Preventive Medicine Reports 23 (2021) 101409

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Limited consumption of 100% fruit juices and sugar sweetened beverages in Japanese toddler and preschool children

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ARTICLE INFO

Keywords:
Obesity
Fruit juice
Preschool
Japan

ABSTRACT

Japanese toddler and preschool children, ages 1.5–5 years, have lower rates of obesity, ≥95 th percentile body mass index, compared with North American ones. We examined parental reported beverage consumption patterns in 3 Japanese based mother-child cohorts from three different regions of Japan compared with data from cross-sectional and longitudinal studies from North America. Specifically, we used data from the Hamamatsu Birth Cohort for Mothers and Children (HBC Study) in Hamamatsu (Shizuoka Prefecture), the Seiiku Boshi Birth Cohort from Setagaya, Tokyo and the TMM BirThree Cohort Study from Miyagi. We additionally compared cross-sectional data from preschoolers from 24 prefectures in Japan as previously reported from a national study. While Japanese children had lower but comparable rates to North American children for introduction of sugar-sweetened beverages and 100% fruit juices, Japanese children consumed these beverages daily at a much lower level than North American children. Additionally, North American children may get more added sugars from soda and fruit juices as a relative percentage of total added sugar. By contrast, Japanese children consume more sweetened dairy drinks as a relative percentage of total added sugar. Sweetened dairy drinks may have the added benefits of including fats, calcium and probiotics which may be associated with lower risk for obesity compared with consumption of other types of sugar sweetened beverages.

1. Background

Japan is somewhat of an anomaly in the industrialized world as there is a much lower percentage of childhood obesity and overweight than in North and South America, Europe and even the rest of Asia (with obesity commonly defined as ≥95th percentile body mass index and overweight ≥85th percentile body mass index) (CDC, 2020). Japanese elementary school children have 1.4–5.9% obesity (using the Japanese definition of obesity as percentage of overweight, (POW) ≥30%) for girls and 2.9–7.0% for boys (Japanese Ministry of Health, Labour and Welfare, 2017). The low prevalence in Japan is in sharp contrast to 18.5% reported among children in the United States (13.9% among 2 to 5-year-old children) as per the National Health and Nutrition Examination Survey (2015-16) (Hales et al., 2017).

A significant number of studies have linked the consumption of sugar sweetened beverages (SSB), defined as beverages with added sugars including sodas, fruit drinks and sugared dairy/milk drinks, to childhood obesity (Ludwig et al., 2001; Ruanpeng et al., 2017). Studies from North America and Europe suggest a high consumption of sugar from all beverage types for US and European preschool and young children with >50% of US children drinking SSBs daily and more than a quarter of European children also consuming SSBs daily (Bleich et al., 2018; Skeie et al., 2019). Additionally, as satiety may be limited from liquid versus solid food intake, calories from SSBs may disproportionately impact the childhood obesity epidemic (Pan and Hu, 2011). In this study, we summarize the consumption of SSBs and other types of beverages in preschool children in Japan from different cross-sectional and cohort studies to better understand overall patterns of beverage intake in young Japanese children. We compare these Japanese studies with patterns of dietary intake among North American children. We focus on North

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https://doi.org/10.1016/j.pmedr.2021.101409
Received 1 August 2020; Received in revised form 11 May 2021; Accepted 25 May 2021
Available online 30 May 2021

American children as a comparison group given the high overall reported intake of SSBs in North American children and the existence of population-based samples with beverage consumption data in early childhood (Hu, 2013).

2. Methods

We compared SSB and 100% fruit juice consumption from North American children based on published reports with data from three Japanese cohorts from different regions of Japan as well as a nationally representative cross-sectional study from Japan as described below. Specifically, we included data from a hospital-based cohort from Hamamatsu called the Hamamatsu Birth Cohort for Mothers and Children (HBC Study) (n = 1258) (Takagai et al., 2016), the Seiiku Boshi Birth Cohort, a prospective hospital-based cohort from Setagaya, Tokyo (Ando et al., 2018; Ogawa et al., 2018) (n = 1385) and the Tohoku Medical Megabank Project Birth and Three-Generation Cohort Study (TMM BirThree Cohort Study) (n = 22,493) from Miyagi (Kuriyama et al., 2019). These three cohorts all collected beverage consumption information during the preschool years (2–5 years of age) as well as 100% fruit juice and/or SSB consumption during the toddler (1–<2 years) or preschool years. Questions were asked about *any* consumption and *daily* consumption (HBC) with Seiiku Boshi and TMM BirThree asking about daily consumption patterns.

All three Japanese cohort studies received ethical approval from their respective universities. For the HBC cohort, ethical approval was obtained from the Hamamatsu University School of Medicine and University Hospital Ethics Committee, and written informed consent was obtained from each mother for her child's participation. For the Seiiku Boshi Cohort, ethical approval was received by the Institutional Review Board (IRB) at the National Center for Child Health and Development and all participants provided written informed consent to participate. For the TMM BirThree Cohort Study in Miyagi, The TMM BirThree Cohort Study protocol was reviewed and approved by the Ethics Committee of Tohoku University Tohoku Medical Megabank Organization and all women provided written, signed consent for their participation. Co-investigators for these three studies are also listed as co-authors on this study.

In addition to analysis of these individual cohort data from different regions of Japan, we compared cohort beverage frequency data with previously published data from a geographically representative study in Japan, the Dietary Observation and Nutrient Intake for Good Health Research in Japanese Young Children (DONGuRI) (Fujiwara et al., 2019; Tajima et al., 2020). While the sample size from the DONGuRI was significantly smaller than the other cohorts (n = 332), children were recruited from nursery schools with more geographical diversity: 24 prefectures in Japan (ages 1.4–3, 4, 5 and 6). Furthermore, more specific dietary intake data was collected in the DONGuRI study. Consumption of total sugar intake was calculated for all children (grams/day) using a 3-day dietary record. Beverages were defined using the following categories: 100% fruit and vegetable juices, fruit drinks (juices with >10% fruit or vegetable juice but <100% juices), milk/dairy beverages, soda (carbonated beverages), sports drinks (including energy drinks) and presweetened teas and coffees.

Lastly, we compared consumption data from Japanese cohorts/cross-sectional studies with published consumption data from North America, including United States samples and cohorts with a focus on dietary intake and nutrition. This included the National Health and Nutrition Examination Survey (NHAHES) 2013–2014 (Bleich et al., 2018), 2009–2012 (Vos et al., 2017), 2009–2014 (Hamner et al., 2017) and 2011–2016 (Herrick et al., 2020). These samples from NHANES included a cross-sectional study of children 12 to 18 months (n = 445; Hamner et al., 2017), 12 to 23 months (n = 651; Herrick et al., 2020), 2–5 years of age (approximately n = 730; Bleich et al., 2018) as well as cross-sectional data on preschool and school age children of different age ranges (n = 3995 (Vos et al., 2017)). We also included the US-based Feeding Infants and Toddlers Study (FITS) (2008, 2016) (Duffy et al., 2019; Briefel et al., 2015) which includes feeding data on toddlers aged 12–24 months (n = 5963). We assessed total sugar intake via SSB categories (e.g. soda and fruit drinks versus milk and dairy drinks) reporting the results as collected from NHANES 2011–2016 in children 11 to 23 months using data on sugar intake from two 24-hour dietary recalls (Herrick et al., 2020) and using NHANES 2009–2012 for children 24 months to 13 years (Vos et al., 2017; Afeiche et al., 2018a). NHANES reports dietary sugar intake by category in teaspoons per day which we converted to grams using the conversion rate of 4.2 g equals 1 teaspoon of sugar (Hamner and Moore, 2020).

We also compared daily sugar intake from SSBs (in grams/day) with Mexican children, 4–13 years (n = 3985) (Afeiche et al., 2018a). Comparable studies from Mexico were included such as the Mexico National Survey of Health and Nutrition (ENSANUT, 2012) (n = 3980 for preschool and n = 949 for toddlers) (Afeiche et al., 2018a, 2018b) and a longitudinal study of primary care-based practices entitled the TARGet Kids! from a network of the Greater Toronto Area, Canada (n = 999) (Ziesmann et al., 2019). We also included two US-based longitudinal cohort studies including the Project Viva study (n = 1163) based in Boston, Massachusetts (Sonneville et al., 2015) and the Early Childhood Longitudinal Study-Birth Cohort, a prospective population-based sample of children born in the United States in 2001 (n = 8950) (Shefferly et al., 2016). These additional studies were added to enable comparison with data from Japanese cohorts on daily and any beverage consumption with those from North America stratifying children by ages (toddler: 12 months–<24 months to preschool: 24 months–4 years) and by frequency of beverage consumption (any versus daily).

3. Results

3.1. Any 100% fruit juice consumption or SSB consumption

Overall, we found a comparable rate of any consumption of 100% fruit juice and SSBs between preschool children with data from regional cohorts in Japan with those from North American cohorts. In the HBC Study (Takagai et al., 2016), parents of children in Hamamatsu reported 33.0% consumed *any* 100% fruit juices at 14 months with numbers rising to 49.3% at 32 months. For Seiiku Boshi in the Tokyo prefecture, the numbers were higher at 81% having consumed any 100% fruit juice at 3 years of age.

A lower proportion of Japanese children had consumed SSBs as toddlers compared with 100% fruit juices. At 14 months in Hamamatsu, 18.6% had consumed SSBs (not including sweetened dairy/milk drinks) and 44.8% had consumed SSBs at 32 months in the HBC cohort. For Seiiku Boshi, by 3 years of age, 44.3% of parents reported that children were drinking any SSBs (not including sweetened dairy/milk drinks) with a higher 55.2% drinking sweetened dairy/milk drinks.

These numbers were comparable with those reported from North American children, including toddlers from FITS (2016) (Duffy et al., 2019). Parents reported any consumption of 100% fruit juice at 48.0% (49.1% in NHANES 2009–2014) (Hamner et al., 2017) with similar numbers in preschool (2–5 years) at 45.4% per NHANES (2013-4) (Bleich et al., 2018). As reported in the ENSANUT study (2012), a lower percentage of Mexican children were drinking any 100% fruit juice (18%) (Afeiche et al., 2018a). For American children, parents reported that 25% of toddlers had some consumption of SSBs (FITS, 2016) (Duffy et al., 2019) with 46.5% of parents reporting consumption in preschool children in 2013–2014 (Bleich et al., 2018). There was some regional variation in North America, with a much higher percentage of Mexican children drinking SSBs as toddlers (63%) as per the ENSANUT study (2012) (Afeiche et al., 2018a).

3.2. Daily 100% fruit juice/fruit drink or SSB consumption

Compared with any exposures to 100% fruit juices or SSBs, young

Japanese children were drinking 100% fruit juices and SSBs on a daily basis much less regularly than their North American counterparts. In Hamamatsu (the HBC Study), 4.9% of toddlers and 6.6% of preschool children had *daily* 100% fruit juice consumption with 6.6% of toddler drinking SSBs *daily* and 12.2% of preschoolers drinking SSBs *daily*. In the Seiiku Boshi birth cohort (Morisaki et al., 2016) in Setagaya, only 2.1% of children at 12 months of age had *daily* consumption of SSBs, (including 100% fruit juice and sweetened dairy). At 3 years of age, parents reported that 3.2% had *daily* SSB consumption rising to 8.9% when 100% fruit juice was included. The majority of the SSB consumption was from flavored dairy/milk products with 2.1% reporting *daily* sweetened dairy consumption. In Miyagi (the TMM BirThree Cohort), a higher percentage of children had *daily* consumption of fruit juice (including 100% fruit juice and fruit drinks). At 2 years of age, 21.4% of children had *daily* fruit juice consumption (100% fruit juice and fruit drinks) and 17.8% at 3 years of age and 15.8% at 3.5 years of age had *daily* fruit juice consumption (Table 1).

The numbers for *daily* consumption of 100% fruit juice and SSBs are much higher for American children compared with Japanese ones with 77.4% of toddlers in Project Viva having *daily* 100% fruit juice intake (Sonneville et al., 2015), 72% of preschoolers from the Early Longitudinal Birth Study (Shefferly et al., 2016) and 42.9% of preschoolers from TARGet Kids) (Ziesmann et al., 2019) having *daily* 100% fruit juice consumption. A high 46.1% also reported *daily* SSB consumption for preschool children from FITS (Briefel et al., 2015).

3.3. Total sugar consumption from beverages

From the DONGuRI study, consumption of free sugars from all beverages (SSBs and 100% fruit juices, including sweetened dairy/milk beverages) was a mean 8.2 g for children 3–6 years of age per day (Fujiwara et al., 2019) (Table 2). Dairy/milk beverages which included flavored milks, yogurt drinks, lactic acid beverages and flavored soy milks were the source of the highest sugar consumption for children at this age for SSBs (total SSB was 6.0 g, without the 100% fruit and vegetable juices) (Tajima et al, 2020; Fujiwara et al., 2019). Of note, American toddler and preschool children as indicated by NHANES had much higher overall consumption of added sugars. Children younger than children from the DONGuRI study (12–23.9 months versus 3–6 years of age in DONGuRI) consumed a mean of 6.6 g/day of sugar from soda and fruit drinks with another 1.4 g from milk and dairy/milk drinks for a total of 8.0 g per day (Herrick et al., 2020). By the time American children are in preschool (2–5 years of age), they are consuming 14.1 g a day of sugar from SSBs (not including milk/dairy beverages), more than double that of their Japanese counterparts (Vos et al., 2017). For North American preschool and school-aged children (4–13 years) in US and Mexico, the total intake of SSBs increases as children get older with the highest amounts from fruit drinks (12–14 g/day) and then from sodas (10–12 g/day) (Table 2) (Afeiche et al., 2018a).

4. Discussion

4.1. Frequency and volume of SSB consumption in young Japanese children

Japanese preschool and toddler children have a much lower daily consumption of SSBs and 100% fruit juice than North American children as indicated by data collected from regional cohort beverage frequency questionnaires and dietary records from national-based samples. North American and Japanese children are exposed and introduced to 100% fruit juice and SSBs in the toddler and preschool years at a similar frequency to North American children, but North American ones are much more likely to drink SSBs and 100% fruit juice on a daily basis as early as the toddler period.

While other studies have suggested that lower added sugar intake among Japanese children may in part explain the lower prevalence of

Table 1
Frequency of beverage consumption by japanese cohort and comparable North American Cohort/Study.

Cohort	HBC Study (Hamamatsu Cohort)	Seiiku Boshi Cohort (Setagaya, Tokyo)	TMM BirThree Cohort (Miyagi)	North American Populations
ANY CONSUMPTION				
Any Fruit or 100% Fruit Juice Consumption (Toddlers)[b]	33.0% (100% fruit juice only) (14 months)			48.0% (FITS, 2016) (100% fruit juice only) (12–23.9 months) (Duffy et al., 2019) 18% (ENSANUT 2012) (100% fruit juice only) (12–23.9 months) (Afeiche et al., 2018a) 49.1% (NHANES 2009–2014) (100% fruit juice only) (12–18 mo)(Hamner et al, 2017)
Any Fruit or 100% Fruit Juice Consumption (Preschool)[b]	49.3% (100% fruit juice only at 32 months)	81.2% (100% fruit juice only, 3 years)		45.4% (NHANES 2013–2014) (100% fruit juice only) (2–5 years) (Bleich et al., 2018)
Any SSB[a] Consumption (Toddlers)	18.6% (no milk/dairy) (14 months)			63% (ENSANUT 2012) (no milk/dairy drinks) (12–23.9 months) (Afeiche et al., 2018a) 25% (FITS, 2016) no milk/dairy drinks) (12–23.9 months) (Duffy et al., 2019) 31.8% (12–18 mo; NHANES 2009–14) (Hamner et al., 2017)
Any SSB[a] Consumption (Preschool)[b]	44.8% (no milk/diary)	44.3% (no milk/dairy drinks)55.2% (only dairy drinks) (3 years)		46.5% (NHANES; 2013–2014) (no milk/dairy drinks) (2–5 years) (Bleich et al., 2018)
DAILY CONSUMPTION				
Daily Fruit or 100% Fruit Juice Consumption (Toddlers)[b]	4.9% (100% fruit juice) (14 months)			77.4% (Project Viva) (100% fruit juice only) (12 months) (Sonneville et al., 2015)
Daily SSB[a] Consumption (Toddlers)[b]	5.9% (no milk/dairy drinks)	2.1% (including milk/dairy drinks and 100% fruit		27.8% (FITS, 2008) (12–23.9 months) (Briefel et al., 2015)

(*continued on next page*)

Table 1 (*continued*)

Cohort	HBC Study (Hamamatsu Cohort)	Seiiku Boshi Cohort (Setagaya, Tokyo)	TMM BirThree Cohort (Miyagi)	North American Populations
		juice) (12 months)		
Daily Fruit or 100% Fruit Juice Consumption (Preschool)[b]	6.6% (100% fruit juice only)	6.4% (100% fruit juice only) (3 years)		72% (Early Longitudinal Birth Study) (2–5 years)(Shefferly et al., 2016); 42.9% TARGet Kids (only 100% fruit juice) (<2.5 years) (Ziesmann et al., 2019)
Daily SSB[a] Consumption (Preschool)[b]	12.2% (no milk/dairy drinks)	8.9% (including milk/dairy drinks) 3.2% (without 100% fruit juice, including dairy/milk drinks) (3 years)	21.4% (2 yrs) 17.8% (3 yrs) 15.8% (3.5 yrs) (100% fruit juice and fruit drinks)	46.1% (FITS, 2008) (no milk/ diary drinks) (24–47.9 months) (Briefel et al., 2015) 3.2% TARGet Kids (no milk/ dairy drinks) (<2.5 years) (Ziesmann et al., 2019)

[a] SSB includes fruit drinks and 100% fruit juice in addition to milk beverages and soft drinks/soda.

[b] Toddler age is between 12 and 24 months and preschool age is >24 months and <5 years of age.

Table 2
Grams of estimated added sugar and free sugar by type of beverage consumed (Japanese versus North American Studies).

	DONGuRI Study (Japanese study)	North American Studies
Type of Drink		
SSB added sugar (toddler) (12–23.9 months)		6.6 g (Soda and fruit drinks) 1.4 g (Milk/dairy drinks) (NHANES 2011–2016) (Herrick et al., 2020)
SSB added sugar and 100% Fruit Juices (free sugar) (preschool) (<6 years and >=24 months)	6.0 g SSBs including milk dairy/drinks 2.2 g (100% Fruit and vegetable juices) (Fujiwara et al., 2019)	10 g (Fruit drinks) 4.1 g (Sodas) (NHANES 2009–2012) (Vos et al., 2017)
SSB added sugar (preschool-primary school) (4–13 years)		12.3 g (Soda) (USA) 12.6 g (Fruit drinks) 7.4 g (milk/dairy drinks) (NHANES 2009–2012; Afeiche et al., 2018a); 10.8 g (Soda) (Mexico) 13.7 g (Fruit drinks) (Mexico) 9.7 g (milk/dairy drinks) (Mexico) (ENSANUT, 2012; Afeiche et al., 2018a)

obesity in this population (Fujiwara et al., 2019; Tajima et al., 2020), no other study to our knowledge has focused exclusively on comparing beverage intake between young Japanese children and North American counterparts.

4.2. Types of beverages consumed and total sugar intake

Interestingly, in contrast with children from North America, a higher proportion of SSB sugar intake in Japanese children was from dairy/milk beverages with a lower relative percentage from soda, sports drinks and fruit drinks (e.g. Seiiku Boshi cohort). This contrasts sharply with the total sugar intake for American children, where the largest intakes were from fruit juices and sodas. Recent US-based interventions have used different approaches to try to curtail the SSB intake of young preschool children including home-based behavioral strategies to limit consumption, educational text messages via smart phones and environmental changes including healthier beverage options in the preschool setting (Nezami et al., 2016, 2018; Grummon et al., 2019). Randomized trials have found that SSB reduction in the preschool years can result in BMI and overweight reduction (Nezami et al., 2016) including those that have replaced SSBs with milk (Zheng et al., 2015). It is possible that the difference between the epidemic of childhood obesity in North America and the absence of such an epidemic among Japanese preschool children can be linked to the intake of liquid sugar calories through SSB consumption (Luger et al., 2017).

4.3. Sweetened milk beverages

Although Japanese preschool children consume less added sugar from SSBs, they consume a higher relative total percentage from sweetened dairy/milks, similar to studies from other parts of Asia (Afeiche et al., 2018a; Yu et al., 2016). Yogurt and dairy/milk drinks may not have the same associated high risk for obesity as other SSBs including 100% fruit juices because of the higher fat and protein content in dairy/milk beverages. Furthermore, the calcium content could increase fat oxidation and increase fat excretion (Sayon-Orea et al., 2017) as well promote satiety through cholecystokinin and glucagon-like peptide-1 (Vanderhout et al., 2020). Our previous work has found that dairy fat in particular may protect against obesity (Beck et al., 2017). Furthermore, there is some evidence to suggest that fermented products (e.g. yogurt drinks) may protect against obesity as certain microbiota can reduce overall inflammation (Sayon-Orea et al., 2017).

Interestingly, overall dairy consumption is much lower in Japanese adults compared with adults in Western countries (Kondo et al., 2013) and previous studies suggest that calcium intake is low in Japanese preschool children, below recommended guidelines due to relatively low dairy consumption (Shibata et al., 2008). The Japanese government launched Dietary Guidelines for Japanese in 2000 emphasizing the need for 2 daily servings of dairy to boost overall dairy intake (Kondo et al., 2013). Although we found a high relative percentage of dairy/milk drink consumption among Japanese preschool children, the total number of servings of dairy or kcal from dairy may still be low compared with other population groups or less than the recommendations.

5. Conclusions and limitations

Our study had certain limitations. The age groups and definitions of SSB in different Japanese cohorts are not consistent with each other or that which are used by North American studies reviewed Some studies include dairy/milk drinks or 100% fruit juice as part of the SSB definition whereas others do not. For the Japanese cohorts surveyed, parents were queried about children's feeding usually at a specific age (e.g. 14 months or 32 months in the HBC Study (Hamamatsu cohort) versus a larger age range used in North American studies such as NHANES and FITS (2–5 years and 12–23.9 months). As such, a precise one-to-one comparison between studies was not possible. However, the overall trend, in comparing these studies suggests that daily consumption of SSBs and 100% fruit juice is much lower among Japanese toddler and preschool children compared with their North American counterparts. While these population groups may have introduced SSBs and 100% fruit juice at a relatively similar rate, there is a striking difference in the

frequency of consumption as indicated by response to food frequency questionnaires and total grams of sugar intake by SSB category. Additional efforts in North America to curb children's consumption of SSBs, in particular the total volume of SSBs consumed, could help speedily address the obesity epidemic.

Funding

Council on Foreign Relations- Hitachi funded this study for JMW as part of Foreign Affars Fellowship to Japan. The TMM BirThree Cohort study was supported by the Japan Agency for Medical Research and Development (AMED, Japan) (grant number, JP20km0105001).

Author credit statements

JMW and NH conceived of the study. JMW conducted analyses. KJT, KM, MI and TO provided data and conducted analyses. All authors contributed to the write-up and approved the final analysis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Thanks to Dr. Reiko Horikawa for use of the Seiiku Boshi dataset and thanks to Aya Fujiwara for discussions regarding the DONGuRI study

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