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Association between Time from Dinner to Bedtime and Sleep Quality Indices in the Young Japanese Population: A Cross-Sectional Study

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Abstract: Sleep quality (duration, efficiency, and latency) is directly associated with human health. An interventional study reported that the time of dinner influenced sleep latency, suggesting that it may also be associated with other sleep quality indices under free-living conditions. Therefore, we cross-sectionally examined the association between the time from dinner to bedtime (TDB) and sleep quality indices under free-living conditions in the young Japanese population. Based on the TDB, 264 participants were separated into three quantiles (T1, ≤3.79 h; T2, 3.80–4.94 h; T3, ≥4.95 h from dinner to bedtime). The T1 (mean ± standard error; 26.4 ± 2.2 min, p = 0.081) and T2 groups (30.8 ± 2.2 min, p = 0.001) showed longer sleep latency compared to the T3 group (19.6 ± 2.2 min), after adjusting for confounding factors. Sleep efficiency in the T1 group (77.5 ± 1.6%) tended to be greater than in the T3 group (72.1 ± 1.6%, p = 0.061), whereas sleep efficiency in the T2 group was not significantly different (77.0 ± 1.6%) from that in the T1 group. Therefore, shortened TDB was associated with prolonged sleep latency in free-living conditions. Meal timing, especially dinner, should be considered along with other sleep hygiene measures to improve human health.

Keywords: meal timing; PSQI; MEQ; students; dietary records; proximity

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1. Introduction

Sleep quality, mainly assessed by sleep duration, efficiency, and latency, is associated with various aspects of health. For example, insufficient sleep duration reportedly attenuates muscle protein synthesis [1] and causes a reduction in muscle mass [2] in the young population. A longitudinal study showed that poor sleep efficiency and onset latency impaired brain structure in adults aged 20–64 years after adjusting for covariates, including age, sex, and physical activity [3]. Thus, the relationships between sleep quality and health-related factors should be assessed to improve the quality of life.

Sleep onset is modulated by melatonin, which is secreted mainly at night [4]. Endogenous melatonin is produced in the pineal gland by the conversion of tryptophan to serotonin; serotonin is subsequently metabolized to melatonin [5]. Thus, tryptophan [6–8] and tryptophan-rich foods (e.g., milk [9,10] and dairy products [11]) are potential enhancers of sleep quality. Furthermore, previous studies have confirmed that plasma tryptophan levels peak 3–4 h after a meal [12,13]. These findings suggest the importance of bedtime meal duration for improved sleep quality. A crossover study found that having a meal 4 h before bedtime resulted in shorter sleep latency than having a meal 1 h before bedtime [14]. This study indicated that the time from dinner to bedtime (TDB) affected sleep indices. A recent observational study showed that eating or drinking close to bedtime was associated with increased risks of reduced sleep duration, assessed based on a 24 h activity report [15]. However, no study has examined the association of meal timing with sleep quality indices using a validated method, such as the Pittsburgh Sleep Quality Index (PSQI) [16]. We aimed to comprehensively investigate the relationships between TDB and sleep quality

indices, considering sleep-related factors (e.g., physical activity, smoking and drinking habits, and fatigue states).

We hypothesized that TDB was associated with sleep quality under free-living conditions. Based on National Sleep Foundation data [17], we focused on sleep latency, duration, and efficiency as sleep quality indices using the PSQI.

2. Materials and Methods

2.1. Study Participants

This cross-sectional survey was conducted between July and September 2017 in Shiga, Japan. The inclusion criteria were healthy individuals aged 18–40 years. The exclusion criteria included individuals belonging to any sports club because intense sports activity may influence the study's outcomes. We recruited participants using flyers and by verbally informing them of the study in classes. A total of 270 healthy college and graduate school students agreed to participate in this study, and 264 students (149 males and 115 females; age $\geq$ 18 years) met the inclusion criteria; six individuals dropped out due to missing information on dietary records. This study was approved by the Ethics Committee for Human Experiments at Ritsumeikan University and was conducted in accordance with the Declaration of Helsinki. The study protocol and any possible risks were explained to the participants verbally and on paper, and informed consent was obtained.

Prior to the commencement of the present study, we used a statistical power analysis program (G*Power 3; Heinrich-Heine-Universität, Düsseldorf, Germany) [18,19] to calculate the required sample size. The settings were as follows: test type = F tests; statistical test = analysis of covariance (ANCOVA) (fixed effects, main effects, and interactions); effect size = 0.25; α error = 0.05; power = 0.95; numerator df = 2; the number of groups = 3, and the number of covariates = 9. The calculation results showed that 251 participants were required to adequately represent the population studied.

2.2. Study Procedure

We collected the three-day dietary records of the participants to assess their nutritional status and meal timings. Using these records, their dietary intake was assessed on two weekdays and one weekend. After data collection, the participants completed self-reported questionnaires and underwent anthropometric measurements. For any missing information or ambiguous answers, the participants were directly approached by a researcher for clarification.

2.3. Anthropometric Measurements

The participants were weighed while barefoot, wearing light clothes, on a digital scale that measured to the nearest 0.1 kg. Height was measured using a stadiometer while the participant was upright and relaxed.

2.4. Dietary Assessment

The study participants were instructed to photograph their three-day dietary records using digital cameras (DIGITAL CAMERA FinePix AX600, FUJIFILM, Tokyo, Japan) to improve the accuracy of dietary assessment and to record the exact mealtime. The dietary records included the following instructions: (1) "Please note your dietary records on 2 weekdays and 1 weekend", (2) "Please note all food items you had including confectionaries and beverages", (3) "Please take pictures of foods or nutrition facts if it is cooked or processed food before you eat", and (4) "Please note your dietary records by referring to the examples provided". In addition, the participants were not restricted from documenting their dietary records on non-consecutive or consecutive days, in order to enable them to report aptly on the usual meal days. Photographic data from the three-day records were collected and confirmed by a registered dietitian via face-to-face interviews with the participants. Data were analyzed using Excel Eiyokun (version 8, Kenpakusha Co., Tokyo, Japan) based on the Standard Table of Food Composition in Japan 2015.

2.5. Self-Reported Questionnaires

Self-reported questionnaires were used to collect information on the participant's lifestyle (living conditions (alone or with family), smoking, and drinking habits), sleep quality according to the PSQI, circadian rhythm type using the Morningness-Eveningness Questionnaire (MEQ), fatigue state according to the Chalder Fatigue Scale (CFS), and physical activity using the International Physical Activity Questionnaire (IPAQ).

2.5.1. Pittsburgh Sleep Quality Index (PSQI)

The Japanese version of the PSQI assesses subjective sleep quality over the preceding month. The PSQI includes seven components (range of subscale scores: 0–3): sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, use of sleeping medication, and daytime dysfunction [20]. A higher PSQI score implies lower subjective sleep quality. We also calculated bedtime, waking time, time in bed, and sleep efficiency (sleep duration/time in bed $\times$ 100) using the PSQI components.

2.5.2. Morningness–Eveningness Questionnaire (MEQ)

The Japanese version of the MEQ evaluates self-rated preferences for habitual activities in the morning or evening [21]. The MEQ consists of 19 items on sleep habits or preferences. The total MEQ score (16–86 points) was calculated by summing all the components. A lower MEQ score indicated a preference for being active during the evening time.

2.5.3. Chalder Fatigue Scale (CFS)

The fatigue levels in recent weeks were assessed using the CFS [22]. The reliability and validity of the Japanese version of the CFS in the student population have been confirmed previously [23]. The fatigue scale consists of 14 questions assessed using a four-level (0–3) scoring system. The total score for the 14-item fatigue scale ranged between 0 and 42, with higher scores indicating a greater degree of fatigue.

2.5.4. International Physical Activity Questionnaire (IPAQ)

The Japanese version of the IPAQ comprises three intensity levels (walking, moderate activity, and vigorous activity) of habitual physical activities, and estimates the time spent sitting per week. However, the questions regarding time spent sitting were developed as separate indicators and not as part of the total physical activity scores [24,25]. The data were assessed for the total weekly physical activity by weighing the reported minutes per week.

2.6. Statistical Analysis

Based on the time of dinner and bedtime (TDB: bedtime—dinner time), we divided the study population into three quantiles (T1: $\leq$3.79 h; T2: 3.80–4.94 h; T3: $\geq$4.95 h). In addition to demographic factors (age, sex, and living status), the covariates were selected according to previous studies as follows: smoking habit [26–29], drinking habit [30–33], MEQ scores [34], CFS scores [35], and IPAQ score [36].

To nullify the effect of energy intake on macronutrient consumption, each macronutrient intake was calculated using the nutrient residual energy-adjusted method. This method functions by regressing the protein consumption of individuals in their total energy intake [37].

Values were displayed as mean (95% confidence interval (lower–upper)) or standard error (SE) (only for the results of ANCOVA) for continuous variables or number (%) for categorical variables. Kruskal–Wallis and chi-square tests were used to compare variables between the groups (Tables 1 and 2), while normality tests and post hoc tests were not conducted because the sample size in each group (n = 88) was not large [38] and we wanted to avoid risks of unnecessary type II errors. ANCOVA was used to compare variables between TDB and sleep indices, with adjustment for confounding factors (Figure 1). Bonferroni corrections as post hoc tests were used when ANCOVA was significant.

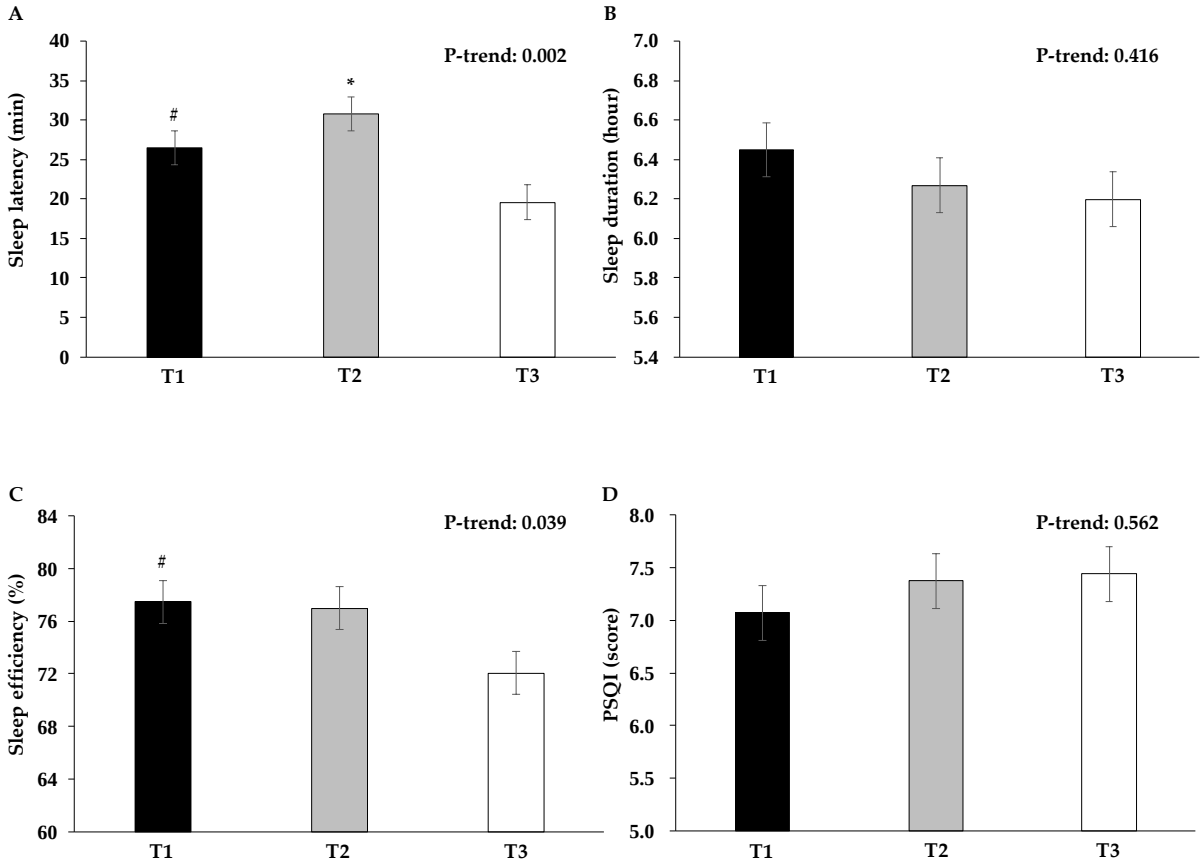

Figure 1. Comparisons of sleep quality indices among the three groups (n = 88 for each group; T1: <=3.79 h; T2: 3.80–4.94 h; T3: >=4.95 h from dinner to bedtime) in (**A**) sleep latency, (**B**) sleep duration, (**C**) sleep efficiency, and (**D**) PSQI score. Values are expressed as mean ± SE, and adjusted for age, gender, living status, smoking, drinking habits, MEQ, CFS, and IPAQ scores (post hoc analysis with Bonferroni correction; * $p < 0.05$ vs. T3 group, # $p < 0.1$ vs. T3 group). Abbreviations: SE, standard error; CFS, Chalder Fatigue Scale; PSQI, Pittsburgh Sleep Quality Index; MEQ, Morningness–Eveningness Questionnaire; IPAQ, International Physical Activity Questionnaire.

All statistical analyses were performed using SPSS version 23.0 for Windows (IBM Corp., Tokyo, Japan). p values < 0.05 using two-tailed tests were considered statistically significant.

3. Results

The characteristics of the study participants are shown in Table 1. Age, sex, living status, smoking and drinking habits, and anthropometric measurements (height, weight, and body mass index (BMI)) were not statistically different among the three groups. Significant differences were observed in lunch and dinner time, bedtime, sleep latency, and sleep efficiency among the groups, while there were no differences in breakfast frequency, breakfast time, wake time, sleep duration, PSQI, MEQ, CFS, and IPAQ scores.

The percentage of participants with a PSQI score of more than 6, indicating poor sleep, was 73.9% (195/264 participants). The average PSQI score in our population was 7.3 (7.0–7.6).

As shown in Table 2, significant differences were observed in terms of energy and macronutrient intake through snacks, whereas the other variables did not show any significant differences. After adjusting for energy intake at snack time, there were no significant differences in macronutrients at snack time among the three groups.

Table 1. Demographic characteristics of the study participants.

	T1 (*n* = 88)		T2 (*n* = 88)		T3 (*n* = 88)		*p* Values
Age, year	21.4	(20.9–21.9)	21.8	(21.2–22.4)	21.1	(20.7–21.5)	0.320
Women	36	(40.9)	38	(43.2)	41	(46.6)	0.746
Living status							
Alone	49	(55.7)	55	(62.5)	57	(65.0)	0.437
Family	39	(44.3)	33	(37.5)	31	(35.2)	
Smoking habit	1	(1.1)	4	(4.5)	3	(3.4)	0.406
Drinking habit	27	(30.7)	25	(28.4)	27	(30.7)	0.930
Height, cm	167.0	(165.2–168.7)	165.8	(163.9–167.6)	166.0	(164.3–167.7)	0.566
Weight, kg	60.9	(58.7–63.1)	58.4	(56.2–60.6)	60.1	(58.0–62.2)	0.261
BMI	21.8	(21.3–22.4)	21.1	(20.6–21.6)	21.7	(21.2–22.3)	0.137
Breakfast frequency, times/week	5.1	(4.6–5.6)	4.7	(4.2–5.2)	4.6	(4.1–5.1)	0.317
Breakfast time, h:min	8:50	(8:29–9:10)	8:38	(8:22–8:55)	8:47	(8:30–9:03)	0.656
Lunch time, h:min	12:59	(12:43–13:16)	12:54	(12:43–13:06)	12:39	(12:29–12:49)	0.039
Dinner time, h:min	21:37	(21:18–21:55)	20:14	(20:01–20:26)	19:12	(19:00–19:24)	<0.001
Bedtime, h:min	0:18	(0:03–0:33)	0:32	(0:21–0:44)	1:07	(0:55–1:20)	<0.001
Wake time, h:min	7:41	(7:22–7:59)	7:32	(7:15–7:48)	7:47	(7:28–8:07)	0.463
Sleep latency, min	25.7	(21.3–30.1)	30.0	(25.0–35.1)	21.1	(17.4–24.7)	0.024
Sleep duration, hour	6.5	(6.2–6.7)	6.3	(6.1–6.6)	6.1	(5.8–6.4)	0.257
Sleep efficiency, %	78.1	(74.1–82.1)	78.0	(74.9–81.2)	70.4	(66.6–74.1)	0.003
PSQI, score	7.0	(6.4–7.5)	7.1	(6.5–7.7)	7.8	(7.2–8.4)	0.147
MEQ, score	53.7	(52.0–55.4)	54.3	(52.7–55.8)	52.3	(50.8–53.8)	0.126
CFS, score	15.8	(14.3–17.3)	15.1	(13.8–16.4)	17.3	(15.6–19.0)	0.190
IPAQ, MET-min/week	2751.5	(2189.1–3313.9)	2522.6	(2049.3–2995.9)	2930.3	(2415.5–3445.1)	0.344
TDB, hour	2.7	(2.5–2.9)	4.3	(4.2–4.4)	5.9	(5.7–6.1)	<0.001

Values are expressed as mean (95% confidence interval, lower–upper) for continuous variables and number (%) for categorical variables; $p < 0.05$ indicates statistical significance. n = 88 for each group; T1: ⩽3.79 h; T2: 3.80–4.94 h; T3: ⩾4.95 h from dinner to bedtime. Abbreviations: BMI, body mass index; CFS, Chalder Fatigue Scale; TDB, time from dinner to bedtime; IPAQ, International Physical Activity Questionnaire; MEQ, Morningness-Eveningness Questionnaire; PSQI, Pittsburgh Sleep Quality Index.

Table 2. Energy and macronutrient intakes of the study participants.

	T1 (*n* = 88)		T2 (*n* = 88)		T3 (*n* = 88)		*p* Values
Total							
Energy, kcal	2015	(1907–2123)	1933	(1832–2034)	1873	(1751–1995)	0.128
Protein, g	72.3	(67.7–76.9)	71.5	(67.3–75.7)	67.8	(62.4–73.1)	0.255
Fat, g	69.8	(65.1–74.7)	65.5	(61.6–69.4)	63.4	(59.1–67.6)	0.107
Carbohydrate, g	264.9	(249.6–280.2)	254.9	(239.3–270.6)	249.3	(231.7–266.8)	0.171
* Energy-adjusted protein, g	70.2	(66.6–73.8)	71.5	(67.8–75.2)	69.4	(65.6–73.2)	0.577
* Energy-adjusted fat, g	67.6	(64.7–70.5)	65.7	(62.9–68.4)	65.0	(62.2–67.7)	0.398
* Energy-adjusted carbohydrate, g	256.3	(246.0–266.7)	255.7	(245.3–266.1)	255.3	(245.9–264.7)	0.965
Breakfast							
Energy, kcal	372	(322–422)	344	(304–384)	359	(310–408)	0.900
Protein, g	12.1	(10.3–14.0)	11.9	(10.3–13.5)	12.3	(10.3–14.3)	0.983
Fat, g	12.6	(10.5–14.7)	10.9	(9.4–12.5)	11.7	(9.9–13.5)	0.740
Carbohydrate, g	52.0	(45.0–59.0)	49.2	(43.3–55.0)	50.7	(43.7–57.7)	0.921
* Energy-adjusted protein, g	11.6	(10.3–12.8)	12.7	(11.5–13.9)	12.0	(10.7–13.3)	0.220
* Energy-adjusted fat, g	12.1	(10.8–13.4)	11.8	(10.7–12.9)	11.4	(10.3–12.6)	0.718
* Energy-adjusted carbohydrate, g	49.9	(45.5–54.3)	52.4	(48.6–56.2)	49.7	(45.5–53.8)	0.817
Lunch							
Energy, kcal	664	(622–707)	655	(610–700)	626	(571–682)	0.719
Protein, g	23.9	(22.4–25.5)	23.4	(21.6–25.3)	21.8	(19.6–24.0)	0.260

Table 2. *Cont.*

	T1 (n = 88)		T2 (n = 88)		T3 (n = 88)		p Values
Fat, g	21.9	(20.0–23.7)	20.8	(18.9–22.7)	20.8	(18.6–22.9)	0.704
Carbohydrate, g	89.4	(82.7–96.0)	90.1	(83.7–96.5)	84.8	(76.7–92.9)	0.562
* Energy-adjusted protein, g	23.8	(22.8–24.9)	23.5	(22.3–24.8)	21.8	(20.1–23.5)	0.050
* Energy-adjusted fat, g	21.8	(20.6–23.0)	20.9	(19.7–22.1)	20.7	(19.2–22.3)	0.553
* Energy-adjusted carbohydrate, g	89.1	(84.9–93.3)	90.6	(86.9–94.2)	84.5	(79.0–90.0)	0.291
Dinner							
Energy, kcal	755	(694–817)	759	(707–811)	753	(678–828)	0.926
Protein, g	30.8	(28.1–33.4)	31.7	(29.2–34.2)	30.1	(26.8–33.5)	0.630
Fat, g	26.9	(24.1–29.6)	28.1	(25.5–30.7)	26.6	(23.7–29.5)	0.714
Carbohydrate, g	92.2	(83.8–100.6)	88.9	(81.9–95.9)	93.0	(83.1–102.8)	0.791
* Energy-adjusted protein, g	31.1	(29.2–33.1)	31.6	(29.4–33.8)	29.9	(27.8–32.0)	0.438
* Energy-adjusted fat, g	27.2	(25.3–29.1)	27.9	(26.1–29.8)	26.4	(24.7–28.1)	0.507
* Energy-adjusted carbohydrate, g	93.2	(87.3–99.2)	88.8	(82.8–94.8)	92.0	(86.4–97.7)	0.623
Snacks							
Energy, kcal	223	(180–266)	175	(141–209)	135	(108–162)	0.013
Protein, g	5.5	(4.2–6.7)	4.4	(3.3–5.6)	3.5	(2.3–4.8)	0.017
Fat, g	8.4	(6.4–10.4)	5.7	(4.5–6.9)	4.3	(3.2–5.4)	0.003
Carbohydrate, g	31.3	(25.4–37.3)	26.8	(21.1–32.4)	20.9	(16.5–25.3)	0.042
* Energy-adjusted protein, g	4.5	(3.6–5.4)	4.6	(3.7–5.4)	4.4	(3.3–5.4)	0.476
* Energy-adjusted fat, g	6.7	(5.7–7.6)	5.9	(5.1–6.7)	5.6	(4.8–6.5)	0.305
* Energy-adjusted carbohydrate, g	25.2	(22.2–28.3)	27.5	(24.3–30.7)	25.6	(22.4–28.8)	0.656

Values are expressed as mean (95% confidence interval, lower–upper) for continuous variables; $p < 0.05$ indicates statistical significance. n = 88 for each group; T1: ⩽3.79 h; T2: 3.80–4.94 h; T3: ⩾4.95 h from dinner to bedtime. *: adjusted with residual methods.

Figure 1 shows the relationships between TDB and the sleep indices after adjusting for age, sex, living status, smoking and drinking habits, MEQ, CFS, and IPAQ scores. Figure 1A shows the results of ANCOVA. The T1 (mean ± SE, 26.4 ± 2.2 min, p = 0.081) and T2 (30.8 ± 2.2 min, p = 0.001) groups showed prolonged sleep latency compared to the T3 group (19.6 ± 2.2 min). The sleep efficiency of the T1 group (77.5 ± 1.6%) was higher than that of the T3 group (72.1 ± 1.6%, p = 0.061), while that of the T2 group (77.0 ± 1.6%) did not differ significantly from that of the other two groups (Figure 1C). There were no differences in sleep duration or PSQI scores among the groups (Figure 1B,D).

4. Discussion

We conducted a cross-sectional study to investigate the association between TDB and sleep quality with the PSQI in the young Japanese population, with adjustment for possible confounding factors. The present study found that longer TDB was associated with shorter sleep latency. However, longer TDB was unlikely to improve sleep efficiency.

In our analysis, in addition to basic characteristics (e.g., age, sex, and living status), factors such as smoking, drinking habits, MEQ, CFS, and IPAQ scores were also included as potential confounders. Smoking [26–29] and drinking [30–33] habits negatively affect sleep quality indices. For example, cross-sectional studies have reported that current smokers had a higher risk of sleep disturbance than non-smokers [26], and 50–60% of individuals who consumed alcohol had trouble falling and staying asleep [33]. We found a very low number of smokers in this study. Thus, we re-analyzed the data without smoking habit as a variable, and we confirmed no differences compared to the analyses with smoking habit as a variable (data not shown). In addition, lower MEQ scores (evening preference) have been reported to be negatively correlated with sleep quality [34]. Furthermore, higher CFS scores (indicating greater fatigue) were reported to be associated with sleep disturbance [35], and higher physical activity using the IPAQ score was associated with better sleep quality [36]. Based on these findings, it can be posited that these factors could have potentially affected

sleep conditions in our study population, and our analysis of these factors emphasizes the strength of our results.

The present findings show that shortened TDB was associated with prolonged sleep latency, indicating difficulty in falling asleep. Although some participants had obstructive sleep apnea, another observation confirmed that eating late was significantly associated with prolonged sleep latency, as assessed by a polysomnography [39]. Mechanistically, this could be explained by plasma tryptophan levels, a precursor of melatonin (the regulator of sleep onset [4]), which peak 3–4 h after a meal [12,13]. These studies support our results that having dinner close to bedtime is a negative factor for sleep latency. However, a previous observational study found no association between meal timing and sleep latency [40]. This may be because it used binary variables for TDB (>3 vs. ≤3 h) and sleep latency (>30 vs. ≤30 min), along with an original online survey [40]. Studies on the association between meal timing and sleep quality are scarce. Therefore, further studies with validated methods are required to elucidate the importance of meal timing for sleep hygiene. There were no significant differences in energy and macronutrient intake among the groups in the present study (Table 2). Furthermore, we confirmed that the associations of TDB with sleep quality indices remained unchanged, even if energy intake at dinner or snack time was included in our analyses as a covariate (data not shown). Having a late meal can negatively affect sleep latency, regardless of dietary intake.

Interestingly, we found a different trend between TDB and sleep efficiency owing to its association with sleep latency. In the present study, shortened TDB tended to induce better sleep efficiency. Although the indices in this study were different from those in the present study, a previous study also indicates that meal timing was differentially associated with sleep indices [15]. For example, a previous study reported that while longer TDB was positively associated with wake after sleep onset, the longer TDB was inversely linked to sleep duration [15]. These findings indicate that the longer TDB is not always appropriate for assessing all the sleep indices. The aforementioned study also reported that while the risk of short sleep duration was lowest at a TBD of <4 h, the lowest risk of waking after sleep onset plateaued at <6-h TDB [15]. From other viewpoints, levels of ghrelin, a well-known appetite hormone [41], might be one of the factors influencing differential responses of sleep indices based on meal timing. Previous studies have consistently reported that ghrelin administration in individuals increased non-rapid eye movement, indicative of deep sleep [42–44]. This clearly demonstrates the importance of blood ghrelin levels for sleep efficiency. A crossover study confirmed that blood total and acylated ghrelin levels peaked at 1.5 h after a meal (590 kcal) and returned to baseline levels 3 h after the meal [45]. This change was different from that in plasma tryptophan levels. These findings suggest that a longer gap between mealtime and bedtime may reduce sleep efficiency. However, further studies are needed to examine the effects of meal timing on sleep efficiency.

The present study has some limitations. First, in this cross-sectional study, we could not fully elucidate the causality between TDB and sleep indices. Further interventional studies should be conducted to examine causality and emphasize the importance of meal timing for sleep hygiene. Second, we did not investigate the use of digital devices during sleeping and caffeine intake. Light exposure [46] and caffeine intake [47] can influence sleep indices. Third, the results in the present study were mainly dependent on the responses of self-reported questionnaires, which warrant consideration. However, previous studies have validated these variables with objective measurements, such as the MEQ [48], PSQI [16], and IPAQ [49]. Fourth, the PSQI score in our population was higher compared to the results of previous studies evaluating a similar population [50,51]. This should be considered while generalizing our results to other populations. Finally, our data were based on different time frames: dietary records were assessed over 3 days; sleep quality, over 30 days; and habitual weekly physical activity. Further studies are needed to include daily activities [52], especially meal and sleep schedules, in the same time frame.

5. Conclusions

We found that shorter TDB was significantly associated with prolonged sleep latency in the young Japanese population under free-living conditions, while it was negatively associated with sleep efficiency. This suggests that the time of dinner was related to sleep quality under free-living conditions and that there is an optimal dinner time that should not be too early or too close to bedtime. Thus, future studies on sleep quality indices should consider meal timing, especially dinner timing, to create robust evidence for improving human health.

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