eating behaviours.

6 | CONCLUSION

To summarize, nurses skipped more meals, consumed less EI from carbohydrates and total daily EI, but increased snacking frequency and had higher EI from snacking on non-day shifts. This may increase their consumption of saturated fat, which may further expose them to a higher risk of cardiovascular diseases or metabolic syndrome. Creating a healthier eating environment at work (e.g. to increase accessibility to healthier foods during the night, to increase time available for food consumption by reducing workload) may alleviate some of the challenges faced by shift workers and be beneficial for non-day workers' cardiometabolic health.

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CONFLICT OF INTEREST

The authors have declared that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

Yue Leon Guo and Judith Shu-Chu Shiao designed the research; Ting-Ti Lin, Yi-Chuan Chen, Hsueh-Ching Wu and Judith Shu-Chu Shiao collected the data; Ting-Ti Lin and Yue Leon Guo analysed the data; Ting-Ti Lin, Yue Leon Guo, Christopher Gordon, Yi-Chuan Chen, Hsueh-Ching Wu, Elizabeth Cayanan, Chung-Mei Ouyang and Judith Shu-Chu Shiao wrote the manuscript; Judith Shu-Chu Shiao had primary responsibility for final content. All authors read and approved the final manuscript.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

The data are not publicly available due to privacy or ethical restrictions.

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