Public Health Nutrition: 26(8), 1634–1643 doi:10.1017/S1368980023000794

Association of breakfast skipping with habitual dietary intake and BMI in female rotating shift workers

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Submitted 21 February 2022: Final revision received 21 November 2022: Accepted 4 April 2023: First published online 20 April 2023

Abstract
Objective: Higher BMI, lower quality of diet and a higher percentage of breakfast-skippers have been reported among rotating shift (RS) workers compared with day shift (DS) workers. As such, this study examined the association between breakfast skipping, habitual food consumption and BMI in RS workers.
Design: Japanese nurses were studied using a self-administered questionnaire that assessed the height, weight, breakfast consumption habits, dietary consumption, physical activity, sleep habits, chronotype and demographic characteristics of the participants.
Setting: A cross-sectional study was conducted in a population of nurses in Japan. Dietary and health-related questionnaires were mailed to 5536 nurses aged 20–59 years, working at 346 institutions.
Participants: A total of 3646 nurses at 274 institutions responded to the questionnaire. After removing those who met the exclusion criteria, 2450 participants were included in the statistical analysis.
Results: The RS breakfast-skippers had lower total energy intake, diet quality and higher BMI than DS workers, whereas the RS breakfast-consumers had a higher total energy intake and BMI than the DS workers. In the RS workers, breakfast skipping on the days of DS and the end days of evening/night shift was associated with a poorer diet quality. Additionally, breakfast skipping on the days of DS was positively associated with BMI, independent of the total energy intake and diet quality.
Conclusions: Breakfast skipping on workdays may contribute to a difference in dietary intake and BMI between RS workers and DS workers and may increase BMI in RS workers, independent of dietary intake.

Keywords
Breakfast skipping
Diet quality
Weight
Rotating shift work

Rotating shift (RS) workers, whose work schedules change between day and night shifts, have higher risks of health problems, such as CVD, abnormal metabolism, obesity and depressive symptoms, than do workers who engage in fixed day shifts (DS) (i.e. DS workers)[1–6]. However, the growth in the percentage of the population aged 65 years and older has increased the social demand for nurses and caregivers, many of whom work on a RS to provide care 24 h a day and 7 d a week in medical and care facilities.

RS work is associated with changes in habitual food consumption. Previous studies[7,8] have demonstrated that RS workers consumed fewer potatoes and starches, green/yellow vegetables, white vegetables, fruits, algae, fish and shellfish, and meats than DS workers. In contrast, they consumed more confectioneries/savoury snacks, alcoholic beverages and sugar-sweetened beverages than DS workers. The available data support the close associations of habitual food consumption/diet quality with the risk of developing lifestyle-related diseases[9–14]. Thus, these changes in habitual food consumption may cause a higher risk of health problems in RS workers.

RS work is also associated with changes in dietary behaviour. For example, the percentage of individuals who habitually skipped breakfast on workdays was higher among RS workers than among DS workers[15]. Breakfast skipping is a dietary behaviour that may increase the risk of obesity through a lower quality of overall food consumption (e.g. lower fibre intake, poorer nutrient intake and

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higher energy density)[16] and/or the misalignment between meal timing and the circadian clock[17].

Considering the association between RS work, habitual dietary intake, obesity and breakfast skipping on workdays, it may be possible that breakfast skipping on workdays contributes to changes in dietary intake and increases in BMI in RS workers. However, the association of breakfast skipping on workdays, dietary intake and BMI in RS workers has not been examined. A deeper understanding of the relationship between breakfast skipping on workdays, dietary intake and BMI may assist in the development of strategies to improve diet quality and lifestyle-related diseases in RS workers, including worksite food environment improvements.

A previous study on nurses has indicated that the diurnal preference for activity timing (i.e. chronotype or morningness-eveningness) is associated with food consumption and that a later chronotype in RS workers compared with DS workers contributes to the differences in food consumption between RS workers and DS workers[18]. A diurnal preference is also associated with dietary behaviour. A previous study of nurses has shown that a later chronotype is associated with abnormal temporal eating patterns (i.e. irregularity in the timing and a later meal timing), which is an obesity-related eating behaviour[19]. A study conducted with non-shift working adults with type 2 diabetes[20] has shown that a later chronotype is associated with more frequent breakfast skipping. Furthermore, a later chronotype has also been associated with a higher BMI in RS workers[18]. Thus, chronotype could be a confounder between breakfast skipping, food consumption and BMI.

Therefore, the purpose of this study was to elucidate the association between breakfast skipping on workdays and habitual dietary intake or BMI among RS workers. For this purpose, we evaluated differences in habitual dietary intake and BMI between RS breakfast-consumers, RS breakfast-skippers, and DS workers and examined the association after controlling for diurnal preference. Considering the possibility of the mediating effects of habitual dietary intake on the association between breakfast skipping and BMI, we further examined the association while controlling for total energy intake and food consumption. In addition, considering that the effect of RS work on habitual food consumption and breakfast skipping has been reported only in studies conducted with female workers, we examined the associations between breakfast skipping and habitual dietary intake or BMI in female RS workers[7,8,15,21,22].

Subjects and methods

Participants

We conducted a cross-sectional survey in 2010, in a population of nurses in Kanagawa Prefecture, Japan. Of the randomly selected nurses (*n* 5536, aged 20–59 years), a total of 3646 nurses (65·9 %) agreed to participate in the survey. Among these 3646 nurses, 1196 nurses were excluded from the analysis because of male sex (*n* 171), age < 20 years or > 59 years (*n* 128), missing data on sex (*n* 71), current work schedules (*n* 121), breakfast consumption habits (*n* 110), chronotype (*n* 261), and dietary intake (*n* 323), or BMI outliers ($\geq$ 35·3 kg/m^2) (*n* 11). Consequently, 2450 participants (1054 DS workers and 1396 RS workers) were analysed. More detail of this study has been shown in previous studies[5,7].

Assessments

The questionnaire included habitual dietary intakes (Excel Eiyoukun)[23], breakfast consumption habits, diurnal preferences (a Japanese version of Morningness-Eveningness Questionnaire (MEQ))[24] and demographic characteristics of the participants. Details of the questionnaire have been shown in previous studies[5,7]. The BMI were calculated from the self-reported heights and weights (weight/height^2 (kg/m^2)). For examining dietary compositions, the intake of each nutrient (i.e. protein, fat and carbohydrate) and food group consumption were adjusted by total energy intake using the residual method[25]. Breakfast skipping was assessed by the response to the question, ‘How often did you usually have breakfast (a meal between 05.00 hours and 11.00 hours) on days of the DS?’ The participants were given a three-point Likert scale with responses defined as follows: (1) ‘Almost always ($\geq$ 80 %)’; (2) ‘Sometimes (20 to < 80 %)’; and (3) ‘Almost never (< 20 %)’. The participants responded to the question by circling one of the given choices. A dichotomous variable was then created, where answers (1) were categorised as ‘consuming’ and answers (2) and (3) as ‘skipping’. Breakfast skipping on the start and end days of the evening/night shifts was also assessed in RS workers. For RS workers, we dichotomised the participants based on their responses to the three questions. We labelled those whose responses to all the three questions were ‘consuming’ as ‘RS workers who consumed breakfast (RS breakfast-consumers)’, and those whose responses to any of the three questions were ‘skipping’ as ‘RS workers who skipped breakfast (RS breakfast-skippers)’. We defined breakfast as a meal in the morning (between 05.00 hours and 11.00 hours) based on the previous results that all of the breakfast consumers of the DS and RS nurses had the first meal of the day of the DS between 05.30 hours and 08.30 hours[8]. The current paper focused only on workdays’ breakfast consumption/skipping due to the interest in the worksite environment.

Statistical analysis

To compare the differences in demographic characteristics and dietary habits between DS workers, RS breakfast-consumers and RS breakfast-skippers, a one-way ANOVA and the χ^2 tests were used for the continuous and categorical variables, respectively. *Post hoc* analyses were performed

https://doi.org/10.1017/S1368980023000794 Published online by Cambridge University Press

using Tukey's Student range tests for ANOVA. For categorical variables, residuals between the observed and expected frequencies were standardised to determine cells which were statistically different from the expected values.

To examine the differences of dietary habits and BMI in the RS breakfast-consumers and RS breakfast-skippers with those in DS workers, multivariable linear regressions were performed with dietary habits and BMI as the dependent variables, groups (dummy: DS workers (reference category) = (0, 0), RS breakfast-consumers = (1, 0), and RS breakfast-skippers = (0, 1)) as the independent variables, and the covariates (age, BMI at 20 years of age, years of experience as a nurse, years of experience as a RS worker, marital status, living alone, drinking habit[26], smoking habit[26], habitual sleep durations on nights between the DS and between days off, MEQ score, and physical activity level)[27].

To examine the independent effects of breakfast skipping on the days of the DS and the evening/night shift on dietary habits in the RS workers, multivariable linear regressions were performed with dietary habits as the dependent variables; breakfast skipping on days of the DS, breakfast skipping on start days of the evening/night shift and breakfast skipping on end days of the evening/night shift as the independent variables (dummy: eating = 0 and skipping = 1); and the covariates (the number of evening/night shifts was also used as a covariate).

In the multivariable linear regressions, which were performed with BMI as a dependent variable, an extended model with the covariates was used: Model 1 = breakfast skipping on days of the DS, breakfast skipping on start days of the evening/night shift, and breakfast skipping on end days of the evening/night shift as the independent variables, and the covariates (the number of evening/night shifts was also used as a covariate); Model 2 = Model 1 plus total energy intake and food consumption. Regarding the missing data in the covariates, since Little's χ^2 test suggested that the missing data were missing completely at random, multivariable analyses were performed using the data set of subjects without missing data (i.e. complete-case data set) (n 2216). P values less than 0·05 using two-tailed tests were considered statistically significant. The corrections for multiple tests in the multivariable linear regressions for dietary habits were performed using the adaptive Benjamini–Hochberg procedure[28]. The procedure controlled for the false discovery rate (FDR) using a sequential modified Bonferroni correction for multiple hypothesis testing. The initial FDR threshold was 0·05. All the statistical analyses were performed with a STATA MP 16 (Stata Corporation).

Results

The demographic characteristics of the DS workers, RS breakfast-consumers and RS breakfast-skippers are shown in Table 1. Age, years of experience as a nurse, years of experience as a RS worker, habitual sleep duration on nights between the DS, habitual sleep duration on nights between days off, MEQ score and the frequency of breakfast skipping were significantly ($P < 0·05$) different between the groups. The BMI was significantly ($P < 0·05$) higher in both the RS breakfast-skippers and RS breakfast-consumers compared with the DS workers. The BMI at 20 years of age was significantly ($P < 0·05$) higher in the RS breakfast-skippers than in the DS workers. The percentage of individuals who were married, living alone, habitual drinkers and habitual smokers among the RS workers were also significantly ($P < 0·05$) different compared with the other groups or with only the DS workers. The physical activity level did not differ ($P > 0·05$) between the groups.

The energy-adjusted habitual nutrient intakes and food consumption of the DS workers, RS breakfast-consumers and RS breakfast-skippers are also shown in Table 2. Consumption of potatoes and starches, green/yellow vegetables, white vegetables, fruits, algae, fish and shellfish, confectioneries/savoury snacks, alcoholic beverages, and sugar-sweetened beverages were significantly ($P < 0·05$) different between the DS workers and RS breakfast-skippers. In contrast, consumption of these did not differ between the DS workers and RS breakfast-consumers. The total energy intake was significantly ($P < 0·05$) higher in the RS breakfast-consumers than in the DS workers, but lower in the RS breakfast-skippers compared with the DS workers. Protein intake was significantly ($P < 0·05$) lower in the RS breakfast-skippers compared with the DS workers and RS breakfast-consumers.

The BMI, energy-adjusted habitual nutrient intakes, and food consumption in the RS breakfast-consumers and RS breakfast-skippers relative to those in the DS workers in the multivariable linear regressions are shown in Table 3 and Fig. 1. In the RS breakfast-skippers, the total energy intake and consumption of potatoes and starches, green/yellow vegetables, and algae were significantly ($P < 0·05$) lower than that of the DS workers. In contrast, the consumption of confectioneries/savoury snacks and sugar-sweetened beverages was significantly ($P < 0·05$) higher in the RS breakfast-skippers than that of the DS workers. The BMI was significantly ($P < 0·05$) higher in the RS breakfast-skippers than in the DS workers. In the RS breakfast-consumers, the total energy intake was significantly higher ($P < 0·05$) than in the DS workers. In contrast, the energy-adjusted habitual nutrient intakes and consumption of all the food groups were not different ($P > 0·05$) from those of the DS workers. The BMI was significantly ($P < 0·05$) higher in the RS breakfast-consumers compared with the DS workers. These results did not change when the reference group was changed from DS workers to DS breakfast-consumers, whose response to the question on the days of the DS was 'consuming,' (n 804), except for potatoes and starches ($P = 0·073$) (online Supplementary Table S1).

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Table 1 Demographic characteristics of the participants

	DS workers (A)			RS breakfast-consumers (B)			RS breakfast-skippers (C)				
	n	Mean or %	SD	*n*	Mean or %	SD	*n*	Mean or %	SD	*P* value	A *v.* B *v.* C (ANOVA)
Age* (years)	1054	41·4	9·4	458	43·6	9·6	937	38·8	10·3	< 0·001	B > A > C
BMI* (kg/m²)	1054	21·2	2·7	458	21·8	3·0	937	21·6	3·3	< 0·001	B,C > A
BMI at 20 years of age* (kg/m²)	1039	20·4	2·2	456	20·7	2·5	929	20·8	2·9	0·004	C > A
Experience as a nurse* (years)	1042	15·7	8·8	452	17·1	9·1	929	13·7	9·2	< 0·001	B > A > C
Experience as a RS worker* (years)	964	8·0	6·3	455	13·6	8·1	925	11·6	8·1	< 0·001	B > C > A
Number of evening/night shifts* (days)	1054	0·0	0·0	452	5·2	2·3	918	5·6	2·3	< 0·001	C > B > A
Marital status (married)† (%)	1041	77·9‡		455	60·4		930	42·3§		< 0·001	–
Living alone† (%)	1031	8·5§		450	20·0		926	33·2‡		< 0·001	–
Habitual drinker† (%)	1052	14·0§		457	16·0		936	19·1‡		0·008	–
Habitual smoker† (%)	1048	23·0§		456	20·6§		935	34·9‡		< 0·001	–
Habitual sleep duration*											
Nights between DS (min)	1040	371	65	450	367	67	919	344	64	< 0·001	A,B > C
Nights between days off (min)	1024	448	78	453	438	83	929	475	107	< 0·001	C > A,B
Physical activity* (METs-h/week)	1053	45·0	66·3	458	42·7	61·5	935	44·1	62·9	0·820	ns
MEQ score* (points)	1054	55·9	6·7	458	56·1	6·6	937	50·8	7·0	< 0·001	A,B > C
Breakfast skipping† (%)	1054			458			937				
Day of the DS											
Never		76·3‡			100·0‡			43·1§		< 0·001	–
Sometimes		11·3§			0·0§			22·4‡			
Everyday		12·4§			0·0§			34·5‡			
Start day of the evening/night shift											
Never		–			100·0‡			22·8§		< 0·001	–
Sometimes		–			0·0§			30·8‡			
Everyday		–			0·0§			46·3‡			
End day of the evening/night shift											
Never		–			100·0‡			39·0§		< 0·001	–
Sometimes		–			0·0§			38·6‡			
Everyday		–			0·0§			22·4‡			

DS, day shift; RS, rotating shift; MEQ, Morningness-Eveningness Questionnaire.
*ANOVA.
†χ^2 test.
‡Adjusted residuals greater than 1·96.
§Adjusted residuals less than –1·96.

In the RS workers, the association of breakfast skipping on the days of the DS, start days of the evening/night shift and end days of the evening/night shift with dietary intakes are shown in Table 4. Multivariable linear regression showed that breakfast skipping on the days of the DS and end days of the evening/night shift were independently and significantly ($P < 0·05$) associated with a lower total energy intake and higher consumption of confectioneries/savoury snacks and sugar-sweetened beverages. These associations survived the FDR correction except for breakfast skipping on the end days of the evening/night shift for consumption of confectioneries/savoury snacks and sugar-sweetened beverages. Breakfast skipping on the days of the DS was also significantly ($P < 0·05$) associated with a higher fat intake, lower carbohydrate intake, and a lower consumption of grains and white vegetables. These associations survived the FDR correction except for white vegetables. Breakfast skipping on the end days of the evening/night shift was significantly $P < 0·05$) associated with a lower consumption of fats and oils.

The associations between breakfast skipping and BMI are shown in Table 5. In Model 1, breakfast skipping on the days of the DS was associated with a higher BMI, at a trend level ($P < 0·10$) (Table 5). In Model 2, breakfast skipping on the days of the DS was positively and significantly ($P < 0·05$) associated with BMI (Table 5), whereas the total energy intake was significantly ($P < 0·05$) associated with BMI (online Supplementary Table S2).

Discussion

The results showed that RS breakfast-skippers had a lower total energy intake, lower diet quality and higher BMI than DS workers. The RS breakfast-consumers had a higher total energy intake and higher BMI than the DS workers. In the RS workers, breakfast skipping on the days of the DS and end days of the evening/night shift was associated with a lower total energy intake and lower diet quality (i.e. a lower carbohydrate intake; higher fat intake; lower consumption of grains, white vegetables, and fats and oils; higher consumption of confectioneries/savoury snacks and/or sugar-sweetened beverages). Breakfast skipping on the days of the DS was positively and significantly associated

Table 2 Habitual dietary intakes of the participants

	DS workers (A)			RS breakfast-consumers (B)			RS breakfast-skippers (C)				
	n	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*P* value	A *v.* B *v.* C (ANOVA)
Dietary intake†	1054			458			937				
Total energy intake (kcal)		1835	468		1949	448		1775	504	< 0·001	B > A > C
Nutrient intake*											
Protein (g)		64·0	10·3		64·7	10·6		61·4	9·6	< 0·001	A,B > C
Fat (g)		65·6	11·5		65·0	10·4		65·6	10·7	0·566	ns
Carbohydrate (g)		231·1	32·1		231·3	30·8		231·5	30·3	0·959	ns
Food group consumption*											
Grains (g)		314·3	127·4		320·8	112·2		302·9	114·6	0·017	B > C
Potatoes and starches (g)		32·8	26·4		31·8	26·9		27·3	24·2	< 0·001	A,B > C
Beans (g)		56·3	38·5		60·4	46·7		51·4	35·8	< 0·001	B > C
Nuts and seeds (g)		2·0	2·7		2·2	3·7		1·8	2·7	0·069	ns
Green/yellow vegetables (g)		69·0	36·7		71·6	40·9		59·0	35·1	< 0·001	A,B > C
White vegetables (g)		115·4	58·9		117·2	68·0		103·6	56·5	< 0·001	A,B > C
Fruits (g)		71·1	62·3		71·4	63·3		58·1	56·0	< 0·001	A,B > C
Algae (g)		4·3	3·6		4·1	3·8		3·6	3·1	< 0·001	A,B > C
Fish and shellfish (g)		60·7	38·6		60·2	42·8		55·2	34·5	0·004	A,B > C
Meats (g)		88·3	42·6		87·4	46·4		83·5	40·8	0·036	ns
Eggs (g)		24·0	15·2		24·3	15·8		23·2	13·9	0·336	ns
Dairy products (g)		120·1	89·6		124·2	108·0		110·1	95·9	0·013	B > C
Fats and oils (g)		12·9	5·5		12·8	6·1		12·4	5·4	0·127	ns
Confectioneries/savoury snacks (g)		88·9	47·1		88·2	44·7		104·5	48·2	< 0·001	C > A,B
Alcoholic beverages (g)		66·0	110·4		68·5	109·4		81·5	127·3	0·009	C > A
Sugar-sweetened beverages (g)		51·2	89·1		46·3	85·5		89·3	120·6	< 0·001	C > A,B

DS, day shift; RS, rotating shift.
*Adjusted by total energy intake using the residual method.
†ANOVA.

Table 3 BMI and habitual dietary intakes in rotating shift (RS) breakfast-consumers and RS breakfast-skippers relative to day shift (DS) workers in multivariable linear model analysis

	RS breakfast-consumers			RS breakfast-skippers		
Dependent variables	B	Robust SE	*P* value	B	Robust SE	*P* value
BMI	0·32	0·16	0·049	0·43	0·14	0·002
Dietary intake						
Total energy intake	124·1	29·08	< 0·001	–54·65	27·61	0·048
Nutrient intake						
Protein	0·48	0·67	0·473	–1·07	0·58	0·064
Fat	–0·02	0·72	0·978	0·62	0·66	0·345
Carbohydrate	–0·30	1·99	0·880	–0·84	1·79	0·636
Food group consumption						
Grains	5·55	7·96	0·485	–12·92	7·38	0·080
Potatoes and starches	–0·80	1·66	0·632	–2·81	1·40	0·045
Beans	0·97	2·76	0·725	–2·72	2·23	0·224
Nuts and seeds	0·10	0·22	0·649	0·05	0·18	0·790
Green/yellow vegetables	0·49	2·35	0·837	–5·07	2·02	0·012
White vegetables	–0·59	3·94	0·881	–4·20	3·23	0·194
Fruits	–3·15	3·76	0·402	–4·34	3·27	0·185
Algae	–0·24	0·24	0·315	–0·44	0·19	0·020
Fish and shellfish	–2·81	2·52	0·265	–2·30	2·02	0·255
Meats	3·29	2·85	0·249	–0·45	2·41	0·850
Eggs	0·80	1·00	0·425	–0·09	0·86	0·921
Dairy products	6·12	6·54	0·349	–3·14	5·37	0·559
Fats and oils	–0·18	0·37	0·617	–0·41	0·31	0·180
Confectioneries/savoury snacks	0·27	2·88	0·926	11·32	2·61	< 0·001
Alcoholic beverages	–2·71	4·68	0·562	4·31	4·38	0·326
Sugar-sweetened beverages	–3·15	5·32	0·554	19·24	5·62	0·001

MEQ, Morningness-Eveningness Questionnaire; B, unstandardised coefficient.
Adjusted by age, BMI at 20 years of age, years of experience as a nurse, years of experience as a RS worker, marital status, resident status, drinking habit, smoking habit, habitual sleep durations on nights between DS and between days off, physical activity level, and MEQ score.

https://doi.org/10.1017/S1368980023000794 Published online by Cambridge University Press

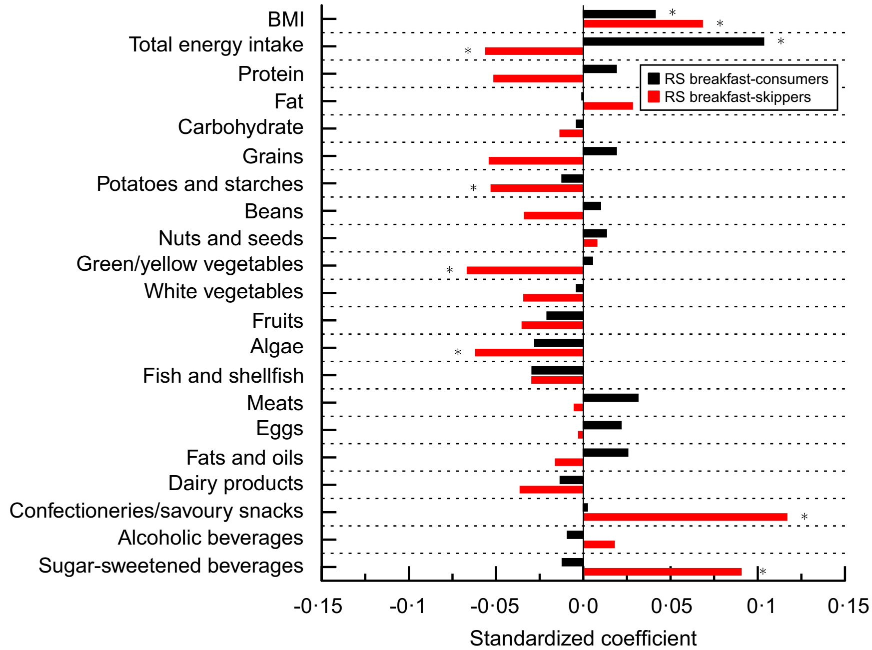

Fig. 1 Standardised coefficients of rotating shift (RS) workers who consumed breakfast (RS breakfast-consumers) and RS workers who skipped breakfast (RS breakfast-skippers) on BMI and habitual dietary intakes in multivariable linear regression. Adjusted by age, BMI at 20 years of age, years of experience as a nurse, years of experience as a RS worker, marital status, resident status, drinking habit, smoking habit, habitual sleep durations on nights between day shifts (DS) and between days off, physical activity level, and Morningness-Eveningness Questionnaire (MEQ) score. $^{*}P < 0·05$. Reference group = DS workers.

with BMI in the RS workers, while controlling for total energy intake and food consumption. The results suggest that breakfast skipping on workdays may contribute to a difference in the dietary intake and BMI between the RS workers and DS workers and may increase BMI in the RS workers, independent of dietary intake.

Consumption of potatoes and starches, green/yellow vegetables, algae, confectioneries/savoury snacks, and sugar-sweetened beverages was different between the RS breakfast-skippers and the DS workers (Fig. 1, Table 3). Among these, the consumption of confectioneries/savoury snacks and sugar-sweetened beverages was associated with breakfast skipping on the days of the DS (Table 4). The consumption was also associated with breakfast skipping on the end days of the evening/night shift before the FDR correction (Table 4). These results indicate that some of the previously reported differences in dietary consumption between the RS workers and DS workers[7,29–31] may have been caused by breakfast skipping on workdays in the RS workers. The consumption of green/yellow vegetables and algae was not significantly associated with breakfast skipping on any of the days of the shifts (Table 4). However, all the coefficients of breakfast skipping had negative values for the green/yellow vegetables (Table 4), indicating that each negative effect of breakfast skipping on the days of the DS, start days of the evening/night shift and end days of the evening/night shift may have contributed to the significantly lower consumption of green/yellow vegetables in the RS breakfast-skippers than in the DS workers (Table 2).

To our knowledge, this is the first study to demonstrate that breakfast skipping on workdays may be associated with habitual dietary intake and BMI in RS workers. Additionally, our results showed that breakfast skipping on workdays may be associated with a higher BMI in the RS workers, independent of dietary intakes (Table 5). Considering that breakfast skipping was associated with a lower total energy intake (Table 4), which, in turn, was associated with a lower BMI (online Supplementary Table S2), the entire effect of breakfast skipping on BMI may have been smaller than the independent effect (Table 5). These results are supported by previous findings in adults, including non-RS workers. For example, a previous study conducted with US adults[32] has shown that breakfast skipping was associated with a lower energy intake and low quality of diet. Another study using data from a National Nutrition Survey in Japan demonstrated that breakfast skipping was associated with low quality of diet in adults aged 18–49 years[33]. Furthermore, recent studies have shown that the timing of the meal intake (i.e. breakfast skipping, a later dinner time or higher energy intake at dinner) contributed to increases in BMI and obesity[9,34], after statistically controlling for total energy intake in individuals not engaged in night shift work. One of the possible mechanisms underlying this

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Table 4 Coefficients of breakfast skipping on days of the day shift (DS), start days of the evening/night shift and end days of the evening/night shift on habitual dietary intakes in rotating shift (RS) workers in multivariable linear model analysis

Dependent variables	Breakfast skipping								
	Breakfast skipping Days of the DS			Start days of the evening/night shift			End days of the evening/night shift		
	B	Robust SE	*P* value	B	Robust SE	*P* value	B	Robust SE	*P* value
Total energy intake	–91·96	33·88	0·007*	–55·03	34·24	0·108	–107·78	28·78	< 0·001*
Nutrient intake									
Protein	–0·40	0·63	0·519	–0·28	0·65	0·673	–1·10	0·58	0·059
Fat	2·76	0·69	< 0·001*	0·01	0·70	0·990	–0·54	0·61	0·373
Carbohydrate	–5·39	1·92	0·005*	–0·53	1·97	0·788	1·88	1·72	0·273
Food group consumption									
Grains	–35·64	7·31	< 0·001*	–0·21	7·40	0·977	–5·35	6·45	0·407
Potatoes and starches	–2·49	1·76	0·158	–1·65	1·71	0·334	–0·96	1·52	0·526
Beans	0·60	2·42	0·806	–1·08	2·57	0·674	–4·25	2·22	0·055
Nuts and seeds	0·10	0·19	0·593	–0·04	0·19	0·840	–0·07	0·18	0·687
Green/yellow vegetables	–4·17	2·36	0·077	–2·12	2·64	0·423	–2·70	2·21	0·224
White vegetables	–8·12	3·71	0·029	5·03	4·12	0·223	–4·19	3·43	0·222
Fruits	–5·89	3·59	0·102	1·31	3·77	0·729	–0·49	3·34	0·882
Algae	0·16	0·21	0·437	–0·17	0·23	0·471	–0·25	0·19	0·199
Fish and shellfish	1·32	2·25	0·557	2·37	2·39	0·321	–2·46	2·08	0·236
Meats	–3·88	2·64	0·143	–0·56	2·79	0·840	–0·95	2·50	0·705
Eggs	0·96	0·96	0·316	–1·38	0·98	0·157	–1·53	0·88	0·082
Dairy products	8·15	6·62	0·219	–9·34	6·94	0·179	3·15	5·70	0·581
Fats and oils	0·65	0·37	0·084	0·08	0·37	0·822	–0·86	0·32	0·007*
Confectioneries/savoury snacks	12·97	3·23	< 0·001*	1·54	3·16	0·627	5·62	2·81	0·046
Alcoholic beverages	–0·15	5·54	0·979	6·05	5·57	0·278	4·46	5·45	0·413
Sugar-sweetened beverages	26·24	7·67	0·001*	0·33	6·76	0·961	13·71	6·48	0·035

MEQ, Morningness-Eveningness Questionnaire; FDR, false discovery rate; B, unstandardised coefficient.
Adjusted by age, BMI at 20 years of age, years of experience as a nurse, years of experience as a rotating shift worker, the number of evening/night shifts, marital status, resident status, drinking habit, smoking habit, habitual sleep durations on nights between day shifts and between days off, physical activity level, and MEQ score.
**P* < 0·05 after FDR corrections.

Table 5 Coefficients of breakfast skipping on BMI in rotating shift (RS) workers in multivariable linear model analysis

Independent variables	B	Robust SE	*P* value	β
Model 1*				
Breakfast skipping on days of the DS	0·29	0·17	0·095	0·04
Breakfast skipping on start days of evening/night shift	–0·11	0·17	0·520	–0·02
Breakfast skipping on end days of evening/night shift	–0·10	0·16	0·540	–0·01
Model 2†				
Breakfast skipping on days of the DS	0·42	0·18	0·018	0·06
Breakfast skipping on start days of evening/night shift	–0·05	0·18	0·772	–0·01
Breakfast skipping on end days of evening/night shift	0·03	0·16	0·834	0·01

β, standardised coefficient; MEQ, Morningness-Eveningness Questionnaire; DS, day shift.
*Adjusted by age, BMI at 20 years of age, years of experience as a nurse, years of experience as a rotating shift worker, the number of evening/night shifts, marital status, resident status, drinking habit, smoking habit, habitual sleep durations on nights between day shifts and between days off, physical activity level, and MEQ score.
†Adjusted by variables in Model 1, total energy intake and food group consumption.

association may have been the decrease in insulin sensitivity later in the day[35].

Habitual nutrient intake and food consumption between the RS breakfast-consumers and DS workers or DS breakfast-consumers did not differ. Considering that the percentages of breakfast consumers of the RS workers were not high (i.e. 62·8 % and 59·0 % on the days of DS and end days of the night shift, respectively), interventions for increasing the frequency of breakfast consumption on these days, including improvements in the worksite food environment in the morning, may be a population strategy for improving diet quality and BMI in the RS breakfast-skippers. However, it should be noted that previous intervention studies have indicated that eating breakfast increased total energy intake and weight[36,37]. Our results also showed that the total energy intake and BMI were both higher in the RS breakfast-consumers than in the DS workers (Table 3) or DS breakfast-consumers (online Supplementary Table S1) and that the total energy intake was positively associated with BMI in the RS workers (online Supplementary Table S2). Future studies should carefully examine the effects of interventions for breakfast consumption, including not only the diet quality, but also the total energy intake and BMI in the RS breakfast-skippers.

Previous animal and human studies have shown that changing meal timing can shift the phase of the circadian clock[38–40]. Additionally, a previous study[41] indicated that the phase angle of a 24-h rhythm in the cardiac autonomic nervous system activity was delayed among RS workers compared with DS workers on the days of the DS, whereas the sleep–wake cycle was not. Given that the misalignment between the sleep–wake cycle and the circadian rhythm causes physical/mental problems[17,42,43], interventions for having breakfast in the RS breakfast-skippers may also be effective for preventing physical/mental problems via the improvement of the misalignment on the days of the DS. Therefore, the effects of the interventions on the phases of the circadian clock, as well as on diet quality, total energy intake and BMI, should be carefully examined.

Although the underlying physiological mechanisms in the association of breakfast skipping with habitual nutrient intake and food consumption are unclear, previous studies have shown several possibilities. For example, a 7-d intervention study in healthy and normal-weight adults[44] found that breakfast skipping increased the level of plasma ghrelin and activation in the brain area associated with a food reward. Other studies have indicated that consumption of food with high added sugar may displace the consumption of more nutrient-dense food[45–47]. This may explain the relationship between breakfast skipping and the higher consumption of confectioneries/savoury snacks and sugar-sweetened beverages and lower consumption of grains, green/yellow vegetables, and algae in the RS workers in the current study results.

We acknowledge the following limitations in this study. First, the current samples consisted of only Japanese female nurses. The generalisation of our results to the general RS workers may have been limited. Second, variables such as breakfast skipping, habitual dietary intake and BMI were self-reported. However, a previous study has reported that BMI computed from self-reported weight and height is well validated[48]. Third, due to the lack of any standard definition of breakfast, we defined breakfast as a meal in the morning (between 05.00 and 11.00) based on the results that all breakfast consumers of the DS and the RS nurses in the previous study had the first meal of the day of the DS between 05.30 and 08.30[8]. To compare the association between breakfast skipping and habitual dietary intake among different samples, a standardised definition of breakfast may be needed. Finally, this cross-sectional study could not establish the cause-and-effect relationship between breakfast skipping, habitual dietary intake and BMI. Longitudinal studies or interventional studies are required to test whether breakfast skipping affects habitual dietary intake and BMI in RS workers.

In conclusion, breakfast skipping on workdays may contribute to a difference in the dietary intake and BMI between RS workers and DS workers and may increase BMI in RS workers, independent of dietary intake. These findings have important implications for the development

https://doi.org/10.1017/S1368980023000794 Published online by Cambridge University Press

of novel strategies to improve the worksite food environment for the prevention of poor health caused by habitual dietary intakes in RS workers.

Acknowledgements

Acknowledgements: We thank Toshiko Hirasawa, who was the President of the Kanagawa Nursing Association at the time that data for this study were collected, and all the individuals who participated in this study. *Financial support:* This study was supported by grants from the Japan Society for the Promotion of Science (Grant-in-Aid for Early-Career Scientists 20K19720, Research Activity Start-up 20800085, Scientific Research (C) 22500690, Challenging Exploratory Research 15K12693, Scientific Research (B) 15H03094). *Conflict of interest:* There are no conflicts of interest. *Authorship:* T.Y., Y.T., T.K. and F.T. conceptualised the study; T.Y. and F.T. analysed the data and drafted the manuscript. All authors played an important role in interpreting the results, provided substantive feedback on the manuscript and approved the final version. *Ethics of human subject participation:* This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving research study participants were approved by the Institutional Review Board of the National Institute of Occupational Safety and Health, Japan (Approval Number: H22027). Informed consent was obtained from all participants by making it clear that proceeding to the survey after reading the information sheet on the front page of the anonymous questionnaire and submitting their results was indicative of informed consent.

Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S1368980023000794

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