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ORIGINAL PAPER

Socioeconomic Status and the Risk of Suspected Autism Spectrum Disorders Among 18-Month-Old Toddlers in Japan: A Population-Based Study

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Abstract The association between family socioeconomic status (SES) and the suspected autism spectrum disorder (ASD) status of 18-month-old toddlers was investigated using a population-based sample in Japan, which has a universal healthcare system and a mandatory health checkup system for toddlers. Questionnaires including SES measurements and modified checklist for autism in toddlers were mailed to all families with 18-month-old toddlers in Chiba, a city near Tokyo (N = 6,061; response rate: 64 %). The results of logistic regression analysis (which were adjusted for potential confounders) indicated that low maternal education, but not paternal education or family income, were associated with having suspected ASD offspring. Lower maternal education was associated with an increased risk of autistic traits in Japan.

Keywords Autism · Autism spectrum disorders · Epidemiology · Health care system · Socioeconomic status

Introduction

Most of previous studies from the United States have reported a positive association between high family socioeconomic status (SES) and autism spectrum disorders (ASD) in children (Bhasin and Schendel 2007; Croen et al. 2002; Durkin et al. 2010; Fountain et al. 2011; Van Meter et al. 2010; Windham et al. 2011), although some studies have reported no association between family SES and ASD (Pinborough-Zimmerman et al. 2010, 2011) and others have reported an inverse association between maternal education and ASD in children (Burd et al. 1999). The positive association between SES and ASD might be due to the healthcare system; that is, ASD might be more likely to be found among children of high-SES families because of their better access to healthcare (Gillberg and Schaumann 1982; Schopler et al. 1979; Tsai et al. 1982; Wing 1980). In fact, the opposite association between SES and ASD (i.e., low SES leads to ASD) has been reported in countries with universal healthcare systems, including Sweden (Rai et al. 2012), England (Emerson 2012), Canada (Dodds et al. 2011), and Denmark (Larsson et al. 2005). To the best of our knowledge, no study has reported the associations between SES and ASD in Asian countries that have universal healthcare systems, such as Japan.

In addition, a higher maternal body mass index (BMI) can be a confounding variable in the association between SES and ASD. Krakowiak et al. (2012) reported that obesity during pregnancy was associated with ASD in offspring (Krakowiak et al. 2012), and there is a consistent link between SES and BMI (Moore and Cunningham 2012), Therefore, it is necessary to adjust for BMI in the investigation of SES and ASD.

Moreover, previous studies have investigated the association between SES and *diagnosed* ASD. However, because the age of diagnosis affects the association between SES and ASD (Fountain et al. 2011), it is optimal to investigate the association between SES and *suspected* ASD, because early identification of ASD is important for early intervention; children with ASD should begin therapeutic programs as early as possible (Charman and Baird 2002). Early detection can enhance the potential of

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children with ASD (Dawson et al. 2010; Sutera et al. 2007) and may assist parents in coping with the situation (Lord et al. 1994). Furthermore, population-based screening to detect suspected ASD cases could avoid the problem of selection bias related to socioeconomic disparities in access to diagnostic services.

Suspected ASD can be assessed using screening questionnaires such as the modified checklist for autism in toddlers (M-CHAT; (Robins et al. 2001)) at a given age. The reliability and validity of the Japanese version of the M-CHAT was acceptable in a sample of Japanese toddlers. Test–retest reliability was high enough ($r = 0.990$) and the M-CHAT score was the highest in the autism group (mean 4.71), followed by pervasive developmental disorders not otherwise specified (mean 2.46) and reference groups (mean 0.58), which differed significantly, showing adequate discriminant validity (Inada et al. 2011). The M-CHAT is composed of 23 items that include specific behaviors related to ASD, such as interest in other children and eye contact (Robins et al. 2001). To the best of our knowledge, few studies have investigated the association between family SES and the M-CHAT items (Scarpa et al. 2013).

In Japan, 18-month-old toddlers receive health and development checkups at health centers free of charge. The participation rate in the 18-month health checkup is over 90 % (Ministry of Health Labor and Welfare 2011). This provides an opportunity for the investigation of the association between SES and suspected ASD among toddlers at age 18 months in a population-based sample.

Thus, the present study investigates the association between family SES and suspected ASD of 18-month-old toddlers assessed using M-CHAT; this question was investigated using a population-based sample in Japan, which has a universal healthcare system and a mandatory health checkup system for toddlers.

Methods

Participants

A questionnaire was mailed to all families with 18-month-old toddlers in Chiba ($N = 95{,}000$). Chiba is located next to Tokyo and composed of six wards as the capital city of Chiba Prefecture. The population of Chiba city is approximately 963,000 and the area covers 272 km^2, resulting in a population density of approximately 3,540 person/km^2. The mothers of toddlers were requested to fill out the questionnaire and bring it to the 18-month health checkup at six health centers from January to December 2011. In total, 8,350 toddlers participated in the health checkup (participation rate: 87.9 %), and 6,106 mothers handed in the questionnaires at the health center. Among them, there were 6,061 valid questionnaires (valid response rate: 63.8 %).

Measures

For SES assessment, parental education and annual household income were assessed via questionnaire. The final school level from which the respondents graduated was asked to assess their educational level, (i.e., junior high school, high school, some college/vocational school, college, or graduate school). For both mothers and fathers, the rates of responding "junior high school" and "graduate school" were small; therefore, these were collapsed with high school and college, respectively. Annual household income was assessed in increments of 2 million yen up to 10 million yen, (i.e., less than 2, 2.1–4, 4.1–6, 6.1–8, 8.1–10, 10.1–15, and 15.1 or more million yen). Because the numbers of families with incomes of less than 2, 10.1–15, and 15.1 or more million yen were too small, the first of these were collapsed with the 2.1–4-million-yen group, and the latter two were grouped with the 8.1–10-million-yen group. Thus, the final annual income categories were 4 or less, 4.1–6, 6.1–8, and 8 or more million yen. At current exchange rates, 1 million yen is equivalent to 12,500 USD. The median annual household income in Japan was 4.5 million yen in 2008 (Ministry of Health Labor and Welfare 2012).

Suspected ASD was evaluated via questionnaire using the Japanese version of M-CHAT (Inada et al. 2011), rated by mothers. Japanese version of M-CHAT showed good sensitivity (0.75 and 0.55) and specificity (0.89 and 0.96) for cutoff scores of two or more and three or more critical items, respectively. However, following the cutoff of the original M-CHAT (Robins et al. 2001), children failing on two or more of the six critical items or three or more of any of the items are considered as having suspected ASD.

Because the association between SES and ASD was of primary interest, the information about the following possible confounders, based on previous studies (Krakowiak et al. 2012; Lampi et al. 2013; Rai et al. 2012; Sullivan et al. 2012), was also included in the questionnaire: maternal age, maternal self-rated health, maternal BMI, maternal employment status, marital status (assessed as living with a husband or partner), living with grandparents or other relatives, and number of children. Self-rated health was assessed by the following question, "How do you rate your health in general?" rated on a 5-point Likert scale (excellent, very good, good, fair, or poor). To compute BMI [weight (kg)/height^2 (m)], participants were asked to record height to the nearest 0.1 cm and weight to the nearest 0.1 kg on the questionnaire.

Table 1 Distribution of positive response for each item of the modified checklist for autism in toddlers (M-CHAT) (n = 6,061)

		N	%
M-CHAT items			
1	Enjoys being swung	134	2.2
2	Interest in other children	141	2.3
3	Climbs up stairs	62	1.0
4	Enjoys peek-a-boo	31	0.5
5	Pretend play	104	1.7
6	Imperative pointing	139	2.3
7	Declarative pointing	184	3.0
8	Functional play	673	11.1
9	Brings objects to show	316	5.2
10	Eye contact	214	3.5
11	Oversensitive to noise	999	16.5
12	Responds to smile	31	0.5
13	Imitation of action	163	2.7
14	Responds to name	39	0.6
15	Point following	116	1.9
16	Walking	81	1.3
17	Gaze-following	515	8.5
18	Unusual finger movement	340	5.6
19	Gaining parent's attention	483	8.0
20	Wondering hearing	188	3.1
21	Understands what is said	157	2.6
22	Stares at nothing	918	15.2
23	Social reference	996	16.4
Suspected autism spectrum disorders			
	Positive	815	13.5
	Negative	5,246	86.6

Analysis

Logistic regression was used to calculate the odds ratio (OR) of suspected ASD for each SES measure. The models included a crude model, one in which each SES measure was added simultaneously (model 1), and one that simultaneously employed all SES measures and potential confounders (model 2). Further, to determine which items of the M-CHAT are associated with SES, the ORs of each SES measure with respect to the M-CHAT items were calculated and adjusted for covariates. Missing cases were treated as dummy variables to maintain statistical power. All statistical analyses were performed using the Stata MP 12, and the level of statistical significance was set at 0.05 (two-tailed). The study was approved by the Ethics Committee of the National Institute for Child Health and Development.

Results

The demographics of the participants were as follows: the mean age of mothers was 32.8 years (standard deviation: 4.8); 97.5 % were married, and 68.9 % were homemakers. Further, 53.9 % had only one child. Regarding maternal SES, the percentage of high school or less, some college, and college or more was 25.9, 44.1, and 27.4 %, respectively. Similarly, the percentage of paternal education as high school or less, some college, and college or more was 26.1, 20.0, and 49.1 %, respectively. Annual income was distributed as follows: ≤4 million yen, 23.4 %; 4.1–6 million yen, 32.8 %; 6.1–8 million yen, 18.4 %; and ≥8.1 million yen, 14.0 %.

Table 1 shows the rate of failure for each M-CHAT item. The rates of failure for the six critical items were as follows: "interest in other children," 2.3 %; "declarative pointing," 3.0 %; "brings objects to show," 5.2 %; "imitation of action," 2.7 %; "responds to name," 0.6 %; and "point following," 1.9 %. Finally, the sample's rate of suspected ASD was 13.5 %.

The ORs of each SES measure for suspected ASD are shown in Table 2. In the crude model, all lowest-SES groups showed significantly higher ORs of ASD in comparison with their corresponding highest-SES groups. When the model was adjusted for these three indices of SES simultaneously, maternal education remained significantly associated with ASD. Further, in model 2, low maternal education remained significantly associated with ASD (OR of high school or less compared with college or more: 1.36, 95 % CI 1.08–1.71), although the OR was slightly attenuated from that of model 1. Interestingly, being overweight and not or part-time employment showed positive association with suspected ASD, while thinness and having a larger number of children showed negative association with suspected ASD.

Table 3 showed the OR of each SES measure for the M-CHAT items, adjusted for covariates. Low maternal education showed an OR of more than 1 for each M-CHAT item except "responds to name" and "unusual finger movement." Specifically, six items showed significantly higher ORs of failure for mothers who had completed high school or less compared with mothers who had completed college or more: interest in other children; gaining parent's attention; enjoys being swung; functional play; social reference; and stares at nothing. On the contrary, paternal education showed an inconsistent association with ASD: 13 items showed ORs of more than 1, and 10 items showed ORs of less than 1. Overall,

Table 2 Odds ratio of socioeconomic status for suspected autism spectrum disorders (ASD)

	ASD (n = 815)		Non-ASD (n = 5,246)		Crude		Model 1		Model 2	
	N	%	N	%	OR	95 % CI	OR	95 % CI	OR	95 % CI
Maternal education										
High school or less	262	32.2	1,310	25.0	**1.51**	**1.24–1.84**	**1.41**	**1.13–1.77**	**1.36**	**1.08–1.71**
Some college	336	41.2	2,334	44.5	1.09	0.90–1.31	1.06	0.87–1.29	1.04	0.85–1.27
College+	194	23.8	1,464	27.9	Reference		Reference		Reference	
Missing	23	2.8	138	2.6						
Paternal education										
High school or less	245	30.1	1,337	25.5	**1.28**	**1.08–1.53**	1.12	0.92–1.36	1.18	0.97–1.44
Some college	156	19.1	1,054	20.1	1.04	0.85–1.27	0.97	0.78–1.19	1.01	0.81–1.25
College+	372	45.6	2,606	49.7	Reference		Reference		Reference	
Missing	42	5.2	249	4.8						
Annual household income										
≤4 million yen	212	26.0	1,206	23.0	**1.31**	**1.01–1.68**	1.12	0.86–1.47	1.00	0.75–1.33
4.1–6 million yen	264	32.4	1,723	32.8	1.14	0.89–1.45	1.05	0.81–1.35	0.97	0.74–1.25
6.1–8 million yen	144	17.7	973	18.6	1.10	0.84–1.44	1.06	0.80–1.39	1.03	0.78–1.35
8.1+ million yen	101	12.4	750	14.3	Reference		Reference		Reference	
Missing	94	11.5	594	11.3						
Mother's age										
<25	39	4.8	237	4.5	Reference				Reference	
25–29	175	21.5	1,045	19.9	1.02	0.70–1.48			1.25	0.85–1.84
30–34	275	33.7	1,961	37.4	0.85	0.59–1.22			1.16	0.79–1.70
35–39	239	29.3	1,517	28.9	0.96	0.66–1.38			1.32	0.89–1.95
40+	77	9.5	416	7.9	1.12	0.74–1.71			1.51	0.97–2.35
Missing	10	1.2	70	1.3						
Self-rated health										
Good/very good/excellent	765	93.9	5,009	95.5	Reference				Reference	
Poor/fair	41	5.0	197	3.8	1.36	0.97–1.92			1.26	0.89–1.79
Missing	9	1.1	40	0.8						
Maternal BMI										
Thinness (<18.5)	109	13.4	886	16.9	**0.80**	**0.64–0.99**			**0.79**	**0.64–0.99**
Normal (18.5 to <25)	549	67.4	3,568	68.0	Reference				Reference	
Overweight (25+)	76	9.3	276	5.3	**1.79**	**1.37–2.34**			**1.64**	**1.25–2.17**
Missing	81	9.9	516	9.8						
Maternal working status										
Full-time work	109	13.4	959	18.3	Reference				Reference	
Part-time work	102	12.5	647	12.3	**1.39**	**1.04–1.85**			**1.40**	**1.03–1.88**
Not working	593	72.8	3,583	68.3	**1.46**	**1.17–1.81**			**1.44**	**1.15–1.81**
Missing	11	1.4	57	1.1						
Living with father/partner										
Yes	772	94.7	5,036	96.0	Reference				Reference	
No	41	5.0	210	4.0	1.27	0.90–1.79			1.33	0.86–2.05
Missing	2	0.3	0	0.0						
Living with grandmother, grandfather, or others										
Yes	736	90.3	465	8.9	1.08	0.83–1.39			0.96	0.73–1.26
No	77	9.5	4,780	91.1	Reference				Reference	
Missing	2	0.3	1	0.02						

Table 2 continued

	ASD (n = 815)		Non-ASD (n = 5,246)		Crude		Model 1		Model 2	
	N	%	N	%	OR	95 % CI	OR	95 % CI	OR	95 % CI
Number of children										
1	492	60.4	2,777	52.9	Reference				Reference	
2	252	30.9	1,883	35.9	**0.76**	**0.64–0.89**			**0.72**	**0.61–0.85**
3+	71	8.7	586	11.2	**0.68**	**0.53–0.89**			**0.60**	**0.45–0.79**

Values in bold are significant at the $p = 0.05$ level

annual household income was not associated with the M-CHAT items in the adjusted model.

Discussion

In this large population-based study conducted in one city in Japan, toddlers whose mothers had lower levels of education showed greater rates of suspected ASD, while paternal education and family income were not independently associated with suspected ASD after adjustment for maternal education. Furthermore, lower levels of maternal education were specifically associated with failure on the M-CHAT items of "enjoys being swung," "interest in other children," "functional play," "gaining parent's attention," "stares at nothing," and "social reference."

To the best of our knowledge, this is the first study to show the inverse association between SES and suspected ASD by using a population-based sample in Japan. A Japanese study undertaken in the 1970s reported a positive association between SES and diagnosed autism (mean age: 8.2 years old), using Kanner's diagnostic criteria (Hoshino et al. 1982). This conflicting result may be due to the difference of outcome, i.e., Hoshino et al. (1982) used *diagnosed* autism, while current study used *suspected* ASD as outcome. Further, time in which the studies were carried out and the age of the children were different. For example, in the 1970s, autism was not as well-known as in the 2010s, which could lead to higher reports of autistic behaviors by mothers with higher levels of education in 1970s.

The findings of the current study are consistent with those from previous studies in other countries in Europe, such as Sweden, where children whose mothers had less than 9 years of education had an OR of 1.1 (95 % CI 1.0–1.2) of having children diagnosed with ASD (Rai et al. 2012). While, the opposite association (i.e., higher maternal education was associated with ASD in children) was reported in the United States (Bhasin and Schendel 2007; Croen et al. 2002; Durkin et al. 2010; Fountain et al. 2011; Van Meter et al. 2010; Windham et al. 2011). However, previous studies in the state of Utah in the United States, which ranks higher than the national average in median household income and has the lower poverty rate among the 50 states, reported no association between family income and ASD in children (Pinborough-Zimmerman et al. 2011; Pinborough-Zimmerman et al. 2010). These findings suggest that children with ASD belonging to low-SES families might be undercounted in the United States. For example, Burd et al. (1999) showed that lower maternal education was associated with higher risk of ASD in the United States in a case-controlled study (Burd et al. 1999), suggesting a possible association between low SES and ASD in children even in the United States.

The present finding of a lack of association between paternal education and household income with having suspected ASD after adjustment for maternal education might be due to the former indices' high correlations with maternal education. In the present study, the Pearson's correlation coefficients of paternal education and household income with maternal education were 0.48 and 0.38, respectively. Alternatively, maternal education might be independently associated with suspected ASD. Research has shown that mothers with lower levels of education are more likely to be exposed to smoking (Hultman et al. 2002), heavy metals (such as mercury; (Adams et al. 2007; Palmer et al. 2006), pesticides (Eskenazi et al. 2007; Rauh et al. 2006; Roberts et al. 2007), or insufficient micronutrients (Curtis and Patel 2008; Filipek et al. 2004; Schultz et al. 2006; Strambi et al. 2006), all of which can be risk factors for ASD during pregnancy or infancy. For example, in one study, education—but not employment or household income—was positively associated with favorable dietary intake patterns in a group of pregnant Japanese women (Murakami et al. 2009). Further research is needed to elucidate the pathway by which low maternal education is associated with suspected ASD in children; such studies need to investigate the exposure to risk factors of ASD during pregnancy.

Consistent with a previous study (Krakowiak et al. 2012), maternal BMI was positively associated with suspected ASD in offspring. Because adding maternal BMI reduced the OR of maternal education and suspected ASD

Table 3 Odds ratio of each socioeconomic status measures for the modified checklist for autism in toddlers items adjusted for covariates

		Maternal education[a] (reference: college+)				Paternal education[b] (reference: college+)			
		HS or less		Some college		HS or less		Some college	
		OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI
1	Enjoys being swung	**1.71**	**1.02–2.89**	1.07	0.67–1.71	0.99	0.62–1.60	1.55	0.99–2.43
2	Interest in other children	**1.93**	**1.16–3.21**	1.19	0.75–1.88	**0.49**	**0.29–0.80**	0.80	0.50–1.26
3	Climbs up stairs	1.99	0.97–4.06	0.62	0.30–1.30	1.03	0.54–1.96	0.57	0.24–1.34
4	Enjoys peek-a-boo	1.12	0.39–3.22	0.91	0.35–2.32	1.02	0.39–2.68	1.10	0.40–3.06
5	Pretend play	1.15	0.64–2.04	0.82	0.50–1.35	0.83	0.47–1.46	1.33	0.79–2.23
6	Imperative pointing	1.02	0.61–1.72	0.94	0.60–1.47	1.01	0.64–1.59	0.97	0.60–1.57
7	Declarative pointing	1.14	0.73–1.77	0.88	0.60–1.29	0.83	0.55–1.25	1.04	0.69–1.57
8	Functional play	**1.32**	**1.03–1.70**	0.96	0.77–1.19	1.20	0.97–1.49	1.16	0.92–1.45
9	Brings objects to show	1.28	0.90–1.81	1.04	0.78–1.40	1.03	0.76–1.39	0.77	0.55–1.08
10	Eye contact	1.40	0.91–2.15	1.22	0.84–1.77	1.27	0.89–1.82	1.00	0.67–1.49
11	Oversensitive to noise	1.08	0.87–1.33	0.97	0.81–1.15	1.18	0.99–1.42	0.99	0.81–1.20
12	Responds to smile	1.37	0.44–4.26	1.35	0.57–3.20	0.58	0.20–1.66	0.73	0.26–2.06
13	Imitation of action	1.47	0.91–2.38	1.08	0.71–1.64	1.05	0.69–1.58	0.76	0.47–1.22
14	Responds to name	0.91	0.35–2.33	0.92	0.41–2.04	0.68	0.28–1.65	0.65	0.25–1.69
15	Point following	1.25	0.70–2.22	1.05	0.65–1.71	0.77	0.46–1.27	0.77	0.45–1.31
16	Walking	1.45	0.72–2.89	1.26	0.70–2.26	0.68	0.36–1.28	0.79	0.42–1.50
17	Gaze-following	1.07	0.81–1.41	0.95	0.75–1.20	0.94	0.74–1.21	0.92	0.71–1.19
18	Unusual finger movement	0.91	0.65–1.27	0.82	0.62–1.10	1.27	0.94–1.71	1.26	0.93–1.72
19	Gaining parent's attention	**1.91**	**1.39–2.61**	**1.63**	**1.23–2.17**	**1.72**	**1.34–2.20**	**1.32**	**1.01–1.73**
20	Wondering hearing	1.09	0.69–1.72	1.02	0.69–1.50	1.05	0.71–1.57	1.10	0.73–1.66
21	Understands what is said	1.37	0.84–2.24	1.16	0.76–1.76	0.82	0.53–1.27	0.84	0.54–1.33
22	Stares at nothing	**1.25**	**1.01–1.56**	1.07	0.89–1.29	1.13	0.94–1.37	0.98	0.80–1.20
23	Social reference	**1.26**	**1.02–1.55**	1.08	0.90–1.28	1.06	0.88–1.27	1.04	0.86–1.26

		Annual household income[c] (reference: 8+ million yen)					
		<4 m		4–5.9 m		6–7.9 m	
		OR	95 % CI	OR	95 % CI	OR	95 % CI
1	Enjoys being swung	0.74	0.40–1.39	0.74	0.42–1.30	**0.50**	**0.25–0.99**
2	Interest in other children	1.17	0.59–2.33	1.22	0.66–2.28	1.45	0.77–2.74
3	Climbs up stairs	0.74	0.28–1.96	0.60	0.24–1.53	1.17	0.48–2.84
4	Enjoys peek-a-boo	1.65	0.31–8.73	1.15	0.22–5.87	3.52	0.75–16.6
5	Pretend play	1.03	0.48–2.21	1.12	0.57–2.21	1.15	0.56–2.33
6	Imperative pointing	1.75	0.88–3.50	1.34	0.70–2.57	1.34	0.67–2.66
7	Declarative pointing	1.57	0.86–2.85	1.17	0.67–2.07	1.47	0.82–2.62
8	Functional play	1.30	0.94–1.79	1.22	0.91–1.64	1.24	0.91–1.70
9	Brings objects to show	0.96	0.62–1.51	1.05	0.70–1.55	1.28	0.86–1.92
10	Eye contact	1.02	0.59–1.76	1.02	0.61–1.68	1.16	0.69–1.98
11	Oversensitive to noise	1.15	0.88–1.49	1.03	0.81–1.31	1.23	0.96–1.58
12	Responds to smile	0.34	0.08–1.53	0.96	0.34–2.71	0.72	0.23–2.29
13	Imitation of action	0.61	0.33–1.11	0.93	0.57–1.54	0.81	0.47–1.39
14	Responds to name	1.85	0.53–6.43	1.40	0.44–4.51	0.74	0.18–3.00
15	Point following	1.25	0.61–7.28	1.43	0.76–2.66	0.54	0.24–1.18
16	Walking	0.99	0.42–2.29	0.69	0.31–1.52	1.36	0.66–2.82
17	Gaze-following	1.22	0.85–1.74	1.27	0.93–1.75	1.12	0.80–1.58
18	Unusual finger movement	1.05	0.69–1.59	0.98	0.66–1.44	0.85	0.56–1.30
19	Gaining parent's attention	0.93	0.64–1.33	0.92	0.65–1.28	1.01	0.71–1.44

Table 3 continued

		Annual household income[c] (reference: 8+ million yen)					
		<4 m		4–5.9 m		6–7.9 m	
		OR	95 % CI	OR	95 % CI	OR	95 % CI
20	Wondering hearing	1.29	0.73–2.29	1.11	0.65–1.88	1.40	0.82–2.39
21	Understands what is said	0.96	0.53–1.74	0.97	0.57–1.64	0.80	0.44–1.43
22	Stares at nothing	0.97	0.74–1.26	0.80	0.62–1.02	0.90	0.69–1.17
23	Social reference	0.80	0.62–1.04	1.00	0.80–1.25	0.85	0.67–1.08

Values in bold are significant at the $p = 0.05$ level

[a] Adjusted for paternal education, household income, maternal age, maternal self-rated health, maternal BMI, maternal working status, living with husband, living with relatives, number of children

[b] Adjusted for maternal education, household income, maternal age, maternal self-rated health, maternal BMI, maternal working status, living with husband, living with relatives, number of children

[c] Adjusted for maternal education, paternal education, maternal age, maternal self-rated health, maternal BMI, maternal working status, living with husband, living with relatives, number of children

of offspring, and low maternal education is associated with larger BMI (Jwa et al. 2013), maternal BMI might be an important confounder of the association between maternal education and suspected ASD. Further study is warranted to elucidate the association between maternal education, BMI, and autistic traits of the offspring.

Certain items of the M-CHAT showed relatively strong associations (i.e., ORs $>$ 1.9) with low maternal education, including failure on “interest in other children” and “gaining parent’s attention.” These findings suggest the possible mechanism of association between lower maternal education and suspected ASD: as mothers with lower levels of education might have fewer friends than more highly educated mothers in Japan (Iwasaki et al. 2002), children of mothers with low levels of education might socialize less with other children. The association between lower maternal education and failure at “gaining parent’s attention” might be due to the poor development of attachment between parents and children in families with low maternal education. Further research is needed to investigate whether the development of attachment mediates the association between low maternal education and suspected ASD among their children.

Another possible explanation for the association between lower maternal education and ASD is that mothers with genetic vulnerabilities related to the broad autism phenotype may be more likely to have lower maternal education and also toddlers with ASD. Although we did not assess maternal autistic traits, it is likely that mothers with ASD, especially ASD with an intellectual disability, are less likely achieve high academic attainment (May et al. 2013). Furthermore, maternal exposure to social stress during pregnancy related to low maternal education may be linked to ASD through epigenetic mechanisms (Kinney et al. 2008), such as DNA methylation of the hypothalamic–pituitary–adrenal axis (Meaney 2001) and programming of the oxytocinergic system, which is associated with ASD (Sauer et al. 2012).

Several limitations of the present study need to be mentioned. First, because the cross-sectional design employed, the causal relationship between low levels of maternal education and suspected ASD in their toddlers is not clear. As discussed above, other predisposing factors, such as genetic ones, might confound this association. Further, it is possible that mothers with less education reported more problems on the M-CHAT. Second, the assessment of ASD relied on a screening tool (i.e., the M-CHAT) that might be less specific from other diagnostic tools for ASD, such as the Autism Diagnostic Observation Schedule (ADOS) or Autism Diagnostic Interview, Revised (ADI-R). In this study, 13.5 % of the children were suspected of having ASD, suggesting a large portion of the suspected ASD cases were false positive. However, it is not realistic to use the ADOS or ADI-R during toddlers’ health checkups. Consequently, the present findings indicate that low maternal education was associated with *suspected* ASD, not *diagnosed* ASD. Third, parental occupational class was not measured in this study. Previous studies found inverse associations between parental occupational class and ASD among children (Rai et al. 2012). Fourth, comorbid health conditions in toddlers such as intellectual disability or language delay, which can be confounders in the association between maternal education and suspected ASD in toddlers, were not investigated in this study, Fifth, the response rate in the current study was not very high, and it is possible that some did not respond to the questionnaire because their children had ASD or lacked interest in contributing to the research due to their low educational attainment. These factors suggest that the association found in this study might be underestimated.

In conclusion, unlike previous studies in the United States, the current study revealed an association between low maternal education and suspected ASD in their 18-month-old toddlers, using a population-based sample in Japan, where universal healthcare and a mandatory health checkup system for children have been implemented. The possible mechanisms of association between maternal education and autistic traits among their toddlers include exposure to toxic elements, genetic factors, maternal stress during pregnancy, lack of social networks, or poor development of attachment. Further research is required to elucidate the etiology of ASD.

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