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Original Contribution

Income Inequality, Parental Socioeconomic Status, and Birth Outcomes in Japan

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The purpose of this study was to investigate the impact of income inequality and parental socioeconomic status on several birth outcomes in Japan. Data were collected on birth outcomes and parental socioeconomic status by questionnaire from Japanese parents nationwide ($n = 41,499$) and then linked to Gini coefficients at the prefectural level in 2001. In multilevel analysis, z scores of birth weight for gestational age decreased by 0.018 (95% confidence interval (CI): –0.029, –0.006) per 1-standard-deviation (0.018-unit) increase in the Gini coefficient, while gestational age at delivery was not associated with the Gini coefficient. For dichotomous outcomes, mothers living in prefectures with middle and high Gini coefficients were 1.24 (95% CI: 1.05, 1.47) and 1.23 (95% CI: 1.02, 1.48) times more likely, respectively, to deliver a small-for-gestational-age infant than mothers living in more egalitarian prefectures (low Gini coefficients), although preterm births were not significantly associated with income distribution. Parental educational level, but not household income, was significantly associated with the z score of birth weight for gestational age and small-for-gestational-age status. Higher income inequality at the prefectural level and parental educational level, rather than household income, were associated with intrauterine growth but not with shorter gestational age at delivery.

income inequality; infant, small for gestational age; intrauterine growth retardation; Japan; preterm birth; socioeconomic status

Abbreviations: CI, confidence interval; OR, odds ratio; PTB, preterm birth; SD, standard deviation; SES, socioeconomic status; SGA, small for gestational age.

Adverse birth outcomes—including low birth weight, preterm birth (PTB), and small-for-gestational-age (SGA) birth—affect infants (1), young children (2), and adult health (3, 4) throughout the life course. Previous studies have examined the influences of individual and area-level socioeconomic characteristics on the risk of adverse birth outcomes (5).

The examination of contextual effects has been hitherto limited to indicators of community deprivation such as median household income (6, 7), percentage of households below the poverty line (8–10), aggregated deprivation indices (11, 12), the unemployment rate (8, 11), racial composition (13–15), crime rate (9, 11, 16), or physical conditions of the neighborhood (17, 18). Few studies have focused on income inequality as a contextual influence on different birth outcomes using a multilevel analytical framework with sufficient adjustment for individual socioeconomic status (SES) (including household income or parental education). Recent studies found a link between income inequality and birth outcomes using an ecological model (19, 20); however, these studies could not avoid the ecological fallacy, suggesting the need for a multilevel analysis of income inequality and birth outcomes. Huynh et al. (21) reported an association between income inequality and PTB, but the associations with low birth weight and SGA birth were not investigated. Nkansah-Amankra et al. (22) reported an association between income inequality and low birth weight and PTB, but SGA birth was not investigated. Furthermore, no previous study has investigated the association between income inequality and birth outcomes as continuous variables (e.g., gestational age at delivery or z score for gestational age).

In the present study, we investigated the association between income inequality and birth outcomes in Japan, which contains 47 prefectures and is considered to have an egalitarian and homogeneous population. A prefecture in Japan is the country's largest subnational administrative unit. The mean area of Japan's 47 prefectures, each with its own elected governor, is 7,805 km^2 (23), and the mean population is approximately 2.7 million (24). We considered the prefecture a meaningful unit of analysis because the prefectural governments are responsible for providing a wide range of public services such as education, public works, health and hygiene, environmental protection, social welfare, and social security. In a previous cross-sectional study, Shibuya et al. (25) found that prefectural income inequality in Japan did not show a significant association with self-rated health among adults in 1995. However, because the Gini coefficient has been increasing in Japan since 1995 (26), this association may be changing (i.e., there may be a threshold level of income inequality above which population health impacts may begin to emerge). In a more recent study of data on income inequality in 2000, 2003, and 2006, Oshio et al. (27) concluded that higher prefectural income inequality in Japan was associated with worse self-rated health.

The Longitudinal Survey of Babies Born in the 21st Century is a large panel study implemented by the Ministry of Health, Labour and Welfare in Japan from 2001 to 2002. Samples were selected from the birth registry, and the survey inquired about individual SES, including parental educational history and household income. We linked data from this survey with prefectural Gini coefficients through each child's residential address at birth. Thus, the purpose of our study was to investigate the impact of income inequality and parents' SES (educational level, employment status, and household income) on birth outcomes in Japan.

MATERIALS AND METHODS

Study sample

This is a data linkage study. The data were obtained from the Japanese panel study the Longitudinal Survey of Babies Born in the 21st Century. The study sample included all babies born between January 10 and 26, 2001, and July 10 and 26, 2001, in Japan, using the birth registration record lists of vital statistics in Japan ($n = 53,575$). Regarding birth registrations in Japan, underregistration is unlikely because a birth certificate signed by a physician must be submitted to the local municipality office within 14 days after delivery in order for the parent to receive payment from the government under the family benefit scheme. Selected subjects were recruited by mail questionnaires when the children were aged 6 months. If the infants were registered as deceased (according to the Ministry of Health, Labour and Welfare records) at the time of sending the questionnaire (approximately when the infants were 3 months of age), the questionnaire was not mailed to the parents of the deceased infants. Based on national neonatal and infant mortality rates (1.6 and 3.1 per 1,000 births, respectively, in 2001 (28)), the number of infants excluded from our sample is estimated to be approximately 100 (0.2%). The subjects were considered to have agreed to participate in the study if they returned the questionnaire to the Ministry of Health, Labour and Welfare. There were a total of 47,015 respondents (response rate, 87.8%). Because this study focused on birth outcomes, children in multiple births were excluded ($n = 976$). In addition, participants lacking information on key covariates, including parental age, SES (parental education, employment status, and household income), and parity, were excluded ($n = 4,540$).

Birth outcomes

Data on birth outcomes were derived from the birth record lists of vital statistics, which cover variables such as the infant's sex, birth weight, gestational age at delivery, and whether the birth was single or multiple. In this study, the z score of birth weight for gestational age, rather than birth weight, was used as a proxy for intrauterine growth. The z score of birth weight for gestational age was calculated on the basis of the growth curve by gestational age, sex, and parity for singleton births in Japan (29). SGA birth was defined as a birth weight below the 10th percentile for birth weight. Gestational age was calculated from the date of the last menstrual period or the clinical estimate of gestational age. PTB was defined as delivery at <37 weeks.

Prefectural-level and individual variables

Information on the prefecture where the infant was born was retrieved from birth record lists of vital statistics. The Gini index at the prefectural level was used as an indicator of income inequality. The Gini index is defined mathematically as half of the absolute difference between 2 incomes selected randomly from the population, normalized on the mean. The theoretical range of the Gini index is between 0.0 (perfect equality) and 1.0 (perfect inequality), with higher scores indicating more inequality. The prefectural Gini index was calculated using the National Consumption Survey in 1999, implemented by the Ministry of Internal Affairs and Communications (30). This survey sample included 55,792 households of 2 or more persons and 5,002 single-person households from all of the cities and 471 towns and villages in Japan from September 1999 to November 1999. The prefectural-level Gini coefficient for total household income was calculated using both sets of data. Furthermore, to adjust for prefectural deprivation and urbanization level, prefectural income per capita in 2000 (31) and population density in 2000 (32) were used as prefectural covariates. The prefectural income per capita was further categorized by quartile. Population density was categorized into 3 groups (i.e., low, being <200 persons/km^2; middle, 200<1,000 persons/km^2; and high, ≥1,000 persons/km^2, on the basis of its distribution). This prefectural information was linked with the data through child's residential address at delivery.

Variables used in this study were retrieved from data gathered in both the first and second panel surveys. Individual variables—for example, parental age (obtained from birth records), maternal employment status 1 year before delivery, household income, number of persons living in the household, and number of children—were obtained from questionnaires used in the first survey implemented in 2001, and information on parental education was obtained from the

Table 1. Sociodemographic Characteristics of Participants by Birth Outcome in a Study of Income Inequality, Parental Socioeconomic Status, and Birth Outcomes ($n = 41{,}499$), Japan, 2001

Predictor Variable	Frequency No.	Frequency %	Mean Birth Weight, g (SD)	Mean Gestational Age, weeks (SD)	Mean Z Score of Birth Weight for Gestational Age (SD)	Small-for-Gestational-Age Birth No.	Small-for-Gestational-Age Birth %	Preterm Birth No.	Preterm Birth %
Infant's sex									
Male	21,527	51.9	3,091.4 (420.7)	38.9 (1.6)	−0.12 (0.90)	1,939	9.0	995	4.6
Female	19,972	48.1	3,012.0 (402.6)	39.0 (1.5)	0.00 (1.01)	1,842	9.2	658	3.3
Mother's age, years									
<25	3,903	9.4	3,034.8 (394.8)	39.1 (1.5)	0.04 (0.93)	299	7.7	156	4.0
25–29	14,515	35.0	3,042.2 (399.5)	39.0 (1.5)	−0.04 (0.94)	1,228	8.5	507	3.5
30–34	16,529	39.8	3,061.8 (417.3)	38.9 (1.6)	−0.10 (0.95)	1,589	9.6	659	4.0
35–39	5,703	13.7	3,068.9 (441.5)	38.8 (1.6)	−0.09 (0.99)	579	10.2	268	4.7
≥40	849	2.1	3,051.8 (477.2)	38.6 (1.8)	−0.03 (1.09)	86	10.1	63	7.4
Father's age, years									
<25	2,490	6.0	3,042.9 (390.0)	39.1 (1.5)	0.06 (0.95)	186	7.5	90	3.6
25–29	10,635	25.6	3,038.6 (401.6)	39.0 (1.5)	−0.02 (0.93)	882	8.3	387	3.6
30–34	15,475	37.3	3,052.9 (406.1)	39.0 (1.5)	−0.08 (0.96)	1,452	9.4	591	3.8
35–39	8,885	21.4	3,063.5 (429.6)	38.9 (1.6)	−0.10 (0.94)	870	9.8	393	4.4
≥40	4,014	9.7	3,076.2 (452.4)	38.8 (1.6)	−0.06 (1.02)	391	9.7	192	4.8
Mother's education									
Less than high school	2,139	5.2	3,037.0 (449.9)	38.9 (1.8)	−0.09 (0.98)	232	10.9	108	5.1
High school	23,684	57.1	3,053.4 (415.9)	38.9 (1.5)	−0.07 (0.97)	2,209	9.3	928	3.9
Some college	9,851	23.7	3,058.4 (407.2)	39.0 (1.5)	−0.04 (0.95)	838	8.5	395	4.0
College or greater	5,825	14.0	3,049.5 (403.9)	39.0 (1.5)	−0.05 (0.91)	502	8.6	222	3.8
Father's education									
Less than high school	3,385	8.2	3,031.0 (439.6)	38.9 (1.6)	−0.12 (1.01)	395	11.7	157	4.6
High school	21,750	52.4	3,051.3 (414.5)	39.0 (1.5)	−0.07 (0.96)	2,012	9.3	861	4.0
Some college	1,290	3.1	3,073.0 (426.2)	39.0 (1.6)	−0.01 (1.00)	113	8.8	53	4.1
College or greater	15,074	36.3	3,059.2 (406.1)	39.0 (1.5)	−0.04 (0.93)	1,261	8.4	582	3.9
Mother's employment status 1 year before delivery									
Working full-time	15,188	36.6	3,033.2 (415.0)	39.0 (1.5)	0.00 (0.95)	1,266	8.3	592	3.9
Working part-time	7,415	17.9	3,044.3 (422.4)	39.0 (1.6)	0.00 (0.98)	646	8.7	307	4.1
Not in labor market	18,304	44.1	3,073.7 (409.4)	38.9 (1.5)	−0.14 (0.94)	1,827	10.0	729	4.0
Other	592	1.4	3,042.7 (393.2)	39.0 (1.5)	0.10 (0.90)	42	7.1	25	4.2
Quartile of annual household income before delivery, per no. of persons living in the household, yen									
First quartile (lowest)	9,417	22.7	3,063.6 (422.0)	38.9 (1.6)	−0.11 (0.95)	968	10.3	386	4.1
Second quartile	10,838	26.1	3,069.2 (413.9)	38.9 (1.5)	−0.09 (0.97)	1,030	9.5	433	4.0
Third quartile	10,302	24.8	3,050.7 (414.0)	38.9 (1.6)	−0.05 (0.96)	897	8.7	416	4.0
Fourth quartile (highest)	10,942	26.4	3,030.6 (406.1)	39.0 (1.5)	−0.01 (0.93)	886	8.1	418	3.8
No. of siblings									
0	20,560	49.5	3,011.2 (405.9)	39.1 (1.5)	0.13 (0.96)	1,404	6.8	796	3.9
1	15,306	36.9	3,085.7 (409.8)	38.8 (1.5)	−0.27 (0.90)	1,775	11.6	605	4.0
2	4,758	11.5	3,111.9 (432.8)	38.8 (1.6)	−0.19 (0.93)	506	10.6	203	4.3
≥3	875	2.1	3,150.7 (460.8)	38.7 (1.5)	−0.06 (1.11)	96	11.0	49	5.6

Abbreviation: SD, standard deviation.

Table 2. Characteristics of Prefecture-Level Variables ($n = 47$) in a Study of Income Inequality, Parental Socioeconomic Status, and Birth Outcomes, Japan, 1999–2001

	Mean (SD)	Median	Range	Spearman's Correlation		
Gini coefficient in 1999	0.323 (0.018)	0.318	0.288–0.385	1		
Prefecture-level income in 1999, million yen	2.74 (0.35)	2.72	2.08–4.20	−0.068	1	
Population density in 2001, no. of persons/km^2	653.5 (1,167.3)	273.3	70.4–5,937.3	0.222	0.563*	1

Abbreviation: SD, standard deviation.
* $P < 0.05$.

second survey (response rate, 93.4%) in 2002. Maternal employment status was categorized as full-time worker, part-time worker, unemployed, and other, including being a student. Household income, adjusted for the number of persons living in the household, was calculated as household income divided by the square root of the number of persons living in the household and was further categorized by quartile. Educational level was categorized into 4 groups: less than high school, high school, some college, and college graduation or more.

Analyses

To examine the contextual effect on individual outcomes, we employed a multilevel model by using the STATA MP statistical package, version 12 (StataCorp LP, College Station, Texas). For continuous outcome variables (i.e., z score of birth weight for gestational age and gestational age at delivery), a random-intercept model was employed using the command "xtmixed," allowing a prefecture-specific intercept term to be estimated as drawn from a random distribution of intercepts, conditional on modeled covariates (33). Similarly, for dichotomous outcome variables, we employed a random-intercept logistic regression model using the "xtlogit" command. For this analysis, Gini coefficients were categorized into 3 groups: low (<mean − 1 standard deviation (SD) (<0.305)), middle (mean − 1 SD to mean + 1 SD (0.305–0.341), and high (>mean + 1 SD (>0.341)). Furthermore, cross-level interactions between prefectural income inequality and maternal/paternal education or household income were investigated. Missing data were not used for analysis. For sensitivity analysis, we repeated the analyses excluding 1 prefecture (Okinawa), which showed the highest Gini coefficient. In all analyses, statistical tests were 2-sided, and $P < 0.05$ was considered statistically significant.

RESULTS

Sample characteristics

The total sample size for this study was 41,499. The SES distributions of participants and birth outcomes by demographic characteristics and SES are shown in Table 1. Approximately 5% of the mothers and 8% of the fathers had less than a high school education. One-third of the mothers worked full-time 1 year before delivery, while 44% of them were unemployed. Almost half of them were primiparas (giving birth for the first time). The mean birth weight was 3,053.2 g (SD, 414.0), ranging from 494 g to 5,532 g. The mean gestational age was 39.0 weeks (SD, 1.5; range, 23–43), and the mean z score for gestational age was −0.06 (SD, −0.95; range, −5.0 to 13.4), implying that the sample was slightly smaller for gestational age than the Japanese reference group of 1995 (29). The proportions of children born SGA and preterm were 9.1% and 4.0%, respectively. Overall, the distribution of adverse birth outcomes was higher in the group with lower parental education. Adverse birth outcome and household income were inversely associated.

Correlations between prefectural variables

Prefectural characteristics and Spearman correlations between prefecture-level variables are shown in Table 2. The mean Gini coefficient among the 47 prefectures in 1999 was 0.323 (SD, 0.018), ranging from 0.288 to 0.385. The Gini coefficient was not associated with prefecture-level income and population density, although these variables were significantly correlated ($\rho = 0.563$).

Association with continuous birth outcomes

The regression coefficients of the prefecture-level Gini coefficients for z score of birth weight for gestational age and gestational age at delivery obtained from multilevel analysis are presented in Table 3. For the z score of birth weight for gestational age, a 1-standard-deviation (equivalent to a 0.018-unit) increase in the Gini coefficient was associated with a decrease in z score of 0.018 (95% confidence interval (CI): −0.029, −0.006) after adjustment for individual demographic characteristics and SES. For individual SES, paternal education was significantly positively associated with the z score for gestational age, while maternal education and household income were not. In contrast, gestational age at delivery was not significantly associated with the Gini coefficient. For individual SES, an increasing level of maternal education was significantly positively associated with gestational age, but paternal education and household income were not associated with gestational age.

Association with dichotomized birth outcomes

The odds ratios for SGA birth and PTB by prefectural Gini coefficient category are shown in Table 4. Infants born in middle- and high-Gini-coefficient prefectures were 1.24

Table 3. Coefficients for *Z* Score of Birth Weight for Gestational Age and Gestational Age at Delivery by Prefecture-Level Income Inequality and Individual Socioeconomic Status in a Multilevel Analysis,[a] Japan, 2001

	Z Score of Birth Weight for Gestational Age		Gestational Age at Delivery	
	Coefficient	95% CI	Coefficient	95% CI
Prefecture-Level Variables				
Gini coefficient				
0.018-unit (1-SD) increase	−0.018	−0.029, −0.006	−0.011	−0.036, 0.014
Prefecture-level income				
First quarter (lowest)	Reference		Reference	
Second quarter	0.006	−0.030, 0.042	−0.027	−0.099, 0.046
Third quarter	−0.0002	−0.035, 0.035	−0.031	−0.101, 0.039
Fourth quarter	0.002	−0.040, 0.045	−0.043	−0.131, 0.045
Population density				
Low	Reference		Reference	
Middle	−0.0009	−0.030, 0.028	0.007	−0.052, 0.065
High	−0.022	−0.062, 0.018	0.038	−0.052, 0.127
Individual-Level Variables				
Infant's sex				
Male	Reference		Reference	
Female	0.107	0.089, 0.125	0.179	0.150, 0.208
Mother's age, years				
<25	Reference		Reference	
25–29	−0.015	−0.055, 0.026	0.018	−0.048, 0.083
30–34	0.009	−0.034, 0.053	−0.038	−0.109, 0.032
35–39	0.038	−0.013, 0.089	−0.156	−0.239, 0.074
≥40	0.064	−0.016, 0.144	−0.357	−0.487, −0.227
Father's age, years				
<25	Reference		Reference	
25–29	−0.026	−0.074, 0.022	−0.067	−0.145, 0.012
30–34	−0.027	−0.077, 0.024	−0.077	−0.159, 0.059
35–39	−0.020	−0.075, 0.034	−0.096	−0.185, −0.008
≥40	0.015	−0.045, 0.075	−0.086	−0.184, 0.012

Table continues

(95% CI: 1.05, 1.47) and 1.23 (95% CI: 1.02, 1.48) times more likely, respectively, to be delivered SGA than those born in low-Gini-coefficient prefectures. However, PTB was not associated with the Gini coefficient. Among other prefectural variables, middle-population-density prefectures showed higher odds of SGA birth than low-population-density prefectures (odds ratio (OR) = 1.11, 95% CI: 1.00, 1.24), while high-population-density prefectures did not. Regarding individual socioeconomic variables, children whose fathers had a college education or more were 30% less likely to be born SGA than those of fathers with less than a high school education (OR = 0.70, 95% CI: 0.61, 0.80), although maternal education and household income were not associated with SGA birth. For PTB, except for maternal education (high school graduate vs. less than a high school education), no SES indicators showed a significant association.

Cross-level interaction

Furthermore, cross-level interaction was investigated for the *z* score of birth weight for gestational age, and we found that among fathers with less than a college education, a 1-standard-deviation increase in the Gini coefficient was significantly inversely associated with the *z* score for gestational age (coefficient: −0.03, 95% CI: −0.04, −0.02); however, among fathers with a college education or more, the Gini coefficient was not significantly associated with birth weight (coefficient: 0.008, 95% CI: −0.009, 0.02) (Figure 1).

Table 3. Continued

	Z Score of Birth Weight for Gestational Age		Gestational Age at Delivery	
	Coefficient	**95% CI**	**Coefficient**	**95% CI**
Mother's education				
Less than high school	Reference		Reference	
High school	0.011	−0.032, 0.053	0.051	−0.018, 0.121
Some college	0.018	−0.029, 0.065	0.078	0.003, 0.154
College or greater	−0.008	−0.058, 0.043	0.093	0.010, 0.176
Father's education				
Less than high school	Reference		Reference	
High school	0.048	0.013, 0.083	0.038	−0.019, 0.095
Some college	0.108	0.046, 0.169	0.055	−0.045, 0.155
College or greater	0.083	0.045, 0.122	0.042	−0.021, 0.105
Mother's employment status 1 year before delivery				
Working full-time	Reference		Reference	
Working part-time	0.026	−0.001, 0.053	−0.019	−0.063, 0.025
Not in labor market	0.024	0.001, 0.048	−0.018	−0.056, 0.020
Other	0.054	−0.025, 0.133	−0.051	−0.179, 0.078
Quartile of annual household income before delivery, per no. of persons living in the household, yen				
First quartile (lowest)	Reference		Reference	
Second quartile	0.017	−0.009, 0.044	−0.007	−0.050, 0.036
Third quartile	0.004	−0.024, 0.031	−0.031	−0.076, 0.014
Fourth quartile (highest)	−0.025	−0.056, 0.005	−0.004	−0.054, 0.047
No. of siblings				
0	Reference		Reference	
1	−0.420	−0.443, −0.397	−0.259	−0.296, −0.222
2	−0.349	−0.382, −0.316	−0.262	−0.316, −0.209
≥3	−0.230	−0.297, −0.164	−0.243	−0.352, −0.135

Abbreviations: CI, confidence interval; SD, standard deviation.
[a] The model included Gini coefficient (continuous), prefecture-level income, and population density as prefectural variables and infant's sex, parental age, parental education, maternal employment status 1 year before pregnancy, household income, and number of siblings as individual variables.

Sensitivity analysis

In order to check for influential outliers, we performed a sensitivity analysis by excluding 1 prefecture (Okinawa) with the highest Gini coefficient, and found that income inequality was still associated with *z* score for gestational age (coefficient: −0.016, 95% CI: −0.03, −0.004) and SGA birth (for middle Gini vs. low Gini, OR = 1.23, 95% CI: 1.04, 1.46; for high Gini vs. low Gini, OR = 1.21, 95% CI: 1.00, 1.46) in multilevel analysis.

DISCUSSION

Higher prefectural income inequality was associated with *z* score of birth weight for gestational age and SGA birth, but not with gestational age and PTB, in a study using a nationally representative sample in Japan. Furthermore, *z* score of birth weight for gestational age was more likely to be affected by income inequality in the lower paternal education group than in the higher paternal education group. Among individual socioeconomic variables, higher parental education showed a robust association with a larger *z* score of birth weight for gestational age. To the best of our knowledge, this is the first study investigating the impact of income inequality on birth outcomes in Japan, which is considered an egalitarian society by comparative international standards. The current study adds to the literature in that a subtle increase in income inequality (i.e., a 0.018-unit increase in the Gini coefficient) resulted in a linear reduction of intrauterine growth. Previous studies investigating the

Table 4. Odds Ratios for Small-for-Gestational-Age Birth and Preterm Birth by Prefecture-Level Income Inequality and Individual Socioeconomic Status in a Multilevel Analysis,[a] Japan, 2001

	Small-for-Gestational-Age Birth		Preterm Birth	
	OR	95% CI	OR	95% CI
Prefecture-Level Variables				
Gini coefficient				
Low (< mean – 1 SD)	Reference		Reference	
Middle (mean – 1 SD to mean + 1 SD)	1.24	1.05, 1.47	1.26	0.95, 1.67
High (> mean + 1 SD)	1.23	1.02, 1.48	1.23	0.88, 1.71
Prefecture-level income				
First quarter (lowest)	Reference		Reference	
Second quarter	0.93	0.82, 1.06	0.98	0.78, 1.22
Third quarter	0.89	0.78, 1.01	1.02	0.82, 1.27
Fourth quarter	0.96	0.83, 1.12	0.85	0.64, 1.12
Population density				
Low	Reference		Reference	
Middle	1.11	1.00, 1.24	0.98	0.82, 1.17
High	1.04	0.83, 1.12	1.00	0.76, 1.31
Individual-Level Variables				
Infant's sex				
Male	Reference		Reference	
Female	1.03	0.97, 1.11	0.70	0.63, 0.78
Mother's age, years				
<25	Reference		Reference	
25–29	1.06	0.90, 1.24	0.86	0.69, 1.08
30–34	1.10	0.92, 1.30	0.99	0.78, 1.26
35–39	1.14	0.94, 1.38	1.16	0.89, 1.52
≥40	1.17	0.87, 1.56	1.87	1.29, 2.70
Father's age, years				
<25	Reference		Reference	
25–29	1.08	0.89, 1.32	1.17	0.89, 1.54
30–34	1.15	0.94, 1.41	1.21	0.90, 1.61
35–39	1.15	0.93, 1.42	1.32	0.98, 1.80
≥40	1.09	0.87, 1.38	1.23	0.88, 1.71

Table continues

association between income inequality and birth outcomes were limited to binary outcomes (low birth weight and PTB) (14, 21). Interestingly, the Gini coefficient was not associated with gestational age at delivery or PTB in our study. The lack of association between income inequality and gestational age or PTB needs careful consideration. The lack of association between the Gini coefficient and gestational age or PTB may be due to the lack of variation in prefectural income inequality. Further, the odds ratios for PTB for prefectures with middle and high Gini coefficients were 1.26 and 1.23, respectively (Table 4), and we likely lacked the statistical power to detect a statistically significant association. The prevalence of PTB in our study was 4.0% as compared with a prevalence of 9.1% for SGA birth. Notably, a previous study conducted in the United States—with a PTB prevalence of 9.2%—did find a significant association between income inequality and PTB (21). Alternatively, infants who die prior to age 6 months are likely to disproportionately comprise very preterm babies. Therefore, their exclusion from our sample may have affected our ability to examine the relationship between income inequality and PTB. A previous US-based study found an association between county-level income inequality and higher postneonatal mortality (21). Thus, our inability to include infants who died prior to 6 months of age may have resulted in underestimation of the association between the Gini coefficient and PTB. On the other hand, the number of deaths prior to age 6 months in our sample is likely to have been

Table 4. Continued

	Small-for-Gestational-Age Birth		Preterm Birth	
	OR	95% CI	OR	95% CI
Mother's education				
Less than high school	Reference		Reference	
High school	0.90	0.77, 1.04	0.78	0.63, 0.96
Some college	0.86	0.73, 1.02	0.81	0.64, 1.02
College or greater	0.91	0.76, 1.09	0.78	0.60, 1.02
Father's education				
Less than high school	Reference		Reference	
High school	0.79	0.70, 0.89	0.86	0.72, 1.03
Some college	0.75	0.59, 0.93	0.89	0.64, 1.24
College or greater	0.70	0.61, 0.80	0.83	0.68, 1.02
Mother's employment status 1 year before delivery				
Working full-time	Reference		Reference	
Working part-time	0.98	0.88, 1.08	1.03	0.89, 1.19
Not in labor market	0.94	0.87, 1.03	0.99	0.87, 1.12
Other	0.92	0.66, 1.27	1.11	0.73, 1.68
Quartile of annual household income before delivery, per no. of persons living in the household, yen				
First quartile (lowest)	Reference		Reference	
Second quartile	0.92	0.84, 1.01	0.99	0.86, 1.14
Third quartile	0.90*	0.82, 1.00	1.00	0.86, 1.17
Fourth quartile (highest)	0.92	0.82, 1.04	0.95	0.80, 1.12
No. of siblings				
0	Reference		Reference	
1	1.76	1.62, 1.91	0.95	0.84, 1.08
2	1.54	1.36, 1.73	0.94	0.79, 1.12
≥3	1.49	1.19, 1.88	1.09	0.79, 1.50

Abbreviations: CI, confidence interval; OR, odds ratio; SD, standard deviation.

[a] The model included Gini coefficient (categorical), prefecture-level income, and population density as prefectural variables and infant's sex, parental age, parental education, maternal employment status 1 year before pregnancy, household income, and number of siblings as individual variables.

* $P = 0.052$.

very small (around 100, or 0.2%, based on national data), which suggests that the exclusion of these infants probably did not affect our conclusions about mean gestational age.

Furthermore, the current study also found that income inequality influenced intrauterine growth (i.e., z score of birth weight for gestational age) among children of fathers with less than a college education but not among children of fathers with a college education or more. With regard to the finding that maternal education and household income are not associated with income inequality, the association between income inequality and paternal education implies a possible pathway of income inequality and birth outcomes. That is, fathers with less than a college education may have been more likely to be sensitive to income inequality regardless of household income, and the impact of paternal psychosocial stress on income inequality may have affected the pregnant mother through paternal behavior—for example, less emotional support or housekeeping (34) or even domestic violence (35, 36)—which may induce intrauterine growth restriction mediated by maternal psychosocial stress (9). Further, higher income inequality erodes social cohesion (37), which has been linked to worse mental health (38). Maternal stress or poor mental health is associated with intrauterine growth retardation (39–42), which is linked to a smaller z score of birth weight for gestational age. Because this study did not measure maternal and paternal stress during pregnancy, further research is needed to elucidate the mechanism of the association.

Other possible pathways at a contextual level have been suggested previously (43). First, income inequality is associated

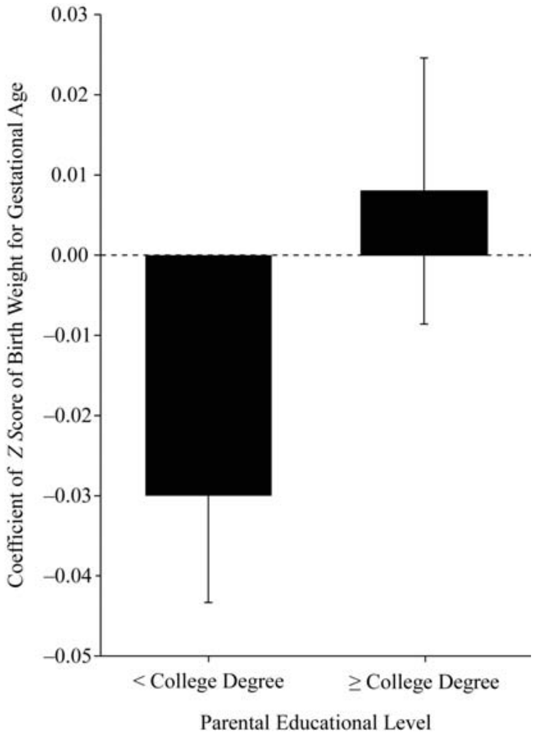

Figure 1. Coefficients of *z* score of birth weight for gestational age for a 0.018-unit (1-standard-deviation) increase in the Gini coefficient according to paternal education, obtained using multilevel analysis, Japan, 2001. Bars, 95% confidence interval.

with systematic underinvestment in social infrastructure. According to US data, higher income inequality is associated with increased per capita medical care expenditure (44). However, this mechanism might not apply in Japan, because income inequality and prefectural income level were not correlated. It is noteworthy that middle-population-density prefectures showed a higher odds ratio for SGA birth than low-population-density prefectures, but not high-population-density prefectures. Middle-population-density prefectures, which are considered semi-urban areas with increasing populations, may not have sufficient social infrastructure to enable all pregnant women to enjoy a physically stress-free environment (stressors might include few parking spaces, crowds and long lines in the shopping center, little green space, etc.) (45). Further study is warranted to explain the association between prefectural factors and birth outcomes in Japan.

The weak association between household income and SGA birth might be due to measurement error, because we used a self-administered questionnaire. Although there are no studies validating the relationship of self-reported income with actual income, several studies have shown an association between self-reported income and health (46–48), suggesting that self-reported income has adequate predictive validity in Japan. Even if misclassification of household income occurs, it should be random, and the association with SGA birth would be weakened toward the null. Thus, although the finding was not significant, mothers whose household income was in the third quartile were 10% less likely to deliver an SGA infant than were mothers whose household income was in the first quartile ($P = 0.052$, Table 3), which is a stronger difference than that found between mothers with household incomes in the second and fourth quartiles (i.e., a U-shaped association). Possibly because mothers in the highest household income group tended to have a thinner body image even during pregnancy (49), which can lead to poor development of the fetus (50), the impact of household income might have been diluted. Further research is warranted to investigate the U-shaped association between household income and SGA birth.

This study had several limitations. First, the data were cross-sectional; therefore, inferences regarding causation are limited. Second, we also lacked data on maternal mental distress during pregnancy that would have helped us test the mediating mechanism between income inequality and adverse birth outcomes. Third, the data on income inequality were not adjusted for taxes and benefits. Fourth, financial support from kin was not taken into account when evaluating the financial status of the household. Last, although the sample size was large, it included only infants born in January and July, and there may be seasonal variation in the incidence of adverse birth outcomes (51).

Despite these limitations, the present study showed that higher income inequality at the prefectural level and paternal educational level, rather than household income, were associated with intrauterine growth in Japan. These associations are more likely to be found among children of fathers with less than a college education. The possible mechanism for the effect of income inequality on intrauterine growth needs to be elucidated in future studies.

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