Free sugar intake and dietary sources in rural Japanese infants aged 18–23 months

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Running title: Free sugar intake in Japanese infants

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ABSTRACT

Background and Objectives: Optimizing sugar intake during early childhood is critical for preventing noncommunicable diseases. Although international guidelines recommend limiting free sugar intake, Japan is yet to consolidate data on free sugar intake among children under 2 years of age. This study examined free sugar intake, dietary sources, and associated factors among Japanese children aged 18–23 months. **Methods and Study Design:** A cross-sectional study was conducted among children attending infant health checkups in Kama City, Japan. Caregivers recorded two non-weighed dietary records (one weekday and one Sunday). Free sugar intake, dietary sources, and related factors were analyzed. **Results:** Among 84 participants, the mean free sugar intake was 13.3 g/day, corresponding to 5.7% of estimated energy requirements. Overall, 44.0% of children exceeded the World Health Organization recommended level of <5% of energy from free sugar, and 16.7% exceeded the <10% threshold. Major sources included confectioneries (43.2%), fruits including 100% fruit juice (27.3%), dairy products (23.3%), and sweetened beverages (4.6%). Free sugar intake was 37% higher on Sundays than on weekdays. Multivariable analyses showed no significant associations between excessive free sugar intake and demographic or lifestyle characteristics. **Conclusions:** A substantial proportion of Japanese infants aged 18–23 months consumed free sugar in excess of World Health Organization recommendations. These findings highlight the need to improve caregiver awareness of major free sugar sources, particularly 100% fruit juice, and support the development of age-specific dietary guidance and pediatric nutrition counseling in Japan.

Key Words: dietary sugars, Japan, infant, caregivers, feeding behavior

INTRODUCTION

Childhood obesity has emerged as a critical global health challenge,[1] with its prevalence having increased by over tenfold from 11 million cases in 1975 to 124 million in 2016.[2] Although Japan has maintained lower childhood obesity rates compared to other high-income countries, national-level data show an upward trend in childhood overweight and obesity in recent decades, raising public health concerns in Japan as well as globally,[2,3] and this trend is particularly alarming given its established role as a risk factor for noncommunicable diseases (NCDs),[2] including cardiovascular disease[4,5] and type 2 diabetes.[6] In Japan, rural–urban differences in diet-related health have also been documented, with children in rural areas showing a greater increase in obesity prevalence over time.[7]

Growing evidence has demonstrated a close link between dietary habits—particularly the consumption of added sugar and free sugar, and the development of NCDs.[6,8,9] Sugar intake in children has been associated with elevated risk for cardiovascular diseases through multiple mechanisms, including increased energy intake, enhanced adiposity, and dyslipidemia.8 Recognizing this, the American Academy of Pediatrics has emphasized the need for pediatricians to play an active role in reducing children's added sugar intake.[10]

In 2015, the World Health Organization (WHO) issued guidelines recommending that free sugar intake—defined as sugars added to foods and drinks and those naturally present in honey, syrups, and fruit juices—should be less than 10% of total energy intake, with a conditional recommendation for an ideal level below 5%.[11] This recommendation provides a standardized reference for evaluating sugar consumption relative to total energy intake, enabling international comparisons across populations. In response, countries including the United States,[12] the United Kingdom,[13] Canada,[14] Germany,[15] Korea,[16] and China[17] have established national sugar intake guidelines. Notably, the US 2020–2025 Dietary Guidelines recommend avoiding added sugars entirely for children under 2 years of age,[12] citing concerns about early taste preference formation and diet quality.[18-21]

The first 1,000 days of life—from conception to age 2—represent a critical window in which nutrition has lasting impacts on physical growth, cognitive development, and long-term health outcomes.[22,23] Dietary patterns established in this period often persist beyond infancy,[24] making early life a key target for preventive strategies. Studies from several countries have reported that many infants and toddlers under 2 years of age consume free sugar in excess of recommended levels.[25-27]

Despite these global trends, Japan has not yet established official sugar intake standards for children, nor do current nutrition labels indicate free sugar content.[28] These gaps hinder public understanding and the promotion of sugar-related dietary behavior change.

To date, only eight studies have assessed sugar intake in Japanese children,[29-36] with none specifically focusing on those under 2 years of age. These eight studies covered children aged 18 months to 19 years. Among them, Fujiwara et al. reported free sugar intake levels specifically for children under 2 years of age.[33] Regarding older children, Fujiwara et al. noted that 21.7% of Japanese children aged 3–6 years exceeded the WHO recommendation of <10% of total energy intake from free sugar.[34] This lack of data is concerning, given the recognized importance of establishing healthy dietary habits early in life.

Considering the absence of national guidelines and the limited evidence base, it is essential to quantify sugar intake among Japanese children under 2 years and explore contributing factors. This study aimed to assess free sugar intake and its dietary sources among children aged 18–23 months and examine potential associations with demographic and lifestyle characteristics. Our focus on children aged 18–23 months was guided by international and national policy considerations. For example, the Dietary Guidelines for Americans 2020–2025 identify children under 2 years of age as a distinct population requiring specific dietary guidance.[12] In Japan, the national health promotion strategy, Health Japan 21 (the third term), also emphasizes the relevance of establishing healthy lifestyle behaviors, including eating habits, from infancy as part of a life-course approach.[37] Altogether, we focused our investigation on this high-impact developmental window. These findings may help inform pediatric nutrition counseling and future guideline development in Japan.

MATERIALS AND METHODS

Study setting and participants

This cross-sectional study was conducted from January 2022 to April 2024 as part of the municipal health surveillance program in Kama City, Fukuoka Prefecture, Japan. It was approved by the Institutional Review Board of Iizuka Hospital (approval number 21075) through an expedited review and conducted in accordance with the Declaration of Helsinki. Because the data were collected anonymously, the requirement for informed consent was waived by the ethics committee. Kama City, a rural municipality with approximately 40,000 residents, offers a statutory 1.5-year health checkup program covering over 95% of eligible children. All infants aged 18–23 months attending the mandatory checkup during the study period were eligible. This age range corresponds to the standardized timing of the municipal health checkup in Japan. Children were included if they were legal residents of Kama City, aged 18–23 months at the checkup, and had completed it. Exclusion criteria included chronic conditions requiring ongoing care; gestational age <37 weeks and birth weight <2,500 g; acute illness (fever ≥37.5° C, vomiting, or diarrhea within 7 days); or current use of oral medications, including supplements. Preterm and low-birth-weight infants were excluded due to known links with feeding difficulties and different nutritional needs.38,39

Data collection and survey procedures

Study request forms, a dietary intake questionnaire, and a daily life questionnaire were mailed to caregivers along with the city's official health checkup documents. All participants were children aged 18–23 months. Caregivers recorded their child's intake on one weekday and one Sunday using a non-weighed dietary record, a method validated in infants and young children aged 6–24 months that accounts for daily intake variability.[40,41] Caregivers were instructed to record all foods and beverages consumed by the child using a structured form, developed in Japanese. Sugar-sweetened beverage intake was assessed using the same caregiver-reported dietary records, including product names and intake amounts. The form included examples of popularly consumed commercial foods and portion size indicators using household measurements (e.g., "1 bottle" and "1 pack"). Completed records were independently reviewed by two registered dietitians. Any discrepancies were resolved through discussion to ensure data accuracy and consistency. The dietary record and questionnaire were specifically designed in Japanese and did not require translation or cultural adaptation. Only commercially available foods with dietary labeling were included, per the Food Labeling Standards defined by the Consumer Affairs Agency of Japan.[42] Target items included both solid foods and beverages consumed at breakfast, lunch, dinner, and snack times. Data collection was restricted to commercially available foods with nutrition labeling to ensure reliable estimation of free sugar intake and minimize caregiver burden. Previous studies in Japan have observed that most free sugar consumed by young children is derived from labeled products, such as confectioneries and beverages.[33]

Measurements

Two registered dietitians estimated the free sugar content of foods recorded on both days. Free sugar was defined as all monosaccharides and disaccharides added by the manufacturer, cook, or consumer, plus sugars naturally present in honey, syrups, fruit juices, and juice concentrates, in line with WHO guidelines.[11] Naturally occurring sugars in intact fruits, vegetables, and plain dairy products were excluded from the calculations. Since nutrition labels in Japan do not state free sugar content, we used the stepwise method by Louie et al.,[43] adapted by Fujiwara et al.[33] Unlike Louie et al.,[43] who measured added sugars, we included fruit juice concentrates to reflect the WHO definition. Food items were classified into 18 food groups based on the Standard Tables;[44] in this food group classification, "fruits" refer to fruit products containing free sugars (e.g., 100% fruit juice), whereas "dairy products" represent sweetened dairy foods (e.g., flavored milk, sweetened yogurt). Intact fruits and plain unsweetened dairy products were outside the scope of the present analysis and were not included in the calculation of free sugar intake. Total sugar, not listed on Japanese labels, was defined as the sum of glucose, fructose, galactose, sucrose, lactose, maltose, and trehalose.[45] It was estimated using the 2020 Standard Tables of Food Composition in Japan[44] and Fujiwara et al.'s method.[33] Details on sugar measurement are provided in the Supplementary Material (Figures 1 and 2, Tables 1 and 2). Briefly, free sugar was assessed using an eight-step approach aligned with WHO's definition. Total sugar was calculated with a six-step method from Fujiwara et al.[33]

Assessment of characteristics and lifestyle factors

The daily life questionnaire covered child sex, height, weight, number of siblings, sleep duration, dental caries treatment history, childcare attendance, screen time, coresidence with grandparents, maternal age at delivery, parental smoking status, and caregiver occupation. Parental smoking status was collected as four categories: neither parent, father only, mother only, or both. Caregiver occupation was collected as managerial/professional, office, sales, service, manual labor, other, or unemployed.

These data were collected using a self-administered questionnaire completed by the caregivers. The questions were developed in Japanese based on national and international guidelines and reviewed for clarity and comprehension by several caregivers; however, no validation was conducted. Height and weight were measured during the checkup by trained public health nurses using standardized procedures and equipment,46 and recorded to the nearest 0.1 cm and 0.1 kg. A sleep duration of <11 h was defined as short sleep, and that exceeding 11 h was defined as reasonable since the recommended sleep duration for children aged 1 year is 11–14 h.[47] A screen time of <30 min was defined as adequate, whereas that over 30 min was defined as excessive based on the recommended screen time for children under 2 years of age.[48-50] Maternal age was categorized using 30.9 years, the national average at first birth in Japan.[51] This cutoff was selected to provide a population-based reference while maintaining sufficient group sizes for exploratory analyses.

Statistical analysis

Excessive free sugar intake was defined as ≥10% and ≥5% of total energy intake, per WHO recommendations.[11] As actual energy intake was not measured, estimated energy requirements (EERs) from the Japanese Dietary Reference Intakes (2020) were used:[28] 950 kcal/day for boys and 900 kcal/day for girls, calculated as the sum of energy expenditure and accumulation. This approach has been applied in previous early childhood nutrition studies where direct energy measurement was not feasible.[25,52,53] Total energy intake was not evaluated because the survey focused solely on commercially available foods with nutrition labeling. This restriction was established because previous studies suggest that most free sugar consumed by children under 2 years was derived from such products;33 this is because a simplified dietary record was essential for minimizing caregiver burden and maximizing response rates. Requiring caregivers to record all foods, including meals prepared at home and at restaurants, may reduce data accuracy and response. Food sources contributing to free sugar were grouped using the same 18 food categories.[44] Descriptive statistics summarized all variables: means and standard deviations for continuous variables, and counts and percentages for categorical ones. Univariate analyses compared excessive vs. adequate intake groups. Fisher's exact test was used for categorical variables; the Wilcoxon rank-sum test for continuous ones. To compare the distribution of food group contributions to total free sugar intake between weekdays and Sundays, an exploratory chi-square test was performed using the total amount of free sugar contributed by each food group on weekdays and Sundays. Univariate analyses were performed as exploratory assessments to examine individual associations between each variable and excessive free sugar intake before multivariable logistic regression analyses. Logistic regression analyzed the association between selected binary independent variables (child sex, sleep duration, screen time, maternal age at delivery, and parental smoking status) and excessive free sugar intake (≥10%E and ≥5%E).

These variables were chosen a priori based on previous literature,[34,54,55] clinical relevance, availability in the questionnaire, and the need to avoid overfitting given the small sample size. They were dichotomized as follows: child sex (reference: boys), sleep (reference: ≥11 h),[47] screen time (reference: <0.5 h/day),[48-50] maternal age (reference: ≤30 years), and parental smoking status (reference: neither parent). For the regression analyses, all variables were entered as binary indicator variables, not as ordinal or continuous variables. Parental smoking status, originally collected in four categories, was dichotomized as any parental smoking versus neither parent for the regression analyses. The reported odds ratios therefore represent the odds of excessive free sugar intake in the category of interest compared with the specified reference group. No adjustments for multiple comparisons were performed, as the analyses were exploratory. Odds ratios (ORs), 95% confidence intervals (CIs), and *p*-values were reported. All analyses were performed using Stata 19.5 (StataCorp, College Station, TX, United States), with two-sided *p*-values <0.05 considered statistically significant.

RESULTS

Study participation and sample selection

A total of 248 questionnaires were distributed to families of children eligible for the 1.5-year health checkup. Among the distributed questionnaires, 25 were provided to families whose infants did not complete the checkup, leaving 223 eligible participants. Among the eligible participants, 166 returned the questionnaires, yielding a response rate of 74.4%. After excluding 4 participants with incomplete demographic information and 70 with insufficient dietary records, 92 participants remained for the initial review. Among 92 remaining participants, 6 were excluded for meeting the medical exclusion criteria and having insufficient dietary recording days, and 2 were excluded for other predefined criteria. Consequently, the final sample for analysis comprised 84 infants (46 boys [54.8%] and 38 girls [45.2%]) (Figure 1, Table 1). Among the 82 questionnaires excluded, 58 contained sufficient demographic information to permit group-level comparisons. Additional analyses comparing the analytic and excluded groups showed no significant differences in sex, BMI, sleep duration, childcare attendance, caregiver occupation, or other core demographic characteristics, suggesting that selection bias related to sample exclusion was likely minimal.

Free sugar intake patterns

Mean daily intake of free sugar was 13.3 g (standard deviation [SD]; 10.5), with the intake being higher on Sunday (15.2 g) than on weekdays (11.1 g), representing a non-significant trend toward a 37% increase (p = 0.083, Wilcoxon signed-rank test). When expressed as a percentage of total energy intake (estimated from age- and sex-specific EERs), the mean contribution of free sugar was 5.7% (SD 4.6), with 4.8% (SD 4.6) on weekdays and 6.6% (SD 6.2) on Sundays. The median daily intake was 10.6 g (interquartile range [IQR] 5.4–18.2 g), indicating a right-skewed distribution.

A tendency toward higher energy intake from free sugar was observed among girls (mean 6.1%) compared to boys (mean 5.5%), although this difference was not statistically significant (p = 0.50, Wilcoxon signed-rank test).

Prevalence of excessive free sugar intake

When evaluated against WHO recommendations, 37 participants (44.0%, 95% CI: 33.2%–54.9%) exceeded the ideal free sugar intake threshold of ≥5% of the total energy intake, whereas 14 participants (16.7%, 95% CI: 8.5%–24.8%) exceeded the acceptable upper limit of ⩾10%. Among those exceeding the 10% threshold, the mean free sugar intake accounted for 14.1% of the total energy intake (range 10.2%–20.0%). The prevalence of excessive intake at the 5% level was similar between boys (43.5%) and girls (44.7%) ($p = 1.00$, Fisher's exact test).

Sources of free sugar

Across all dietary records, caregivers reported a total of 445 individual food items. The most frequently documented food group was confectioneries (group 15), accounting for 201 items (45.2%), followed by dairy products (group 13) with 117 items (26.3%), and fruits including 100% fruit juice (group 7) with 40 items (9.0%). As defined in this study's food group classification, "fruits" include items containing free sugars such as 100% fruit juice, whereas "dairy products" represent sweetened dairy foods. Intact fruits and plain unsweetened dairy products were not included in the calculation of free sugar.

Regarding free sugar contribution, confectioneries were the primary source (43.2% of the total intake), followed by fruits (27.3%), dairy products (23.3%), and beverages other than 100% fruit juice (group 16, 4.6%) (Figure 2). Figure 2 presents the percentage contribution of each food group to total free sugar intake across all dietary records. Notably, although fruits ranked third in frequency, they contributed disproportionately to free sugar intake, indicating a high sugar content per item (Figure 3).

The distribution of free sugar sources remained similar between participants with excessive (≥5% energy) and adequate (<5%) intake, suggesting that both groups primarily differed in terms of food quantity rather than source.

The distribution of food group contributions to total free sugar intake differed significantly between weekdays and Sundays in an exploratory chi-square test ($\chi^2 = 178$, df = 4, $p < 0.001$). Although confectioneries remained the top contributor on both days, dairy products ranked second on weekdays (33.3%), whereas fruits including 100% juice ranked second on Sundays (32.7%) (Figure 4), indicating a higher relative contribution of fruit-based items on Sundays.

Factors associated with excessive free sugar intake

Univariate analysis revealed a significant association between parental smoking status and excessive free sugar intake (≥5% energy) ($p = 0.009$, Fisher's exact test). The prevalence of excessive intake was highest among children from households where both parents smoked (88.9%, 8 of 9), compared with nonsmoking households (33.3%, 14 of 42) and households with only paternal smoking (46.7%, 14 of 30). Other variables, including child sex, sleep duration, screen time, maternal age at delivery, number of siblings, and childcare attendance, were not significantly associated with excessive free sugar intake.

Multivariable logistic regression analysis adjusting for child sex, sleep duration, screen time, maternal age at delivery, and parental smoking status found that no variable was significantly associated with excessive free sugar intake (Table 2). For parental smoking, the adjusted odds ratio was 2.27 (95% CI: 0.89–5.78; p = 0.086). Although elevated, this association did not reach statistical significance and should be interpreted with caution because of the wide confidence interval.

Similar results were observed when excessive intake was defined using the ≥10% energy threshold, although the small number of participants in this group (n = 14) might have limited the ability to detect significant differences (Table 3).

DISCUSSION

This cross-sectional study is the first to assess free sugar intake patterns among Japanese infants aged 18–23 months in a rural setting. Our key finding was that 44.0% of participants exceeded the WHO's ideal threshold for free sugar intake (5% of total energy intake), suggesting the importance of early dietary guidance targeting key free sugar sources—particularly 100% fruit juice and confectioneries—while ensuring that nutrient-dense foods such as fruits and dairy products are not discouraged. Previous studies in infants of the same age have shown mean intakes of 13.2%E in the US,[26] 10.4%E (29.3 g/day) in Australia,25 and 9.0%E (25.1 g/day) in Ireland.[27] Herein, the mean daily free sugar intake was 13.3 g (5.7% of total energy), indicating that Japanese infants consumed less free sugar than their international counterparts; however, a considerable proportion exceeded the recommended intake levels during this critical developmental period.

This study has several methodological strengths. First, our study population was recruited through a municipal health checkup program targeting all children eligible for the 1.5-year checkup in Kama City, Fukuoka Prefecture. This approach may have reduced selection bias within the local population and provided data from a rural Japanese setting that has been underrepresented in previous research. Second, dietary intake was assessed using 2-day dietary records (one weekday and one Sunday), which is more robust than the single-day assessments commonly used in pediatric nutrition research.[56,57] The inclusion of both weekdays and weekends reduced the potential for bias caused by temporal variation, particularly given the tendency for sugar intake to be higher on weekends than on weekdays.[58,59] Third, the data collection spanned approximately 2 years, which may have helped reduce seasonal biases.[60,61] Fourth, two trained registered dietitians applied the objective measurement methodology from Louie et al.[33,43] In our assessments, the majority of foods were assessed up to Step 6, ensuring that most measurements were completed at the highest level of confidence. Finally, the exclusion criteria were established based on pediatric considerations, such as recent infection or low birth weight, which could affect feeding behavior. Supplemental analyses comparing the analytic sample with excluded participants showed no significant differences in core demographic characteristics, suggesting that substantial selection bias arising from participant exclusion was unlikely.

Our study identified confectioneries as the primary source of free sugar (43.2% of intake) followed by fruits including 100% juice (27.3%), providing important insights for targeted intervention strategies. Particularly noteworthy was the disproportionate contribution of 100% fruit juice, which represented more than one-quarter of the total free sugar intake despite comprising only 9.0% of recorded food items. This finding suggests the notable contribution of 100% fruit juice to free sugar intake in this population and is in line with growing concerns regarding excessive fruit juice consumption in early childhood.[62-64] Because our study focused on free sugar intake as defined by the WHO, intact fruit consumption itself was outside the scope of the assessment. Therefore, we could not determine whether the contribution of 100% fruit juice or fruit-based products reflected broader fruit consumption patterns or intake of these products independent of intact fruit consumption. This point should be considered when interpreting the dietary context of fruit-based sources of free sugar.

Our findings are consistent with the limited previous research conducted among Japanese children, particularly that by Fujiwara et al.,33 which reported mean free sugar intakes of 6–7%E (17–18 g/day) in toddlers aged 18–35 months and 7–8%E (26–27 g/day) in preschool children aged 3–6 years, indicating consistently low intake levels across a broader age range. However, our study extends these findings by demonstrating concerning intake patterns even before the age of 2 years, earlier than previously documented in the Japanese population. The 16.7% and 44.0% prevalence of participants who exceeded the WHO 10% and 5% thresholds estimated using EERs-based energy references compares favorably to international data. In the United States, toddlers aged 12–23 months consumed on average 24 g/day (7.6%E),[65] and among children aged 2–5 years, 62.9% exceeded the WHO 10%E threshold.[26] In Canada, 80% of preschool children exceeded the 5%E threshold and 32% exceeded the 10%E threshold.[66-68] In Australia, just over 50% of 2-year-olds consumed ≥10%E.[25] In Ireland, mean free sugar intake among 1–4-year-old children was 12%E (37.6 g/day), with average intakes of 13–14%E in 3- to 4-year-olds, indicating that the majority exceeded the 10%E threshold.[27] Although caution is warranted due to cross-national differences in food categorization, our finding that confectioneries were the largest source of free sugar aligns with reports from other high-income countries identifying similar sweet food categories (e.g., "sugar and sweets," "bakery products") as leading contributors.[66-69] In contrast, the substantial contribution of 100% fruit juice in our study population may reflect specific dietary practices in rural Japanese communities, where fruit juice consumption might be perceived as supporting adequate fruit intake among young children. The notable variation in intake patterns between weekends and weekdays, as evidenced by a 37% higher consumption on weekends, has also been observed in other pediatric populations[58,59] and may reflect changes in family routine and food availability. This temporal pattern suggests that intervention strategies may benefit from addressing both routine weekday feeding practices and special occasion or weekend dietary behaviors.

Several important considerations may account for the lack of significant associations between excessive free sugar intake and hypothesized risk factors, including sleep duration, screen time, and maternal age. First, the studied age group represents a period when parental control over dietary intake is nearly complete, potentially masking individual behavioral factors that become more prominent in older children. This is supported by evidence showing strong dietary resemblance between parents and young children.[70] Second, the relatively homogeneous rural population may display limited variation in socioeconomic and lifestyle factors, reducing our ability to detect meaningful associations. This interpretation is supported by the household income distribution in our study region (Kama City), indicating that most households fell within the low-to-middle-income brackets and that the proportion of high-income households (≥10 million Japanese yen [JPY]) was substantially lower than that of the national average (2.9% vs. 15.3%).[71] The observed association between parental smoking and excessive intake in the univariate analysis, which was attenuated in the multivariable models, warrants careful interpretation. Although this could represent a true association mediated by shared lifestyle behaviors or attitudes toward health recommendations,[72] the attenuation after adjustment may also reflect confounding by measured or unmeasured factors, as well as limited statistical power. Potentially important confounding factors, such as parental educational attainment, household income, caregiver health literacy, and detailed feeding practices including breastfeeding history, were not collected and therefore could not be adjusted for in the analyses. These factors may influence both household food choices and children's free sugar intake; therefore, residual confounding may remain, and the observed associations or lack of associations should be interpreted cautiously.

The small sample size also limits our study's power to detect modest but clinically meaningful associations, raising the possibility of type II error.

Several limitations warrant consideration when interpreting these findings. First, this study only assessed the intake of commercially available foods and did not include free sugar from home-prepared foods or meals provided at daycare facilities, potentially underestimating the total intake of free sugar. However, given the age group of the participants studied, most of the free sugar sources are presumed to be commercial products.[25,26,33,66,68,73] Because meals served at daycare facilities were not directly observed and often include commercial snacks, free sugar intake consumed during daycare may have been partially underreported, particularly on weekdays. Second, the EERs were used as a proxy for total energy intake, which was not directly measured. Although this method does not reflect individual energy intake, it has been commonly used in studies of toddlers where precise energy assessment is challenging.[25,52,53] Therefore, the estimated %E should be interpreted as an approximate indicator of the relative contribution of free sugars to total energy needs, rather than a precise energy proportion. Third, reliance on published literature and recipe-based information for certain foods may introduce some degree of measurement error, although the use of a validated protocol and consistent evaluation by trained dietitians likely mitigated this issue. Fourth, although the dietary record form and self-administered questionnaire were specifically developed in Japanese and tailored for this population, they have not undergone validation. This may limit the reliability of certain responses, particularly regarding the estimation of portion sizes and recognition of commercial food products and some self-reported measures. Fifth, potential reporting bias due to caregiver misreporting and social desirability bias cannot be ruled out; prior studies have documented underreporting of sweet foods, which may lead to underestimation of free sugar intake.[74] In addition, this observational cross-sectional study was not prospectively registered; therefore, the analyses of associated factors should be interpreted as exploratory. Although data collection was conducted continuously across approximately 2 years, seasonal variation in dietary intake was not separately adjusted for in the analyses. Thus, the possibility that seasonal differences in food availability or dietary habits influenced free sugar intake cannot be completely excluded. Although supplemental comparisons indicated no major differences between the analytic and excluded groups, some degree of self-selection bias cannot be entirely ruled out because demographic information was unavailable for a portion of excluded and nonresponding families. Moreover, no a priori power analysis was conducted, as this study used data from a municipal health checkup program that included all eligible children in the study area and was not originally designed for hypothesis testing; thus, the small sample size may have limited the power to detect modest but practically meaningful associations. In addition, analyses using the ≥10%E threshold should be interpreted cautiously because the limited number of participants in this group may have resulted in unstable estimates and wide confidence intervals. The findings may also not be generalizable to younger infants, who may have different feeding patterns and dietary exposures, because this study included only children aged 18–23 months. Lastly, given that this study was conducted in a single rural area with a relatively small sample size, our results may not be generalizable to urban populations or other rural areas with different dietary environments and access to food products.[75]

Conclusions

In this study of Japanese infants aged 18–23 months, 16.7% exceeded the WHO recommendation of <10% of energy from free sugar, and 44.0% exceeded the ideal threshold of <5%. Confectioneries were the largest contributor to free sugar intake, followed by fruits including 100% juice, which accounted for more than one-quarter of total free sugar despite relatively infrequent consumption. No significant associations were observed between excessive intake and demographic or lifestyle characteristics. These findings highlight the substantial contribution of 100% fruit juice to free sugar intake in children under 2 years of age and provide foundational data on early-life dietary patterns. Future studies are needed to evaluate whether nutritional guidance targeting caregivers through early health checkups may support healthier dietary behaviors from infancy.

SUPPLEMENTARY MATERIALS

All supplementary tables and figures are available upon request from the editorial office, and are also accessible on the journal's webpage (apjcn.qdu.edu.cn).

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DISCLOSURE ON THE USE OF AI AND AI-ASSISTED TECHNOLOGIES

AI-assisted technologies were used for the creation and visual refinement of the graphical abstract. All scientific content, data interpretation, and final decisions regarding the figure design were made by the authors.

CONFLICT OF INTEREST AND FUNDING DISCLOSURE

The authors declare no conflict of interest.

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Table 1. Participant characteristics (n = 84)

Variable	Total	≥5% of energy from free sugar	<5% of energy from free sugar	*p*-value
Participants, n (%)	84 (100)	37 (44.0)	47 (56.0)	—
Continuous variables				
Free sugar (g/day), mean (SD)	13.3 (10.5)	22.4 (9.3)	6.1 (3.5)	—
Free sugar (% of total energy intake), mean (SD)	5.7 (4.6)	9.7 (4.1)	2.6 (1.5)	—
Height (cm), mean (SD)	80.1 (3.0)	80.1 (3.4)	80.0 (2.8)	0.550
Weight (kg), mean (SD)	10.7 (1.1)	10.8 (1.2)	10.6 (1.1)	0.500
Percentage overweight (%), mean (SD)	3.9 (8.0)	4.9 (8.7)	3.1 (7.5)	0.470
Categorical variables				
Sex				1.000
Boys	46 (54.8)	20 (54.1)	26 (55.3)	
Girls	38 (45.2)	17 (45.9)	21 (44.7)	
Number of siblings				0.850
1	29 (34.5)	11 (30.1)	18 (40.0)	
2	29 (34.5)	14 (38.9)	15 (33.3)	
3	19 (22.6)	9 (25.0)	10 (22.2)	
4	4 (4.8)	2 (5.6)	2 (4.4)	
Sleep duration				0.690
<8 h	4 (4.8)	1 (2.8)	3 (6.4)	
8–11 h	65 (77.4)	28 (77.8)	37 (78.7)	
11–14 h	14 (16.7)	7 (19.4)	7 (14.9)	
≥14 h	0 (0)	0 (0)	0 (0)	
History of dental caries treatment				0.500
Yes	2 (2.4)	0 (0)	2 (4.3)	
No	81 (96.4)	36 (100)	45 (95.7)	
Attending kindergarten				1.000
Yes	71 (84.5)	31 (86.1)	40 (85.1)	
No	12 (14.3)	5 (13.9)	7 (14.9)	
Screen time				0.980
≤30 min	16 (19.1)	7 (19.4)	9 (19.1)	
30 min–1 h	32 (38.1)	13 (36.1)	19 (40.4)	
1–3 h	31 (36.9)	14 (38.9)	17 (36.2)	
≥3 h	4 (4.8)	2 (5.6)	2 (4.3)	
Living with grandparents				0.750
Yes	11 (13.1)	4 (10.8)	7 (14.9)	
No	73 (86.9)	33 (89.2)	40 (85.1)	
Mother's age at childbirth				0.170
≤30 years	43 (51.2)	22 (61.1)	21 (45.7)	
≥31 years	39 (46.4)	14 (38.9)	25 (54.3)	
Parental smoking status				0.009
Neither parent smokes	42 (50.0)	14 (38.9)	28 (59.6)	
Only the father smokes	30 (35.7)	14 (38.9)	16 (34.0)	
Only the mother smokes	2 (2.4)	0 (0)	2 (4.3)	
Both parents smoke		8 (22.2)	1 (2.1)	
Occupation				0.240
Company employee		25 (69.4)	35 (74.5)	
Government worker		3 (8.3)	5 (10.6)	
Self-employed		7 (19.4)	3 (6.4)	
Part-time worker		0 (0)	3 (6.4)	
Unemployed		1 (2.8)	1 (2.1)	

Fisher's exact test was applied for categorical variables, and the Wilcoxon rank-sum test was used for continuous variables.

Table 2. Multivariable logistic regression analysis to identify variables associated with free sugar intake ≥5% of the total energy intake

Variable	Univariable OR (95% CI)	*p*-value	Multivariable OR (95% CI)	*p*-value
Child sex	1.05 (0.44–2.50)	0.908	1.26 (0.50–3.22)	0.622
Sleep duration	0.73 (0.23–2.29)	0.584	0.56 (0.16–1.96)	0.368
Screen time	0.98 (0.33–2.95)	0.973	0.86 (0.26–2.83)	0.801
Mother's age at childbirth	0.53 (0.22–1.30)	0.166	0.53 (0.21–1.34)	0.178
Parental smoking status	2.32 (0.95–5.63)	0.064	2.27 (0.89–5.78)	0.086

OR, odds ratio; CI, confidence interval.
Multivariable model adjusted for child sex, sleep duration, screen time, mother's age at childbirth, and parental smoking status.

Table 3. Multivariable logistic regression analysis to identify variables associated with free sugar intake ≥10% of the total energy intake

Variable	Univariable OR (95% CI)	*p*-value	Multivariable OR (95% CI)	*p*-value
Child sex	1.78 (0.56–5.67)	0.331	1.83 (0.53–6.36)	0.339
Sleep duration	0.62 (0.15–2.63)	0.518	0.52 (0.11–2.41)	0.405
Screen time	0.76 (0.18–3.16)	0.706	0.61 (0.13–2.76)	0.521
Mother's age at childbirth	0.38 (0.11–1.32)	0.127	0.37 (0.10–1.39)	0.141
Parental smoking status	1.45 (0.46–4.64)	0.526	1.28 (0.37–4.41)	0.699

OR, odds ratio; CI, confidence interval.
Multivariable model adjusted for child sex, sleep duration, screen time, mother's age at childbirth, and parental smoking status.

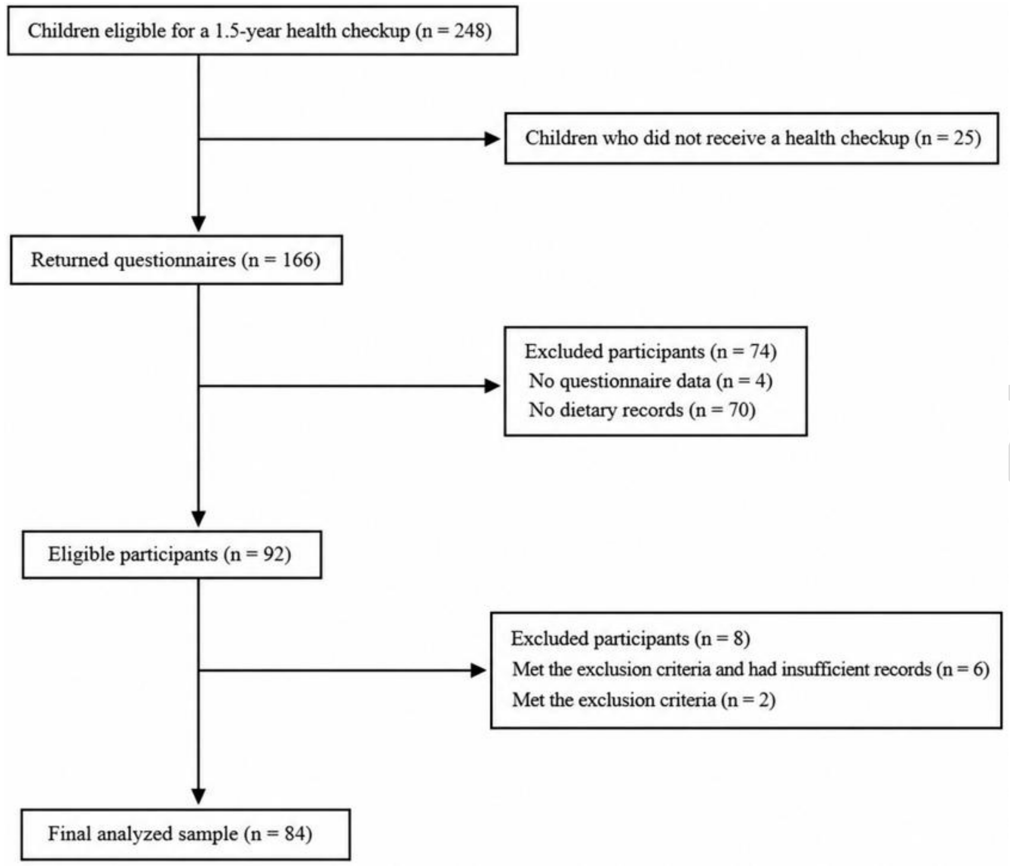


Figure 1. Participant flow diagram

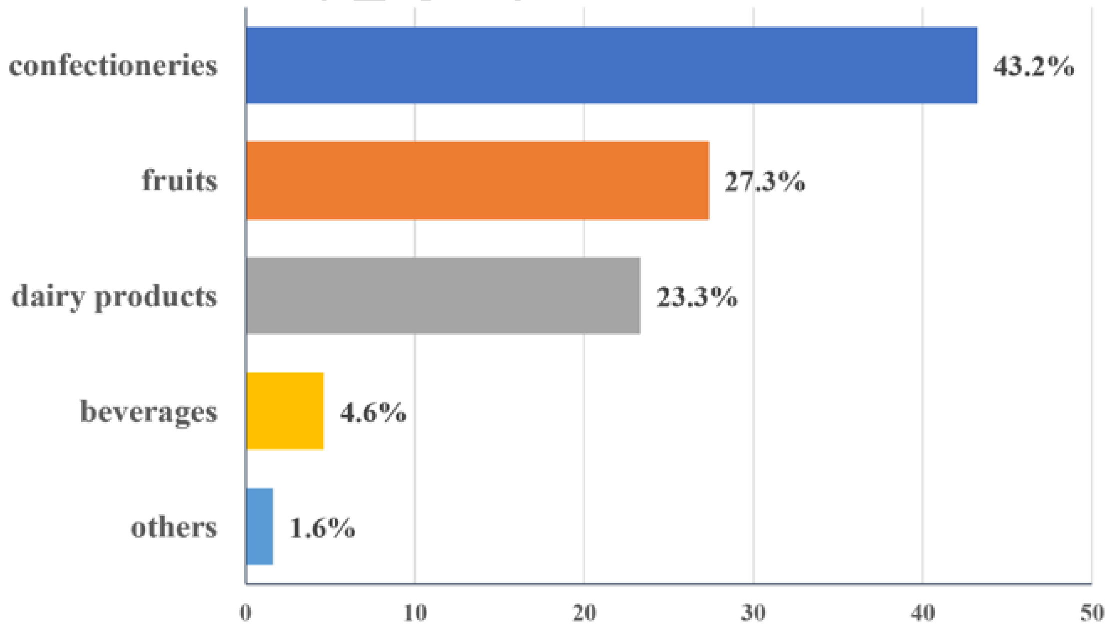


Figure 2. Percentage contribution of major food groups to total free sugar intake among Japanese infants aged 18–23 months

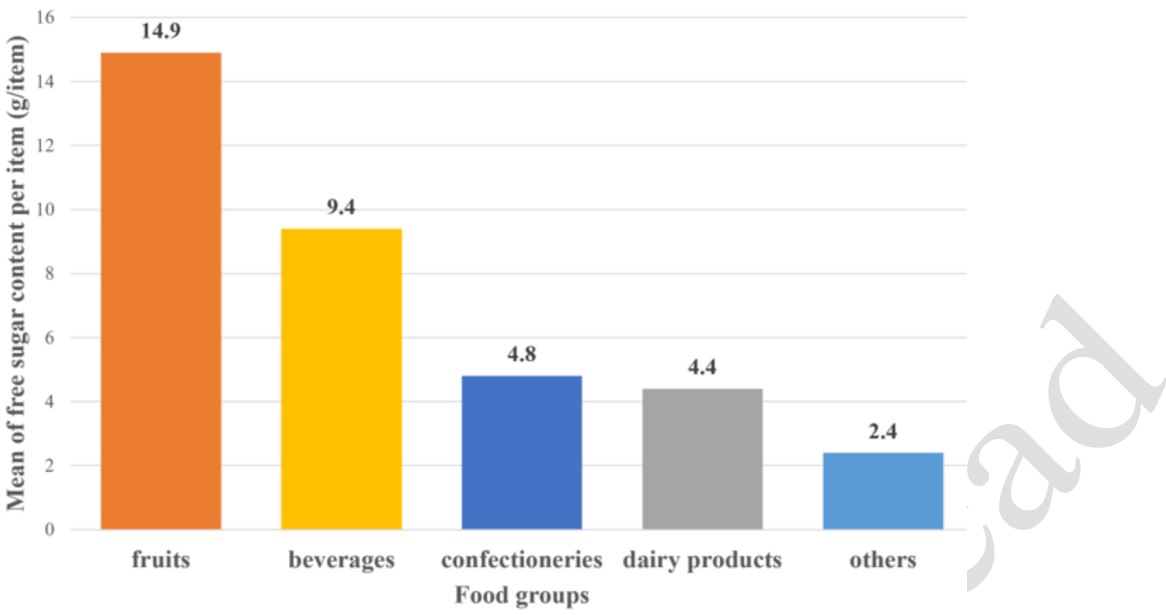


Figure 3. Mean free sugar content per consumed item for each major food group

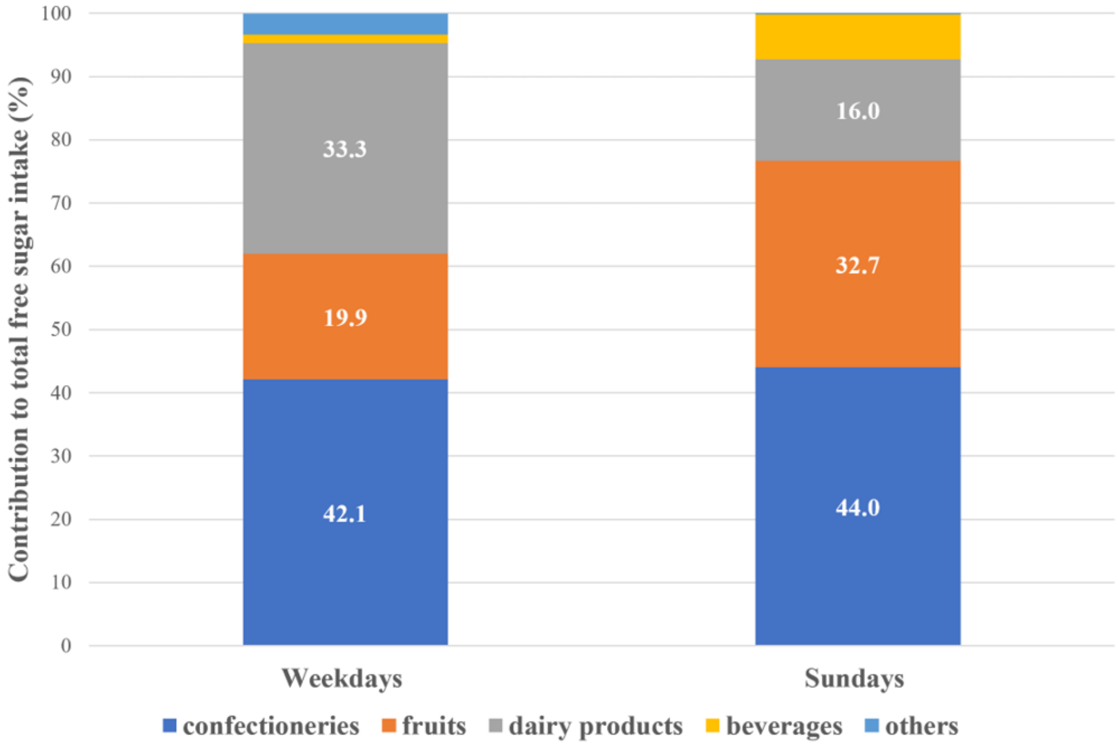
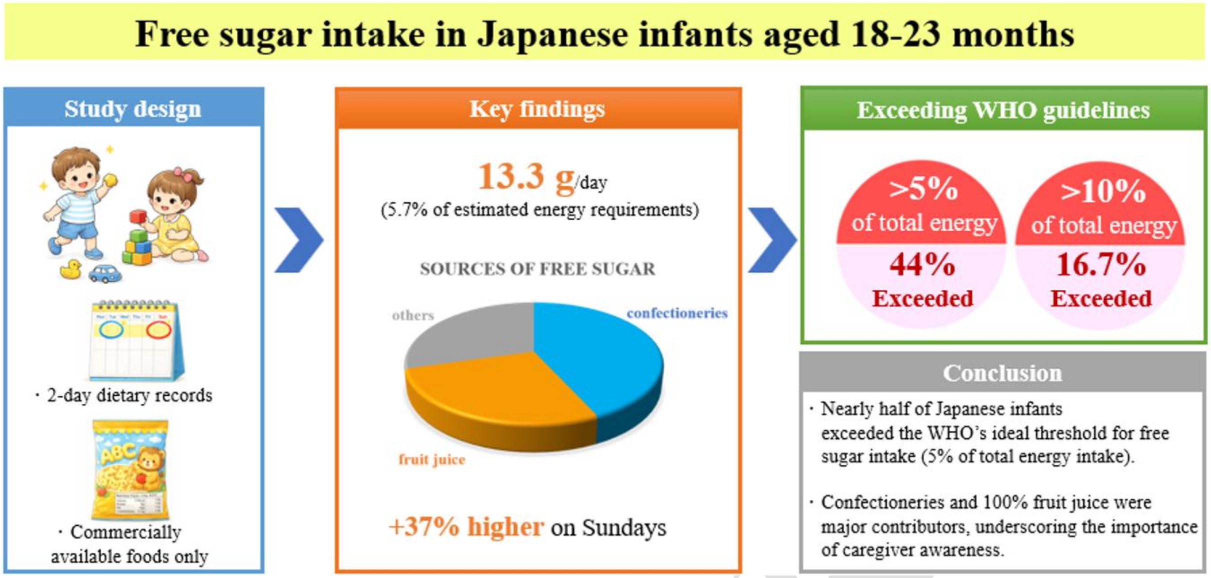


Figure 4. Percentage contribution of food groups to total free sugar intake among Japanese infants aged 18–23 months on weekdays and Sundays



Graphical abstract