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Associations between paternal autism traits and parenting from the Japan environment and children's study

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There are few studies on the parenting of fathers with autism traits. To investigate this issue, we examined the type of parenting performed by fathers with autism traits using data from a nationwide birth cohort study, the Japan Environment and Children's Study. Paternal parenting was evaluated by mothers or caregivers when the child was 2 years old. Father's autism traits were measured using the Japanese version of the self-administered Autism Spectrum Quotient. Logistic regression analysis was performed to statistically analyze the data. Fathers with autism traits were significantly less likely to prepare meals for their child and helping them eat (adjusted OR (aOR): 1.11, 95% confidence interval (CI): 1.01–1.23), to helping the child change clothes (aOR: 1.17, 95% CI: 1.04–1.31). However, there were no associations between some parenting behaviors and autism traits (not changing diapers, not bathing with the child, and not playing with the child). Father's communication skill difficulties by autism traits associated with a lower tendency to perform all types of parenting. Interestingly, there were association between difficulties with social skills or attention-switching and more performing change diapers. These results indicate it is important to respect the child-rearing that fathers with autistic tendencies are able to do, while supporting them in child-rearing that they are significantly less able to do than fathers without autistic tendencies.

Keywords Autism traits, Autism spectrum disorder, Father, Parenting behavior, The Japan Environment and Children's Study

The recent societal increase in concerns about fathers' participation in childcare has prompted substantial research focus on paternal parenting behavior, which has led to greater understanding of the relationships between infants and their fathers^{1,2}. Paternal participation in parenting can reduce maternal stress and have positive effects on the physical (including neuronal) development of infants^{3,4}. A lack of paternal parenting assistance is associated with a higher risk of maternal postpartum depression and parenting anxiety⁵, and of problem behaviors in children⁶. This association between paternal parenting and both maternal mental health and infant development highlights the importance of identifying ways to encourage fathers to participate in childcare.

Several papers have discussed the factors associated with the absence of paternal parenting behavior. The risk of fathers not participating in child-rearing is increased if the family live with grandparents^{7,8}, if mothers do not work or work part-time^{7,9,10}, if fathers work long hours¹⁰, and younger paternal age^{10,11}. Psychological health problems also affect paternal parenting behavior. Depression in fathers is associated with less positive parenting (e.g., lower frequency of reading, singing songs, and telling stories¹²), and more negative parenting¹³. Attention-deficit/hyperactivity disorder symptoms in fathers are associated with negative parenting, child-rearing disagreements¹⁴, lax or permissive parenting^{15,16}, and less involvement with their children¹⁷. However, comparatively few studies have investigated the parenting behaviors of autistic fathers¹⁸.

According to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, autism spectrum disorder (ASD) is characterized by persistent deficits in social communication and interaction, as well as a restricted, repetitive patterns of behaviors, interests, or activities¹⁹. Dissanayake et al.²⁰ found the association

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between parents with ASD and more difficulties in modelling and teaching their child behaviors, understanding the needs of their child, being spontaneous in parenting situations, and coping with sensory stimuli around their child. According to cross-sectional study, there was the association between mothers with ASD and a lax parenting style¹⁶. In interview to mothers with ASD, they may experience stress owing to both higher sensory stimulation during lactation and higher auditory stimulation when children cry or play²¹. In interview or internet survey, mother with ASD answered that they may have difficulties when required to multitask or ask an expert for child-rearing support, feel isolated from others, and experience high anxiety^{18,22}. Compared with research on mothers with ASD, parenting behavior in fathers with ASD is not elucidated. Although the study investigated that autistic fathers associated with lower parenting efficacy²³, there were still unknown. Because there is a higher incidence of ASD among men and that men with ASD show more restricted, repetitive, and stereotyped behaviors than women^{15,24}, it is important that the parenting styles or behaviors of father with ASD are investigate the population-based study.

However, in previous study, there were studies about parents with ASD using interview to mothers and small size questionnaire survey, there are no big population-based studies on the parenting behavior of parents with autism traits. It has been suggested that research on childcare and ASD should focus not only on parents with diagnosed autism but also on those with milder ASD-like cognitive and personality traits but no autism diagnosis^{23,25}. Thus, we investigated the association between autism traits and parenting behaviors in fathers using Japanese general populations.

Results

In this study, we measured autistic characteristics in fathers regardless of the presence of an ASD diagnosis. A total of 6.7% of fathers reported autism traits as screened by the AQ-J-10 (Table 1, supplementary Fig. 1). There was significant difference between existence of father’s autism traits and depression, education, number of children and house income, however, there were no difference between existence of father’s autism traits and marriage status, mother’s working and living with grandparents (Table2). Caregivers/mothers reported that 25.9% of fathers with autism traits did not prepare meals for the child or assist the child in eating; 22.3% did not change the child’s diapers or clean up the waste; 12.0% did not bathe with the child; 18.1% did not help the child to change clothes; and 4.7% did not play with the child (Table 3).

To investigate which parenting behaviors were performed by fathers with autism traits compared with fathers without autism traits, logistic regression analysis was performed. We found that fathers with autism traits had a significant tendency to not prepare meals for the child, not assist the child in eating, not help the child to change clothes; and not play with the child (crude OR = 1.10 [95% CI: 1.01, 1.21]; crude OR = 1.18; 95% CI [1.06, 1.30]; crude OR = 1.24; 95% CI [1.03, 1.49]) (Table 3). Adjusted model, which included all the confounders, showed an association between autism traits in fathers and not preparing meals for the child or helping the child to eat and not helping the child to change clothes (adjusted OR = 1.11; 95% CI [1.01, 1.23]; adjusted OR = 1.17; 95% CI [1.04, 1.31]). However, we found no significant association between the other paternal parenting behaviors

	N	%
Fathers’ autism traits (all over score)	(n = 39,864)	
AQ-J-10 (≥ 7)	2,684	6.7
AQ-J-10 (< 7)	37,180	93.3
AQ-J-10 subscales		
AQ Social skills	(n = 39,864)	
Score = 0	9,784	24.5
Score = 1	16,804	42.2
Score = 2	10,237	25.7
Score = 3	3,039	7.6
AQ Communication	(n = 39,864)	
Score = 0	26,521	66.5
Score = 1	10,689	26.8
Score = 2	2,654	6.7
AQ Imagination	(n = 39,864)	
Score = 0	4,859	12.2
Score = 1	14,426	36.2
Score = 2	15,128	37.9
Score = 3	4,574	11.5
Score = 4	877	2.2
AQ Attention-switching	(n = 39,864)	
Score = 0	29,319	73.5
Score = 1	10,087	25.3

Table 1. Father’s AQ-10 score. AQ-J-10= Autism Spectrum Quotient 10 Japanese version.

	Total	%	Father with Autism Traits	%	Father without Autism Traits	%	N = 39,864 P
Fathers' psychological distress	(n = 39,526)		(n = 2650)		(n = 36,876)		
K6 score (≥ 13)	716	1.8	145	5.5	571	1.5	<0.001
K6 score (< 13)	38,810	97.4	2505	94.5	36,305	98.5	
Length of fathers' workday	(n = 39,264)		(n = 2635)		(n = 36,629)		
≥ 9 h	27,548	69.1	1822	69.1	25,726	70.2	0.238
< 9 h	11,716	29.4	813	30.9	10,903	29.8	
Fathers' education	(n = 39,511)		(n = 2666)		(n = 36,845)		
≥ 16 years	13,999	35.1	854	32.0	13,145	35.7	<0.001
< 16 years	25,512	64.0	1812	68.0	23,700	64.3	
Fathers' age	(n = 38,679)		(n = 2606)		(n = 36,073)		
≤ 19 years	49	0.1	2	0.1	47	0.1	0.350
≥ 20 years	38,630	99.9	2604	99.9	36,026	99.9	
Marriage status	(n = 39,275)		(n = 2645)		(n = 36,630)		
Not married	41	0.1	4	0.2	37	0.1	0.440
Married	39,234	99.9	2641	99.8	36,593	99.9	
Family structure	(n = 39,864)		(n = 2684)		(n = 37,180)		
Living with grandparents	8278	20.8	581	21.6	7697	20.7	0.244
Not living with grand- parents	31,586	79.2	2103	78.4	29,483	79.3	
Mothers' employment status	(n = 38,768)		(n = 2615)		(n = 36,153)		
Not employed	22,540	56.5	1541	58.9	20,999	58.1	0.397
Employed	16,228	40.7	1074	41.1	15,154	41.9	
Number of children	(n = 38,780)		(n = 2612)		(n = 36,168)		
1	17,989	45.1	1264	48.4	16,725	46.2	0.033
≥ 2	20,791	52.2	1348	51.6	19,443	53.8	
Household income	(n = 37,490)		(n = 2496)		(n = 34,341)		
< 2,000,000 JPY	1544	3.9	141	5.6	1403	4.1	<0.001
≥ 2,000,000 JPY, < 4,000,000JPY	12,587	31.6	887	35.5	11,700	34.1	
≥ 4,000,000 JPY, < 6,000,000JPY	12,895	32.3	868	34.8	12,027	35.0	
≥ 6,000,000 JPY	9811	24.6	600	24.0	9211	26.8	

Table 2. Characteristics of participants. *P* value was calculated by Chi-square test. K6 = Kessler screening scale for psychological distress.

	All (N = 39,864)		Fathers with autism traits (n = 2,684)		Fathers without autism traits (n = 37,180)	
	N	%	N	%	N	%
Preparing meals for the child and helping them eat	(n = 37,102)		(n = 2,498)		(n = 34,604)	
Yes	27,467	68.9	1,804	67.2	25,663	69.0
No	9,635	24.2	694	25.9	8,941	24.0
Changing the child's diapers and cleaning up the waste	(n = 37,247)		(n = 2,509)		(n = 34,738)	
Yes	28,826	72.3	1,911	71.2	26,915	72.4
No	8,421	21.1	598	22.3	7,823	21.0
Bathing with the child	(n = 37,574)		(n = 2,528)		(n = 35,046)	
Yes	33,012	82.8	2,207	82.2	30,805	82.9
No	4,562	11.4	321	12.0	4,241	11.4
Helping the child change clothes	(n = 37,278)		(n = 2,515)		(n = 34,763)	
Yes	30,909	77.5	2,029	75.6	28,880	77.7
No	6,369	16.0	486	18.1	5,883	15.8
Playing with the child	(n = 37,472)		(n = 2,526)		(n = 33,535)	
Yes	35,936	90.1	2,401	89.5	33,535	90.2
No	1,536	3.9	125	4.7	1,411	3.8

Table 3. Fathers' participation in parenting behaviors.

and autism traits (not changing the child’s diapers and cleaning up the waste; not bathing with the child; and not playing with the child) (Table 4).

To determine whether particular types of autism traits were associated with specific parenting behaviors, we performed logistic regression analyses of the associations between each AQ-J-10 subscale score and each paternal parenting behavior. We found some associations between subscale scores and parenting behaviors (Table 5). Fathers with poorer communication skills had a tendency not to perform most parenting behaviors. Interestingly, fathers with deficits in social skills and deficits in attention-switching had a tendency to change diapers in a score-dependent manner (for social skills: adjusted $OR = 0.90$, 95% $CI [0.85, 0.97]$ for a score of 1; $0.85 [0.79, 0.92]$ for a score of 2; and $0.77 [0.69, 0.87]$ for a score of 3; for attention-switching: adjusted $OR = 0.93$, 95% $CI [0.87, 0.99]$ for a score of 1).

Discussion

To our knowledge, this is the first study to examine the associations between autism traits and paternal parenting behaviors. We found that although fathers with autism traits had significantly different parenting tendencies to fathers without autism traits. Father’s autism traits (i.e., those who scored ≥ 7 on the AQ-J-10) were significantly

Outcome		Not preparing meals for the child and helping them eat	Not changing the child’s diapers and cleaning up the waste	Not bathing with the child	Not helping the child change clothes	Not playing with the child
Exposure		Fathers’ autism traits				
Crude	OR [95% CI]	1.10 [1.01, 1.21]	1.08 [0.98, 1.18]	1.06 [0.94, 1.19]	1.18 [1.06, 1.30]	1.24 [1.03, 1.49]
Adjusted (n = 33,429)	OR [95% CI]	1.11 [1.01, 1.23]	1.07 [0.96, 1.18]	1.06 [0.93, 1.21]	1.17 [1.04, 1.31]	1.17 [0.95, 1.44]

Table 4. Association Between Paternal Autism Traits and Non-Participation in Parenting Behaviors. *CI* Confidence interval; *OR* Odds ratio; *ref* Reference. Adjusted for fathers’ psychological distress, length of fathers’ workday, fathers’ education, fathers’ age, mothers’ employment status, living with grandparents, marital status, household income, mothers’ psychological distress, firstborn, sex of child, and cognitive developmental delay (child).

	Not preparing meals for the child and helping them eat		Not changing the child’s diapers and cleaning up the waste		Not bathing with the child		Not helping the child change clothes		Not playing with the child	
	Crude	Adjusted (n = 33,429)	Crude	Adjusted (n = 33,429)	Crude	Adjusted (n = 33,429)	Crude	Adjusted (n = 33,429)	Crude	Adjusted (n = 33,429)
	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]	OR [95% CI]
Social skills (Reference category = 0)										
1	0.97 [0.91, 1.03]	0.96 [0.90, 1.02]	0.92 [0.86, 0.98]	0.90 [0.85, 0.97]	1.03 [0.96, 1.12]	1.05 [0.97, 1.15]	0.95 [0.88, 1.01]	0.94 [0.87, 1.01]	1.00 [0.88, 1.14]	0.98 [0.84, 1.13]
2	0.95 [0.89, 1.01]	0.94 [0.88, 1.01]	0.85 [0.79, 0.91]	0.85 [0.79, 0.92]	1.01 [0.93, 1.10]	1.03 [0.94, 1.14]	0.94 [0.87, 1.01]	0.92 [0.85, 1.00]	1.06 [0.92, 1.23]	1.03 [0.88, 1.21]
3	0.95 [0.87, 1.05]	0.94 [0.84, 1.04]	0.80 [0.73, 0.89]	0.77 [0.69, 0.87]	1.06 [0.93, 1.20]	1.00 [0.87, 1.15]	0.96 [0.86, 1.07]	0.92 [0.81, 1.03]	1.21 [0.99, 1.48]	1.16 [0.93, 1.45]
Communication (Reference category = 0)										
1	1.04 [0.98, 1.09]	1.04 [0.98, 1.10]	1.02 [0.97, 1.08]	1.00 [0.94, 1.06]	1.08 [1.01, 1.16]	1.06 [0.98, 1.14]	1.02 [0.96, 1.09]	1.01 [0.94, 1.08]	1.17 [1.04, 1.31]	1.16 [1.02, 1.31]
2	1.16 [1.06, 1.27]	1.16 [1.05, 1.29]	1.17 [1.07, 1.29]	1.15 [1.03, 1.28]	1.20 [1.06, 1.35]	1.17 [1.03, 1.34]	1.24 [1.12, 1.38]	1.22 [1.08, 1.37]	1.36 [1.12, 1.64]	1.16 [0.93, 1.44]
Imagination (Reference category = 0)										
1	1.01 [0.93, 1.09]	0.99 [0.91, 1.08]	1.05 [0.96, 1.14]	1.07 [0.98, 1.17]	1.01 [0.91, 1.12]	1.01 [0.90, 1.13]	1.05 [0.95, 1.14]	1.06 [0.96, 1.17]	1.02 [0.86, 1.21]	0.97 [0.81, 1.17]
2	1.02 [0.95, 1.10]	1.02 [0.94, 1.11]	1.07 [0.98, 1.16]	1.10 [1.01, 1.20]	1.02 [0.92, 1.13]	1.02 [0.91, 1.14]	1.05 [0.96, 1.15]	1.05 [0.95, 1.16]	0.98 [0.83, 1.17]	0.91 [0.75, 1.09]
3	1.07 [0.98, 1.18]	1.06 [0.96, 1.18]	1.12 [1.01, 1.24]	1.16 [1.04, 1.24]	1.05 [0.92, 1.19]	1.04 [0.91, 1.20]	1.13 [1.01, 1.26]	1.12 [0.99, 1.27]	1.21 [0.98, 1.48]	1.08 [0.86, 1.35]
4	1.06 [0.90, 1.26]	1.06 [0.88, 1.27]	1.13 [0.95, 1.35]	1.16 [0.95, 1.41]	1.00 [0.80, 1.26]	1.05 [0.82, 1.34]	1.30 [1.08, 1.57]	1.24 [1.00, 1.53]	1.74 [1.27, 2.37]	1.67 [1.19, 2.34]
Attention-switching (Reference category = 0)										
1	1.00 [0.95, 1.05]	1.01 [0.95, 1.07]	0.93 [0.88, 0.98]	0.93 [0.87, 0.99]	1.02 [0.95, 1.09]	1.02 [0.95, 1.11]	0.97 [0.91, 1.03]	0.97 [0.91, 1.04]	1.15 [1.03, 1.29]	1.14 [1.00, 1.29]

Table 5. Association Between Autism Trait Subscale Scores and Non-Participation in Parenting Behaviors. *CI* Confidence interval; *OR* Odds ratio; *ref* Reference. Adjusted for fathers’ psychological distress, length of fathers’ workday, fathers’ education, and fathers’ age; mothers’ employment status and mothers’ psychological distress; and living with grandparents, marital status, household income, firstborn, sex of child, and presence of cognitive developmental delay (child).

associated with less likely to assist the child in putting on or taking off clothes compared with fathers without autism traits, and to prepare meals for their 2-year-old children, help the child to eat. However, the analysis of AQ-J-10 subscale scores showed that fathers who reported difficulties with attention-switching and social skills associated with changing diapers.

One possible reason why the association between autism traits and not to help the child change clothes may relate to the fact that children develop a sense of self at approximately 2 years. Children at this age are less likely to listen to parental instructions²⁶. This may lead to more hostile parent–child relationships, resulting in behaviors such as the child resisting when changing clothes, not sitting still, running around naked, or being particular about preferred clothing (reflecting the development of the ego). Because individuals with autism traits may have difficulty understanding the emotions and intentions of others, solving problems flexibly, and educating their children about appropriate behavior^{20,27}, it may be difficult for fathers with autism traits to understand why their child is agitated when changing clothes, to respond to their child's unpredictable movements, or to persuade the child to change their clothes. Additionally, effective child-rearing requires parents to be sensitive to children's needs according to their behaviors in particular situations, and to respond to accordingly²⁸. Fathers with autism traits may find it difficult to quickly recognize the needs of their children (e.g., when clothes are dirty from eating or sweating) and to react spontaneously; thus, they may be less able to encourage and help their child to change clothes by themselves. Therefore, it may be necessary for mothers or other caregivers to inform fathers with autism when they need to change a child's clothes. One possible reason why the association between autism traits and not to prepare meals for their 2-year-old children and help the child to eat is that children gradually develop the ability to eat on their own; fathers with autism traits may be less likely to help meals for their child because they may find it difficult to judge the appropriate level of help the child needs. Most parents of 2-years-olds direct them to focus on eating rather than playing at mealtimes and encourage food intake if it is insufficient²⁹. However, there was a report about the association between parents with autism traits and difficulty to attend to and instruct children²⁰, and it may therefore be less able to help their children at mealtimes.

We found no evidence for an association between paternal autism traits and the extent to which fathers played with their children, the most interactive of the evaluated parenting behaviors. Although these results were unexpected, it is favorable for parents and children. This is because play is important in promoting children's development and emotional stability, and fathers' play with their children also helps reduce the mother's burden of housework and childcare. In addition, they may contribute to children's development in a different way to mother's play^{30,31}. However, it is possible that fathers with autism traits simply engage in their own preferred activities in the same space as their child. Thus, further study to understanding father's parenting behavior with autism traits should be needed.

In this study, we also analyzed the associations between paternal parenting behaviors and scores on the four subscales of the AQ-J-10, which measure difficulty in social skills, communication, imagination, and attention-switching. Father's autism traits in social skills associated with changing diapers. This indicates that these fathers, who may prefer to be alone or have difficulty understanding others, may find the mechanical behavior of diaper-changing easier to perform because it requires less interaction with children. Men with ASD tend to repeat the same behaviors^{24,32} and to do so accurately^{33,34}; both characteristics are likely helpful when changing diapers. In addition, attention-switching deficits also associated with changing diapers. Fathers with attention-switching difficulty may have a strong interest in a particular task or subject and feel uncomfortable if they are not immersed in it. Although it is difficult to fully understand the mechanisms underlying parenting behaviors, it may be that fathers with autism traits recognized these characteristics in themselves and so chose to change diapers because this task does not require immediate attention and takes little time to perform. It is also possible that others understood the father's characteristics and suggested that they take on that particular task. Whatever the reason, it is notable that we were able to identify an aspect of childcare that makes good use of the strengths of fathers who have difficulty with social skills and attention-switching.

In contrast, fathers with greater difficulty in communication skills significantly associated with not to perform most parenting behaviors. Generally, people with autism traits may experience problems with interpersonal communication, either because they phrase things in a way that others find rude or because they do not like to interact with others. Although infancy (birth to 12 months) requires mostly basic childcare (e.g., feeding and bathing), toddlerhood (12 to 35 months) requires more social interaction³⁰. Therefore, fathers with communication difficulties may find it hard to perform parenting behaviors both during and beyond toddlerhood. It is important to respect the childcare that autistic fathers are able to do, while supporting them in childcare that they are significantly less able to do compared to non-autistic fathers.

There were three main study limitations. First, we used a simple evaluation of the frequency with which each paternal parenting behavior was performed (categorized as *yes* or *no*); therefore, the ways in which the parenting behaviors were actually performed were not assessed. To elucidate this, future studies should examine the specific ways and situations in which parenting behaviors are performed. Second, because the AQ-J-10 questionnaire was self-administered, autism traits may have been overestimated or underestimated. Third, it is unknown whether fathers with autism traits perform multiple types of parenting behavior simultaneously. Mothers with autism traits can experience difficulty multitasking while performing parenting behaviors²², so additional studies on this issue are warranted. Despite these limitations, this study is the first to examine parenting behavior in fathers with autism traits. Notably, we were also able to identify specific characteristics that are advantageous to parenting behavior, which may extend the parenting tasks in which fathers with ASD can excel. More research is needed to identify the specific child-rearing situations of fathers with ASD using research designs that can overcome the above-mentioned limitations.

Conclusions

Fathers with autism traits were significantly less likely than those without autism traits to help their children in changing clothes and at mealtimes. In contrast, fathers who had difficulties with social skills and attention-switching were more likely to change diapers. There is a need to promote the aspects of child-rearing that capitalize on the strengths of fathers with autism, while compensating for the areas in which they perform less well.

Methods

Study design and participants

The Japan Environment and Children's Study (JECS) is a nationwide birth cohort study funded by the Japanese Ministry of Environment. The purpose of the JECS is to identify specific environmental factors that affect children's health and development. Kawamoto et al.³⁵ have described the details and protocol of the JECS. In brief, the JECS recruited 97,413 mothers who lived in the study areas (15 regional centers across Japan) between January 2011 and March 2014.

In this study, we analyzed the dataset jecs-ta-20190930. This dataset was released in October 2019 and contains information from 104,062 records, including the data collected from 2011 to 2014. This dataset does not contain any information that could identify participants.

Participants

Of the 104,062 records in the JECS dataset, we excluded 55,599 records that had missing data because of non-participation of the father, the father had participated more than twice, or the presence of multiple births or stillbirths. We excluded a further 6904 records because the children were not living with their parents at age 2 years or because of missing data on family structure. We excluded 1695 records with missing data for more than one question on the Autism Spectrum Quotient (AQ10). Therefore, the sample comprised 39,864 records containing the data for single-birth children who lived with both parents, and whose parents had answered all the AQ-J-10 questions (Fig. 1). In analysis, we performed complete-case analysis.

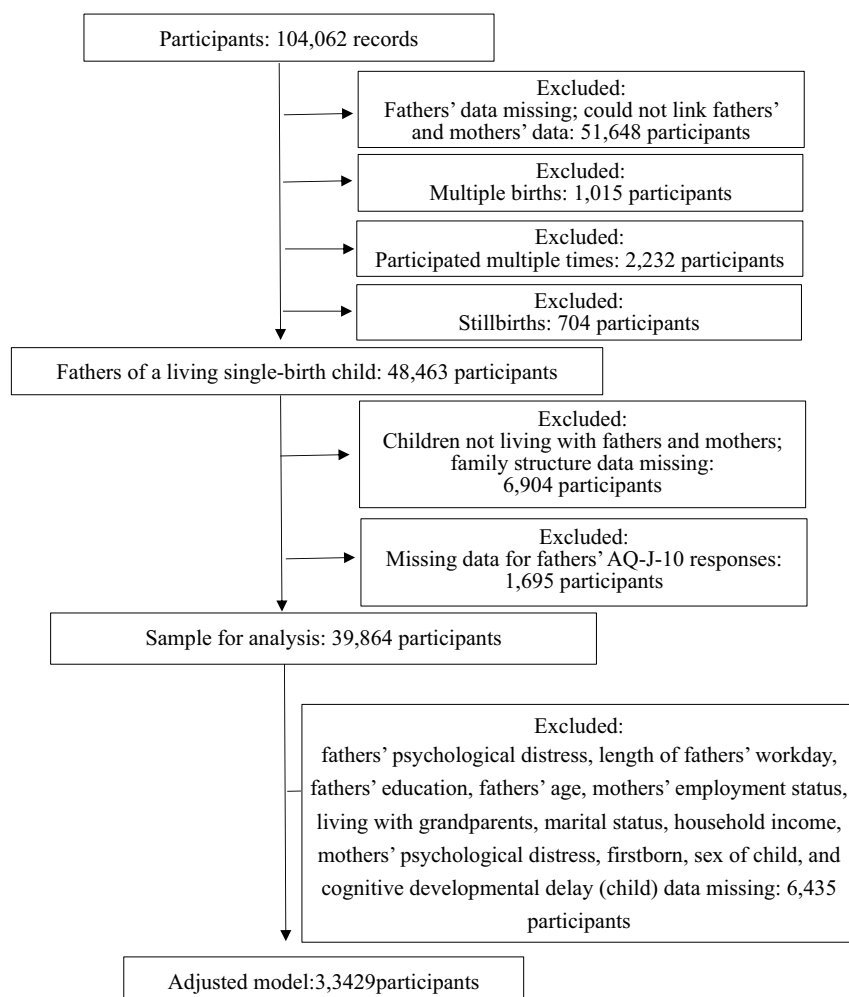


Figure 1. Flowchart of Participant Selection Process.

Measurement of autism traits

The AQ was originally developed by Baron-Cohen and his colleagues³⁶ to screen for ASDs in adults. The AQ10 Japanese version (AQ-J-10) uses 10 questions from the original AQ to screen for high-functioning pervasive developmental disorder in Japanese adults³⁶. We measured the autism traits of fathers using the AQ-J-10³⁷. AQ-J-10 was answered by fathers.

Participants rated each of the 10 questions on a 4-point Likert scale with the following options: *definitely agree*, *slightly agree*, *slightly disagree*, and *definitely disagree*. Agree responses (*definitely* or *slightly*) were given a score of 1; disagree responses (*definitely* or *slightly*) were given a score of 0. For reversed items, the scores were reversed: *slightly disagree* and *definitely disagree* were scored as 1; *definitely agree* and *slightly agree* were scored as 0. The cutoff value for the AQ-J-10 is 6/7 and the diagnostic accuracy is 88%³⁶. The AQ-J-10 comprises four subscales measuring social skills, communication, imagination, and attention-switching. The social skills items are “I prefer to do things with others rather than on my own” (reverse content), “I find it easy to work out what someone is thinking or feeling just by looking at their face” (reverse content), and “I find it difficult to work out people’s intentions.” The communication items are “Other people frequently tell me that what I’ve said is impolite, even though I think it is polite” and “I am often the last to understand the point of a joke.” The imagination items are “When I’m reading a story, I find it difficult to work out the character’s intentions,” “I would rather go to the theater than to a museum” (reverse content), “I like to collect information about categories of things (e.g., types of cars, birds, trains, plants)” and “I find it difficult to imagine what it would be like to be someone else.” The attention-switching items are “I tend to have very strong interests, which I get upset about if I can’t pursue”^{37,38}.

Measurement of paternal parenting behavior

Paternal parenting behavior was evaluated when children were 2 years old using a questionnaire completed by mothers or caregivers, who were asked to rate the frequency with which fathers performed five different childcare behaviors: “Father’s frequency of preparing meals for the child and helping her or him eat”; “Father’s frequency of changing the child’s diapers and cleaning up the waste”; “Father’s frequency of taking a bath with the child”; “Father’s frequency of helping the child change clothes”; and “Father’s frequency of playing with the child.” Responses of *always* or *sometimes* were given a dummy variable value of 0 and counted as a *yes*, and responses of *seldom* or *not at all* were given a dummy variable value of 1 and counted as a *no*.

Covariates

Based on previous studies about related factors about the father’s parenting behavior, we selected the covariates. Furthermore, it should be noted that autism and psychosis tend to co-occur³⁹, that autism has been suggested to have genetic factors⁴⁰, and that children may have developmental issues. Therefore we selected the following items as covariates: for fathers, psychological distress^{2,12} (Kessler Screening Scale for Psychological Distress [K6] score of < 13 or ≥ 13)⁴¹, daily working hours^{10,42} (≤ 9 h or > 9 h), education⁴² (university or not), age^{10,11} (< 16 years or ≥ 16 years); for mothers, employment status^{7,10} (employed/not employed), psychological distress^{43,44} (K6 score of < 13 or ≥ 13)³⁸; for children, birth order⁴⁵ (1st born or ≥ 2nd born), sex^{9,10} (male/female), cognitive developmental delay⁴⁶ (yes/no); and for socioeconomic factors, marital status⁴⁷ (married or not married), household income⁴¹ (< 2 million yen or ≥ 2 million yen; 1 million yen = approximately 6500 US dollars), and living with grandparents^{7,8} (no or yes). There was no multicollinearity between these factors (VIF range is 1.000–1.032).

Statistical analysis

Participants status was summarized by descriptive statistics. To investigate the difference between fathers with autism traits and without autism traits, we performed Chi-square test. To calculate crude ORs, we performed a univariate logistic regression analysis using paternal parenting behaviors as objective variables and fathers’ autism traits as the explanatory variable. To calculate adjusted ORs, we then performed a multivariate logistic regression analysis using the following model: Adjusted for fathers’ psychological distress, length of fathers’ workday, fathers’ education, and fathers’ age, mothers’ working status, living with grandparents, marital status, and household income, mothers’ psychological distress, firstborn, sex of child, and presence of cognitive developmental delay. To analyze the autism traits, we summed the scores on each AQ-J-10 subscale. We defined a score of 0 as the reference category for each subscale, generated the dummy variables, and calculated the ORs of each score. IBM SPSS Statistics 27 (IBM Corp., Armonk, NY, USA) was used for the analysis, with the significance level set at $p < 0.05$.

Ethical declarations

The study was conducted according to the principles of the Declaration of Helsinki. The JECS protocol was reviewed and approved by the Ministry of the Environment’s Institutional Review Board for Epidemiological Studies and the ethics committees of all participating institutions. Written informed consent was obtained from all study participants.

Data availability

Data are unsuitable for public deposition due to ethical restrictions and the legal framework of Japan. It is prohibited by the Act on the Protection of Personal Information (Act No. 57 of 30 May 2003, amendment on 9 September 2015) to publicly deposit data containing personal information. Ethical Guidelines for Medical and Health Research Involving Human Subjects enforced by the Japan Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Health, Labour and Welfare also restricts the open sharing of epidemiologic data. All inquiries about access to data should be sent to jeecs-en@nies.go.jp. The person responsible for handling inquiries sent to this e-mail address is Dr Shoji F. Nakayama, JECS Programme Office, National Institute for Environmental Studies.

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Author contributions

AS, TM, and the JECS Group were involved in the study design and data interpretation. AS and TM were involved in the data analysis, wrote the manuscript, and created the figures. YK and the JECS Group were involved in data collection. All authors reviewed the manuscript, and approved the final report.

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Competing interests

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Additional information

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