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Early childhood exposure to maternal smoking and obesity: A nationwide longitudinal survey in Japan

Miho Yamashita[1] | Takashi Yorifuji[2] | Naomi Matsumoto[2] | Toshihide Kubo[3] | Hirokazu Tsukahara[4]

[1]Department of Foods and Human Nutrition Faculty of Human Life Sciences, Notre Dame Seishin University, Okayama, Japan

[2]Department of Epidemiology, Okayama University Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, Okayama, Japan

[3]Department of Pediatrics, National Hospital Organization, Okayama Medical Center, Okayama, Japan

[4]Department of Pediatrics, Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, Okayama University, Okayama, Japan

Correspondence
Miho Yamashita, Department of Foods and Human Nutrition Faculty of Human Life Sciences, Notre Dame Seishin University, 2-16-9 Ifuku-cho, Kita-ku, Okayama 700-8516, Japan.
Email: yamashita@m.ndsu.ac.jp

Summary

Involuntary exposure to tobacco smoke is suspected to be one of the risks factors that are associated with obesity in children. The purpose of this study was to examine the relationship between early childhood exposure to tobacco smoke and the risk of obesity and overweight in Japan. This study utilized a nationwide, population-based longitudinal survey. The participants were restricted to 32 081 children who had available information on maternal smoking history as well as childhood height and weight. We conducted a binomial log–linear regression analysis with children of non-smoking mothers as the reference group. The children with mothers who were smokers had a higher risk of developing obesity or being overweight compared to the children with mothers who were nonsmokers. The risk ratios were 1.20 (95% confidence interval [CI]: 1.09–1.32) for overweight and 1.17 (95% CI: 0.95–1.44) for obesity. Early exposure to maternal smoking increases the risk of being overweight and having obesity during childhood. The increased risk is more pronounced among children with mothers, smoked heavily, or parents, who were smokers.

KEYWORDS
children, maternal smoking, national survey, obesity

What is already known about this subject

- Obesity is on the rise worldwide, and Japan has a relatively low number of individuals with obesity.
- Maternal smoking during pregnancy and the early postnatal period may put children at risk for childhood obesity in many countries.
- Smoking by guardians other than mothers can also put children at risk of childhood obesity.

What this study adds

- A nationwide population-based longitudinal survey in Japan revealed the association of early childhood exposure to maternal smoking and obesity.
- The risk of obesity and overweight in children due to secondhand smoke is higher in parents than in mothers or fathers alone.
- The number of cigarettes in secondhand smoke increased in a higher risk of obesity in children and overweight.

1 | INTRODUCTION

Secondhand smoke refers to involuntary exposure to tobacco smoke. The effects of involuntary exposure to tobacco smoke on children's health include sudden infant death syndrome,[1] low birth weight,[2–5] small for gestational age (SGA),[6–8] acute respiratory infections, ear problems and asthma.[9,10] Involuntary exposure to tobacco smoke may also play a role in childhood obesity. Obesity in children is also associated with a higher rate of obesity in adulthood, which can lead to coronary artery disease; early onset of lifestyle-related diseases, such as type 2 diabetes; and high blood pressure.[11,12]

Further, previous studies indicate that there is an association between secondhand smoke exposure and childhood overweight and obesity worldwide[12–19]; however, the evidence is conflicting. For example, some studies indicated positive associations between secondhand smoke exposure and obesity in children, in developed countries, whereas other studies from developing countries showed the effect of smoking on childhood underweight.[13] Moreover, Asian countries have different characteristics in terms of obesity,[20] and Japan has low prevalence of childhood obesity,[21] but the evidence from Asian countries for the association between secondhand smoke exposure and risk of obesity in children is limited.

We have considered two hypotheses for this study. One is that the increase in obesity among children is attributable to the high proportion of low income in smoking households in Japan, whereas the second is that secondhand smoke may increase SGA, preterm birth, and LBW infants. In connection with this, those infants are more likely to develop obesity and lifestyle-related diseases in the future.[22–24]

In this study, we examined the association of early childhood exposure to maternal smoking and childhood obesity in Japan, using a nationwide, population-based longitudinal survey.

2 | MATERIALS AND METHODS

2.1 | Study participants

In this research, the data were obtained from the Longitudinal Survey of Babies in the 21st Century, which was conducted in Japan by the Ministry of Health, Labor, and Welfare.[25] Baseline questionnaires were sent to all families with children born between 10 and 17 January 2001 or 10 and 17 July 2001 when the children were 6 months old. Among 53 575 families who were queried, 47 010 completed and returned the questionnaires (response rate 87.7%). Follow-up questionnaires were sent to the participating families each year. In this study, data from the first and seventh surveys were used. This is because early childhood (until the age of 7) is an important period of remarkable growth in terms of physical, cognitive, social and language skills. Obesity in children at 7 years of age has been associated with adulthood obesity.[26] The data that were obtained for each child was also cross-referenced with the child's birth records from the Vital Statistics System of Japan. These records include birth length; birth weight; gestational age; singleton, twin, or other; multiple birth; sex; parity; parental age at delivery; and residence of the parents at birth.

2.2 | Maternal and paternal smoking

Maternal smoking information was obtained from the first survey that was given to the families when their child was at 6 months of age. The questionnaire from this survey examined two exposure factors; smoking status and the number of tobacco smoked per day. Smoking status was classified as smoking or non-smoking. The number of tobaccos smoked was classified as non-smoking, light smoking (<10 tobaccos/day) and heavy smoking (>10 tobaccos/day). The same survey also included paternal smoking. The questionnaire item did not evaluate smoking status during pregnancy or habitual smoking but only included a question for the smoking status when their children were at 6 months of age. A total of 272 children, who lacked maternal and paternal smoking information, were excluded, leaving 46 737 children for subsequent analyses.

2.3 | Children's overweight and obesity

Height and weight information was obtained from the self-administered questionnaire when the children were 7 years old. The participants' overweight and obesity assessments were conducted using sex- and age-specific cut-off values for BMI, which were developed by the International Obesity Task Force for children aged 24 months and older.[27]

2.4 | Statistical analysis

First, the demographic characteristics between children whose mothers were nonsmokers and those whose mothers were smokers were compared. We also compared the demographic characteristics between the participants who provided height and weight information at 7 years of age and those who failed to follow-up. The relationship between maternal smoking status and the risk of being overweight and having obesity was examined using a binominal log–linear regression analysis and the estimated risk ratios (RRs) with their 95% confidence intervals (CIs). The children whose mothers were nonsmokers were identified as the reference group. The maternal and paternal smoking status' (non-smoker vs. smoker) were combined to repeat the regression analysis.

After estimating the crude RRs, we adjusted for child factors, parental factors, and residential area in the model. Child factors include sex (dichotomous) and, single or multiple foetuses (dichotomous). Parental factors include maternal age at delivery, parity (dichotomous: 0 or ≥1 sibling), maternal education history, and paternal education history. The mother's age at birth, sex of the children and parity were obtained from the birth records. Maternal and paternal education status was obtained from the second survey and

TABLE 1 Demographic characteristics of eligible children before excluding those lost to follow-up at 7 years of age ($n = 46\,737$)

	Total children ($n = 46\,737$)	Maternal smoking status[a]	
		Non-smoker ($n = 38\,565$)	Smoker ($n = 8172$)
Characteristics of children			
Sex, *n* (%)[b]			
Boys	24 277 (51.9)	20 011 (51.9)	4266 (52.2)
Girls	22 460 (48.1)	18 554 (48.1)	3906 (47.8)
Singleton or multiple birth, *n* (%)[b]			
Singleton birth	45 763 (97.9)	37 725 (97.8)	8038 (98.4)
Multiple birth	974 (2.1)	840 (2.2)	134 (1.6)
Parental characteristics			
Mean maternal age at delivery, years (SD)[b]	30 (4.5)	30.3 (4.3)	28.1 (4.8)
Parity, *n* (%)[b]			
0	22 851 (48.9)	18 975 (49.2)	3876 (47.4)
≥ 1	23 886 (51.1)	19 590 (50.8)	4296 (52.6)
Maternal educational attainment, *n* (%)[c]			
University or higher	6005 (13.8)	5776 (15.9)	229 (3.2)
Junior college or vocational school	17 946 (41.3)	16 012 (44)	1934 (27.3)
High school	17 076 (39.3)	13 365 (36.8)	3711 (52.4)
Junior high school and others	2423 (5.6)	1219 (3.4)	1204 (17)
Paternal educational attainment, *n* (%)[c]			
University or higher	15 554 (36.2)	14 611 (40.5)	943 (13.7)
Junior college or vocational school	6731 (15.7)	5782 (16)	949 (13.8)
High school	17 072 (39.7)	13 580 (37.6)	3492 (50.9)
Junior high school and others	3602 (8.4)	2121 (5.9)	1481 (21.6)
Residential area, *n* (%)			
Wards	10 244 (21.9)	8352 (21.7)	1892 (23.2)
Cities	27 549 (58.9)	22 857 (59.3)	4692 (57.4)
Towns or villages	8944 (19.1)	7356 (19.1)	1588 (19.4)

Abbreviation: SD, standard deviation.
[a]Obtained from the first survey (at the age of 6 months).
[b]Obtained from birth records.
[c]Obtained from the second survey (at the age of 18 months).

classified into four categories: university (4-year programme) or higher; junior college or vocational school; high school; and junior high school and others. Residential area at birth was obtained from the 2001 census and classified into the three categories: ward, city, town, or village.[28] These potential confounders were selected a priori based on previous studies or directed acyclic graph.[26,29,30]

Furthermore, sensitivity analyses were conducted to determine the credibility of the results. Since socioeconomic status is strongly associated with obesity risk,[31] we adjusted for paternal income in the seventh survey instead of paternal education attainment. Given the lack of information on maternal smoking status during pregnancy, we performed two types of sensitivity analyses to rule out the possible effects of smoking during pregnancy. First, we excluded infants who were born SGA, i.e., those with birth weights lower than the 10th percentile, and repeated the analyses. Second, we restricted children who were born at term but were not LBW infants (i.e., birth weight less than 2500 g) and repeated the analyses. These analyses were conducted because smoking during pregnancy was associated with those birth outcomes (i.e., SGA, preterm birth, and LBW).[2–8]

All statistical analyses were performed using the software Stata SE version 17 (StataCorp). This study was approved by the Ethics Committee at Okayama University Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences (No.1506-073).

3 | RESULTS

The demographic characteristics of the participants before excluding those lost to follow-up (i.e., those who lacked information on BMI) at 7 years of age are shown in Table 1. Children with mothers who were

TABLE 2 Demographic characteristics of eligible children included and lost to follow-up at 7 years of age ($n = 46\ 737$)

	Age 7 years	
	Included ($n = 32\ 081$)	Lost to follow-up ($n = 14\ 656$)
Characteristics of children		
Sex, *n* (%)[a]		
Boys	16 654 (51.9)	7623 (52)
Girls	15 427 (48.1)	7033 (48)
Singleton or multiple birth		
Singleton birth, *n* (%)[a]	31 426 (98)	14 337 (97.8)
Multiple birth, *n* (%)[a]	655 (2)	319 (2.2)
Parental characteristics		
Mean maternal age at delivery, years (SD)[a]	30.4 (4.3)	29 (4.8)
Parity, *n* (%)[a]		
0	15 856 (49.4)	6995 (47.7)
≥ 1	16 225 (50.6)	7661 (52.3)
Maternal smoking status, *n* (%)[b]		
Non-smoker	27 725 (86.4)	10 840 (74)
Smoker	4356 (13.6)	3816 (26)
Maternal educational attainment, *n* (%)[c]		
University or higher	4889 (15.5)	1116 (9.4)
Junior college or vocational school	13 593 (43.1)	4353 (36.5)
High school	11 764 (37.3)	5312 (44.5)
Junior high school and others	1262 (4)	1161 (9.7)
Paternal educational attainment, *n* (%)[c]		
University or higher	12 319 (39.4)	3235 (27.6)
Junior college or vocational school	4943 (15.8)	1788 (15.3)
High school	11 885 (38)	5187 (44.3)
Junior high school and others	2107 (6.7)	1495 (12.8)
Residential area, *n* (%)		
Wards	7169 (22.4)	3075 (21)
Cities	18 905 (58.9)	8644 (59)
Towns or villages	6007 (18.7)	2937 (20)

Abbreviation: SD, standard deviation.
[a]Obtained from birth records.
[b]Obtained from the first survey (at the age of 6 months).
[c]Obtained from the second survey (at the age of 18 months).

smokers were more likely to have parents with lower educational attainment compared to children with mothers who were non-smokers. We also present the demographic characteristics of children who had height and weight information at 7 years of age ($n = 32\ 081$) and those who did not (i.e., lost to follow-up) ($n = 14\ 656$) in Table 2. The participants who failed to follow-up more often had mothers who were smokers and parents with lower educational attainment compared to the children who were included for further analysis. The demographic characteristics separated by smoking status among the children who were included in the further analyses ($n = 32\ 081$) are illustrated in Table S1. The same tendency observed in Table 1 was detected.

The results from the binominal log–linear regression analysis are shown in Table 3. Children with mothers who were smokers had higher risks of being overweight or having obesity compared to the children whose mothers were nonsmokers. The RRs were 1.20 (95% CI: 1.09–1.32) for overweight and 1.17 (95% CI: 0.95–1.44) for obesity. This RR was greater when the frequency of smoking per day was included for further analysis, especially for overweight. The RRs for overweight were 1.11 (95% CI: 0.98–1.24) for children with mothers who were light smokers and 1.40 (95% CI: 1.21–1.62) for those with mothers who were heavy smokers. Among the participants who were exposed to both maternal and paternal smoking, the RRs were elevated compared to the children with paternal smoking only, maternal smoking only, or parental non-smoking (Table 4). Moreover, several sensitivity analyses did not substantially alter the results (Table 5).

4 | DISCUSSION

In this study, we examined the relationship between early childhood exposure to maternal smoking and the risk of childhood overweight and obesity. Children with mothers who smoked had a higher risk of developing obesity or being overweight at 7 years of age compared to children with mothers who were nonsmokers. The increased risk was also supported by the analyses when we considered the frequency of smoking per day.

The findings of this study are consistent with previous research that has been conducted in other countries.[12–19] We provide further evidence on this issue based on the findings from the country with the lowest obesity proportion in the world.[21] Numerous studies in the past suggest that secondhand smoke is associated with LBW and SGA infants, and several studies also report that LBW and SGA are related to an excess of fat and the increasing incidence of type 2 diabetes.[22–24] These mechanisms may explain the present findings. Because excluding LBW and SGA children in the sensitivity analyses of this study did not significantly alter the risk of childhood overweight and obesity, the association may also be attributable to other mechanisms; further clarification is warranted.

In the analysis combining both maternal and paternal smoking, smoking in both parents had the highest effect estimates (Table 4). A possible interpretation is that when mothers smoked in addition to fathers, the effect estimates are stronger versus that of paternal smoking alone, because families with maternal smoking only were very rare. Japan is a country where children spend more time with their mothers than other adults. Therefore, a substantial influence due to smoking by mothers is expected.

TABLE 3 Crude and adjusted[a] RRs for associations between maternal smoking status and overweight or obesity at 7 years of age

	N*case*/N	% of cases	Crude RR (95% CI)	Adjusted RR[a] (95% CI)
Overweight				
Maternal smoking status				
Non-smoker	2477/27725	8.9	1 (ref.)	1 (ref.)
Smoker	511/4356	11.7	1.31 (1.2–1.44)	1.2 (1.09–1.32)
Maternal smoking status				
Non-smoker	2477/27725	8.9	1 (ref.)	1 (ref.)
Smoker (less than or equal to 10 cigarettes per day)	313/2945	10.6	1.19 (1.06–1.33)	1.11 (0.98–1.24)
Smoker (more than 10 cigarettes per day)	198/1411	14.0	1.57 (1.37–1.8)	1.4 (1.21–1.62)
Obesity				
Maternal smoking status				
Non-smoker	535/27725	1.9	1 (ref.)	1 (ref.)
Smoker	127/4356	2.9	1.51 (1.25–1.83)	1.17 (0.95–1.44)
Maternal smoking status				
Non-smoker	535/27725	1.9	1 (ref.)	1 (ref.)
Smoker (less than or equal to 10 cigarettes per day)	70/2945	2.4	1.23 (0.96–1.58)	1.03 (0.8–1.34)
Smoker (more than 10 cigarettes per day)	57/1411	4.0	2.09 (1.6–2.74)	1.44 (1.07–1.94)

Abbreviations: CI, confidence interval; RR, risk ratio.
[a]Adjusted for child factors (sex, singleton or not), parental factors (maternal age at delivery, parity, maternal educational attainment, and paternal educational attainment), and residential area.

TABLE 4 Crude and adjusted[a] RRs for associations between maternal or paternal smoking status and overweight or obesity at 7 years of age

	N*case*/N	% of cases	Crude RR (95% CI)	Adjusted RR[a] (95% CI)
Overweight				
Maternal or paternal smoking status				
Non-smoking parents	971/12266	7.9	1 (ref.)	1 (ref.)
Paternal smoking only	1474/15147	9.7	1.23 (1.14–1.33)	1.19 (1.1–1.29)
Maternal smoking only	35/347	10.1	1.27 (0.93–1.75)	1.22 (0.88–1.68)
Both paternal and maternal smoking	460/3867	11.9	1.5 (1.35–1.67)	1.37 (1.22–1.54)
Obesity				
Maternal or paternal smoking status				
Non-smoking parents	204/12266	1.7	1 (ref.)	1 (ref.)
Paternal smoking only	326/15147	2.2	1.29 (1.09–1.54)	1.18 (0.99–1.42)
Maternal smoking only	6/347	1.7	1.04 (0.46–2.32)	0.87 (0.39–1.95)
Both paternal and maternal smoking	118/3867	3.1	1.83 (1.47–2.29)	1.35 (1.05–1.73)

Abbreviations: CI, confidence interval; RR, risk ratio.
[a]Adjusted for child factors (sex, singleton or not), parental factors (maternal age at delivery, parity, maternal educational attainment, and paternal educational attainment), and residential area.

A strength of this study is it contained a large sample size. The participants in this research were nationally representative, consisting of approximately 1/20 of the children who were born in Japan in 2001.[32] Moreover, the baseline high response rate (88.7%) strengthens the validity of the findings.

This study also has several limitations. First, the majority of the data was obtained from self-administered questionnaires, which can lead to misclassification. Second, data on smoking status during pregnancy were not obtained. Third, we could not adjust for overweight and mothers with obesity in the analyses, despite previous studies indicating maternal weight as an important risk factor for childhood obesity.[33–35] Future studies in this field of research should consider including maternal weight history for data analysis. Finally, we experienced loss to follow-up, and many participants lost to follow-up at 7 years of age had mothers who were smokers and parents with lower educational attainment compared to the children who were included for further analyses (Table 2). This selection bias might have underestimated the true findings.

TABLE 5 Sensitivity analyses for associations between maternal smoking status and overweight or obesity at 7 years of age

	Overweight	Obesity
Adjustment of paternal income instead of paternal educational attainment		
Adjusted RR[a] (95% CI)	1.23 (1.11–1.36)	1.25 (1.01–1.55)
Restriction to non-SGA infants		
Adjusted RR[a] (95% CI)	1.19 (1.07–1.32)	1.19 (0.96–1.48)
Restriction to term & non-LBW infants		
Adjusted RR[a] (95% CI)	1.2 (1.08–1.33)	1.19 (0.96–1.48)

Abbreviations: CI, confidence interval; LBW, low birth weight; RR, risk ratio; SGA, small for gestational age.
[a]Adjusted for child factors (sex, singleton or not), parental factors (maternal age at delivery, parity, maternal educational attainment, and paternal educational attainment), and residential area. RRs were estimated using children from non-smoking mothers as a reference.

In summary, the findings of this study indicate that early childhood exposure to maternal smoking is associated with an increased risk of childhood overweight and obesity. Future studies should elaborate the possible long-term effect of childhood exposure to maternal smoking on type 2 diabetes or coronary artery disease during follow-up. At this point, the present finding can promote awareness regarding the effects of early smoke exposure on children's health and encourage parents to avoid smoking in order to reduce their children's risk of developing obesity.

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CONFLICT OF INTEREST

No conflict of interest was declared.

ORCID

Miho Yamashita https://orcid.org/0000-0002-4823-6325

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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