

Association between cheese intake in children at age 1 year and child neurodevelopment at 3 years: The Japan Environment and Children's Study

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Abstract

Background

Active cheese consumption has been reported to prevent and improve cognitive decline in older people. However, no studies have examined the association between cheese and neurodevelopment in infants and young children, especially in large populations. The development of brain function is particularly pronounced during childhood, with the presence or absence of developmental delays becoming clear at approximately 3 years of age. Therefore, the purpose of this study was to determine the association between the frequency of cheese intake at 1 year of age and neurodevelopment at 3 years of age.

Methods

This birth cohort study used data from a nationwide, government-funded study called the Japan Environment and Children's Study (JECS), covering 70,316 mother–child pairs. Children's cheese intake was categorized into three groups based on mothers' responses: < 1 time/week, 1–2 times/week, or ≥ 3 times/week. Children's neurodevelopment was evaluated using the Ages and Stages Questionnaires-3 across five domains: communication, gross motor, fine motor, problem-solving, and personal-social.

Results

In all five Ages and Stages Questionnaires-3 domains, cheese consumption > 1 time/week at age 1 year significantly reduced the risk of neurodevelopmental delay at age 3 years, compared to consumption < 1 time/week.

Conclusions

Active consumption of cheese at age 1 year is associated with a reduced risk of neurodevelopmental delay at age 3 years.

Background

Recent studies have reported that the active consumption of cheese has many positive effects on our health, including prevention of metabolic syndrome [1], decreased risk of sleep deprivation [2], and improved fluid intelligence, which is the ability to memorize, calculate, and intuit [3]. For example, Klindinst et al. (2020) surveyed 46- to 77-year-old individuals and reported that those who responded that they consumed cheese daily on a food frequency questionnaire showed improved Fluid Intelligence Test scores [3]. In addition, Kim et al. (2023) measured the association between cheese intake and Mini-Mental State Examination (MMSE) scores in 1503 adults aged 65 years and older. The results showed a negative association between cheese intake and lower cognitive function, suggesting that active cheese consumption may help to prevent various symptoms associated with age-related cognitive decline [4]. Accordingly, higher cheese consumption is expected to lead to improvements in many areas of cognitive function in adults. However, the human studies have been insufficient, with few studies focusing on large populations or on children.

The diet of the mother during pregnancy is one of the most important factors with a long-term impact on the development and health of the unborn child. For example, the intake of foods containing probiotics, fermented foods,

and seafood is attracting attention due to their relationship with the health of mothers and fetuses [5, 6]. Specifically, it has been reported that children born to mothers who actively consume cheese during pregnancy are less likely to suffer from sleep deprivation at the age of 3 years [5, 6]. Similarly, the active consumption of seafood during pregnancy is linked to a reduced risk of delayed neurodevelopment in children at the ages of 6 months, 1 year, and 3 years [7].

Brain development begins in the fetal period and continues throughout adulthood, with the most pronounced development occurring during childhood [8]. On the other hand, congenital developmental delay becomes noticeable around the age of 3 years [9]. Generally, by this age, children are able to understand the meaning of words and express their intentions [10], and their ability to determine their own behavior is nearing completion [10]. In Japan, mental developmental tests have been introduced for testing in early childhood [11], and the early detection and follow-up of developmental delays is considered important [12]. In particular, 3–4 years of age is expected to be an important developmental stage, as this is the time when social activities increase before compulsory education, such as kindergarten enrollment. Therefore, the purpose of the present study was to clarify the relationship between the frequency of cheese intake at the age of 1 year in children and the children's neurology at the age of 3 years.

Methods

Study population

The Japan Environment and Children's Study (JECS) protocol has been extensively detailed elsewhere [13]. The JECS, a government-funded nationwide birth cohort study, explores the effect of environmental factors on child health and development. For the study, 15 Regional Centres in Japan enrolled women in the first trimester of pregnancy from January 2011 to March 2014. Follow-up consultations were held during the second or third trimester, at childbirth, and 1 month after delivery. Follow-ups at 12 and 36 months postpartum were carried out via mail.

The present study is based on the jecs-qa-20210401 dataset, which was released in April 2021. The full dataset comprises 103,057 pregnancies, but we excluded 5647 records because of multiple participations, 948 records because of multiple births, and 3521 records because of miscarriages/stillbirths (Figure 1). We also excluded 10,031 children due to no response or missing data on cheese intake and 12,594 mothers due to no response or missing data on the ASQ-3 (Ages and Stages Questionnaires®, Third Edition) or pre-pregnancy body mass index (BMI). This left data on 70,316 mother–child pairs for analysis.

Ethics approval and consent to participate

The JECS protocol was reviewed and approved by the Ministry of the Environment's Institutional Review Board on Epidemiological Studies (authorization number: 100910001) and the Ethics Committees of all participating institutions. The JECS is conducted in accordance with the Helsinki Declaration and other national regulations, and written informed consent was obtained from the all participants. This specific study was approved by the Ethics Committee of the University of Toyama (R2018032).

Data assessment

Exposure

To assess the frequency of cheese intake the following question was included in a self-administered questionnaire that mothers completed 1 year after delivery: "How many times a week does your child have cheese?". The response options were < 1 time/week, 1–2 days/week, 3–4 days/week, 5–6 days/week, 1 time/day, 2 times/day, and ≥ 3

times/day. Because few children consumed cheese more than 3 times a week, we classified the children into the same three groups as in previous studies: < 1 time/week, 1–2 times/week, or ≥ 3 times/week [14].

Outcome

The validity of the parent-completed ASQ-3 screening tool for identifying children with developmental delays has been established in epidemiological research [15]. The Japanese version of the ASQ-3 has also been validated and used in several studies [7, 16]. The ASQ-3 evaluates a child’s progress in communication (language skills), gross motor skills (arm, body, and leg movements), fine motor skills (hand and finger movements), problem-solving abilities, and personal-social skills (self-help skills and social play). Individuals scoring on or below the cut-off values are categorized as screen-positives for each area. Taking early delivery into account, if a parent’s completion date was not within 3 years ± 1 month (from 35 months 0 days to 36 months 30 days) from the estimated delivery date, the data were treated as missing values in accordance with the scoring guidelines.

Covariates

The covariates adjusted for were maternal age (< 25, 25–<30, 30–<35, or ≥ 35 years), BMI (< 18.5, 18.5–<25, or ≥ 25), number of previous deliveries (multiparous or nulliparous), parents’ educational background (≤ 12, >12–≤16, >16 years), annual household income (< 4 million JPY, 4–6 million JPY, or ≥ 6 million JPY), folic acid intake (≤ 165, 166–228, 229–312, or ≥ 313 µg), antimicrobial use (no or yes), cesarean section (no or yes), child sex (male or female), birth weight (g), gestational age at birth (weeks), major congenital anomaly (no or yes), alcohol status 1 month after delivery (never, former, current), smoking status 1 month after delivery (never, quit, current), marriage status 6 months after delivery (married, unmarried), employment status 1 year after delivery (no or yes), and breastfeeding status 1 year after delivery (no or yes). These variables were categorized according to standard medical practice or common practice in Japan [17, 18] and as shown in Table 1.

Statistical analyses

We calculated both unadjusted and adjusted odds ratios (ORs) with 95% confidence intervals (95% CIs). ORs and 95% CIs were calculated using logistic regression analysis with cheese as the lowest tertile criterion. Adjusted ORs were calculated using the covariates described in the previous section, and crude ORs were calculated without these covariates.

Results

Due to incomplete responses to the questionnaire, the number of respondents included in the analysis decreased from 92,941 to 70,316. Those who were excluded from the analysis were characterized as cigarette smokers, multiparous, and having fewer years of education and a lower annual income. Table 1 shows the maternal or child characteristics according to the tertile for child’s cheese intake. Participants whose children had higher cheese intake were more likely to be older, to be primiparous, to have more years of education, to have a higher household income, to have higher folic acid intake, and to be unemployed.

Table 1. Characteristics of participants according to child’s frequency of cheese intake at 1 year of age

		Frequency of cheese intake					
		None		1–2 times/week		3 times or more/week	
		n	(%)	n	(%)		(%)
Before pregnancy							
Body mass index, kg/m ²	<18.5	5,407	(16.3)	4,547	(16.3)	1,524	(16.6)
	18.5–<25	24,499	(73.9)	20,663	(73.8)	6,893	(75.2)
	≥25	3,260	(9.8)	2,776	(9.9)	747	(8.2)
During pregnancy							
Age, y	<25	2,932	(8.8)	2,458	(8.8)	646	(7.1)
	25–<30	9,160	(27.6)	7,907	(28.3)	2,498	(27.3)
	30–<35	12,011	(36.2)	10,038	(35.9)	3,219	(35.1)
	≥35	8,886	(26.8)	7,450	(26.6)	2,761	(30.1)
	Missing	177	(0.5)	133	(0.5)	40	(0.4)
Years of education, y	≤12	11,078	(33.4)	9,467	(33.8)	2,551	(27.8)
	>12–≤16	14,132	(42.6)	11,940	(42.7)	4,054	(44.2)
	>16	7,641	(23.0)	6,321	(22.6)	2,475	(27.0)
	Missing	315	(1.0)	258	(0.9)	84	(0.9)
Years of education of partner, y	≤12	13,848	(41.8)	11,496	(41.1)	3,286	(35.9)
	>12–≤16	7,446	(22.5)	6,423	(23.0)	2,117	(23.1)
	>16	11,393	(34.4)	9,655	(34.5)	3,635	(39.7)
	Missing	479	(1.4)	412	(1.5)	126	(1.4)
Annual household income, million JPY	<4	12,220	(36.8)	9,908	(35.4)	3,014	(32.9)
	4–<6	10,270	(31.0)	8,861	(31.7)	2,970	(32.4)
	≥6	8,288	(25.0)	7,389	(26.4)	2,625	(28.6)
	Missing	2,388	(7.2)	1,828	(6.5)	555	(6.1)
Folic acid intake, µg	≤165	8,768	(26.4)	6,548	(23.4)	1,571	(17.1)
	166–228	8,375	(25.3)	7,005	(25.0)	2,129	(23.2)
	229–312	8,185	(24.7)	7,216	(25.8)	2,540	(27.7)
	≥313	7,658	(23.1)	7,083	(25.3)	2,884	(31.5)
	Missing	180	(0.5)	134	(0.5)	40	(0.4)
Antimicrobial use	No	29,345	(88.5)	24,712	(88.3)	8,103	(88.4)
	Yes	3,492	(10.5)	3,020	(10.8)	965	(10.5)

	Missing	329	(1.0)	254	(0.9)	96	(1.1)
Birth characteristics							
Child's sex	Male	17,046	(51.4)	14,350	(51.3)	4,682	(51.1)
	Female	16,120	(48.6)	13,636	(48.7)	4,482	(48.9)
Birth weight, g	≥2,500	30,370	(91.6)	25,705	(91.9)	8,455	(92.3)
	<2,500	2,718	(8.2)	2,211	(7.9)	681	(7.4)
	Missing	78	(0.2)	70	(0.3)	28	(0.3)
Gestational age, weeks	<37	1,620	(4.9)	1,183	(4.2)	359	(3.9)
	≥37	31,485	(94.9)	26,753	(95.6)	8,781	(95.8)
	Missing	61	(0.2)	50	(0.2)	24	(0.3)
Major congenital anomaly	No	32,392	(97.7)	27,387	(97.9)	8,963	(97.8)
	Yes	774	(2.3)	599	(2.1)	201	(2.2)
Parity	Primiparous	13,818	(41.7)	12,127	(43.3)	4,527	(49.4)
	Multiparous	18,520	(55.8)	15,183	(54.3)	4,350	(47.5)
	Missing	828	(2.5)	676	(2.4)	287	(3.1)
Cesarean section	No	26,827	(80.9)	22,730	(81.2)	7,459	(81.4)
	Yes	6,202	(18.7)	5,132	(18.3)	1,657	(18.1)
	Missing	137	(0.4)	124	(0.4)	48	(0.5)
Postpartum							
Alcohol intake at 1 month	Never	30,566	(92.2)	25,367	(90.6)	8,351	(91.1)
	Former	1,281	(3.9)	1,292	(4.6)	440	(4.8)
	Current	1,099	(3.3)	1,168	(4.2)	308	(3.4)
	Missing	220	(0.7)	159	(0.6)	65	(0.7)
Smoking status at 1 month	Never	20,543	(61.9)	16,536	(59.1)	5,704	(62.2)
	Quit	11,386	(34.3)	10,281	(36.7)	3,202	(34.9)
	Current	979	(3.0)	1,006	(3.6)	197	(2.2)
	Missing	258	(0.8)	163	(0.6)	61	(0.7)
Marital status at 6 months	Married	32,200	(97.1)	27,134	(97.0)	8,907	(97.2)
	Unmarried	514	(1.6)	466	(1.7)	130	(1.4)
	Missing	452	(1.4)	386	(1.4)	127	(1.4)
Employed status at 1 year	No	17,307	(52.2)	14,163	(50.6)	5,167	(56.4)
	Yes	15,434	(46.5)	13,440	(48.0)	3,866	(42.2)
	Missing	425	(1.3)	383	(1.4)	131	(1.4)

Breastfeeding at 1 year	No	12,351	(37.2)	10,990	(39.3)	3,485	(38.0)
	Yes	20,648	(62.3)	16,817	(60.1)	5,632	(61.5)
	Missing	167	(0.5)	179	(0.6)	47	(0.5)

--- Insert Table 1 near here. ---

Table 2 shows the multivariable ORs (with 95% CIs) for the scoring of each psychomotor development domain at age 3 years according to the tertile of cheese intake at age 1 year (n = 70,316). The results showed that, in all five ASQ-3 domains, cheese consumption > 1 time/week at age 1 year significantly reduced the risk of neurodevelopmental delay at age 3, compared to consumption < 1 time/week. Adjusted ORs for 1–2 times/week or ≥ 3 times/week for children who consumed cheese < 1 time/week were 0.74 and 0.69 for communication (95% CI, 0.68–0.81 and 0.61–0.79). Similarly, the adjusted ORs were 0.73 and 0.71 (95% CI, 0.67–0.79 and 0.63–0.79) for gross motor, 0.79 and 0.74 (95% CI, 0.75–0.84 and 0.67–0.81) for fine motor, 0.74 and 0.73 (95% CI, 0.70–0.79 and 0.67–0.80) for problem-solving, and 0.72 and 0.68 (95% CI, 0.66–0.79 and 0.59–0.78) for personal-social.

Table 2. Cases, prevalence, and crude and adjusted odds ratios (95% confidence intervals) for developmental delay at 3 years of age in each area assessed using the ASQ-3 according to frequency of cheese intake at 1 year of age in children

		Frequency of cheese intake			<i>p</i> for linear trend
		None	1–2 times/week	3 times or more/week	
		(n = 33,166)	(n = 27,986)	(n = 9,164)	
Communication	Case, n	1,590	995	307	
	Prevalence, %	4.79	3.56	3.35	
	Crude odds ratio	1.00 (Ref.)	0.73 (0.68–0.79)	0.69 (0.61–0.78)	<0.001
	Adjusted odds ratio	1.00 (Ref.)	0.74 (0.68–0.81)	0.69 (0.61–0.79)	<0.001
Gross motor	Case, n	1,801	1,097	367	
	Prevalence, %	5.43	3.92	4.00	
	Crude odds ratio	1.00 (Ref.)	0.71 (0.66–0.77)	0.73 (0.65–0.82)	<0.001
	Adjusted odds ratio	1.00 (Ref.)	0.73 (0.67–0.79)	0.71 (0.63–0.79)	<0.001
Fine motor	Case, n	2,844	1,937	591	
	Prevalence, %	8.58	6.92	6.45	
	Crude odds ratio	1.00 (Ref.)	0.79 (0.75–0.84)	0.74 (0.67–0.81)	<0.001
	Adjusted odds ratio	1.00 (Ref.)	0.79 (0.75–0.84)	0.74 (0.67–0.81)	<0.001
Problem-solving	Case, n	2,876	1,818	591	
	Prevalence, %	8.67	6.50	6.45	
	Crude odds ratio	1.00 (Ref.)	0.73 (0.69–0.78)	0.73 (0.66–0.80)	<0.001
	Adjusted odds ratio	1.00 (Ref.)	0.74 (0.70–0.79)	0.73 (0.67–0.80)	<0.001
Personal-social	Case, n	1,345	814	259	
	Prevalence, %	4.06	2.91	2.83	
	Crude odds ratio	1.00 (Ref.)	0.71 (0.65–0.77)	0.69 (0.60–0.79)	<0.001
	Adjusted odds ratio	1.00 (Ref.)	0.72 (0.66–0.79)	0.68 (0.59–0.78)	<0.001

--- Insert Table 2 near here. ---

Discussion

The current study examined the association between the frequency of cheese consumption at age 1 year and neuropsychiatric development—communication, gross motor, fine motor, problem-solving, and personal-social—at age 3 years in 70,316 mother–child pairs. The results showed that children who consumed cheese at least once a week were more likely to exhibit a reduced risk of developmental delay at age 3 years in all five domains.

Active cheese consumption can help to improve age-related cognitive decline [3, 4, 19] and animal experiments are revealing the mechanisms [20, 21]. For example, a study of elderly women with mild cognitive impairment showed that eating 30 g of Camembert cheese per day for 3 months had beneficial effects on brain-derived neurotrophic factor (BDNF) levels, which are associated with cognitive decline [22]. Milk-derived peptides that are produced during the fermentation of cheese are also expected to prevent or ameliorate cognitive decline [23]. Kita et al. (2019) conducted a

12-week double-blind study using β -lactolin (β -lactopeptide of glycine-threonine-tryptophan-tyrosine), a milk-derived peptide. The results showed that, among healthy adults aged 50–75 years who had impaired brain functions such as memory loss, the β -lactopeptide-treated group reported higher scores on the Stroop task and verbal fluency task [19].

Animal experiments provide further insights into the mechanisms by which cheese and its derivatives may influence neurological health. The gut-brain axis is known to play a critical role in regulating cognitive functions and mood [24, 25]. For instance, studies have demonstrated that milk-derived peptides and fermented dairy products can modulate gut microbiota composition, which in turn influences the gut-brain axis [26, 27]. Moreover, specific peptides found in cheese have been shown to interact with NMDA receptors in the brain, which are critical for synaptic plasticity and memory formation [28]. In rodent models, supplementation with fermented dairy products led to increased expression of neurotrophic factors such as BDNF and reduced neuroinflammation markers [28]. These findings suggest a potential link between the bioactive compounds in cheese and enhanced cognitive resilience.

The content of the child's own diet is important for the child's good health and good development, in addition to the mother's diet during pregnancy [5-7]. Cheese is rich in calcium, protein, fat, vitamins, and other nutrients and has been reported to be associated not only with recovery of cognitive function [3, 19], especially in older people, but also with reduced risk of acute myocardial infarction [29], prevention of osteoporosis [30], and recovery from fatigue [31]. For example, Zheng et al. (2015) categorized 15 young males into three groups: a diet high in milk, a diet high in cheese with equal amounts of dairy calcium, and a control diet containing butter but no other dairy products. The participants followed these diets for 14 days. The results showed that cheese consumption significantly reduced urinary citric acid, creatine, and creatinine concentrations compared to cow's milk. As background, it has been suggested that microbial and lipid metabolism may be involved in the effects of dairy products on blood cholesterol levels [1]. Delays in a child's neurological development become noticeable around the age of 3 [8]. As a child's brain continues to develop from the time they are conceived until after they are born, the impact of what the child eats themselves, in addition to the mother's diet during pregnancy, is considered important. Active cheese consumption may help to prevent various diseases and improve health.

This study has several strengths. The first is the sample size. The study included more than 70,000 children and covered a wide geographical area, spanning 15 Regional Centres, and is thus considered reflective of Japan as a whole. Second, the study focused on widely consumed foods. Fermented dairy products, such as Camembert cheese, are familiar foods and are therefore considered safe and easy to consume as part of a daily diet. However, there are also several limitations to this study. First, the frequency of children's cheese consumption and reported neuropsychiatric development depended on mothers' responses. Second, we were not able to identify the type of cheese. Finally, there may be factors that are not fully adjusted for in the covariates. In this study, mothers who actively included cheese in their children's diet had a higher final education, higher annual household income, more active folic acid intake, and higher "health consciousness", suggesting that cheese may have a positive effect on health. Although we adjusted for many covariates, it is possible that "health consciousness" remained a hidden factor independent of other factors. Finally, the number of respondents was decreased by more than 20,000, from 92,941 to 70,316 individuals, for various reasons, including incomplete questionnaire responses.

Conclusions

This study examined the association between the frequency of cheese consumption at age 1 year and neuropsychiatric development—communication, gross motor, fine motor, problem-solving, and personal-social—at age 3 years in 70,316 mother–child pairs. Active consumption of cheese at age 1 year is associated with a reduced risk of neurodevelopmental delay at age 3 years.

Declarations

Author contributions

M.I., K.M., and H.I. drafted the paper and analyzed the data. M.I. and H.I. conceived and designed the study. A.T. and the JECS Group critically reviewed the draft and checked the analyses. The JECS Group collected the data and obtained the funding. All authors approved the submission of the manuscript in its current form.

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Data availability

Data are unsuitable for public deposition due to ethical restrictions and legal framework of Japan. It is prohibited by the Act on the Protection of Personal Information (Act No. 57 of 30 May 2003, amended 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 restrict the open sharing of epidemiologic data. All inquiries about access to data should be sent to jecs-en@nies.go.jp. The person responsible for handling enquiries sent to this e-mail address is Dr. Shoji F. Nakayama, JECS Programme Office, National Institute for Environmental Studies.

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Figures

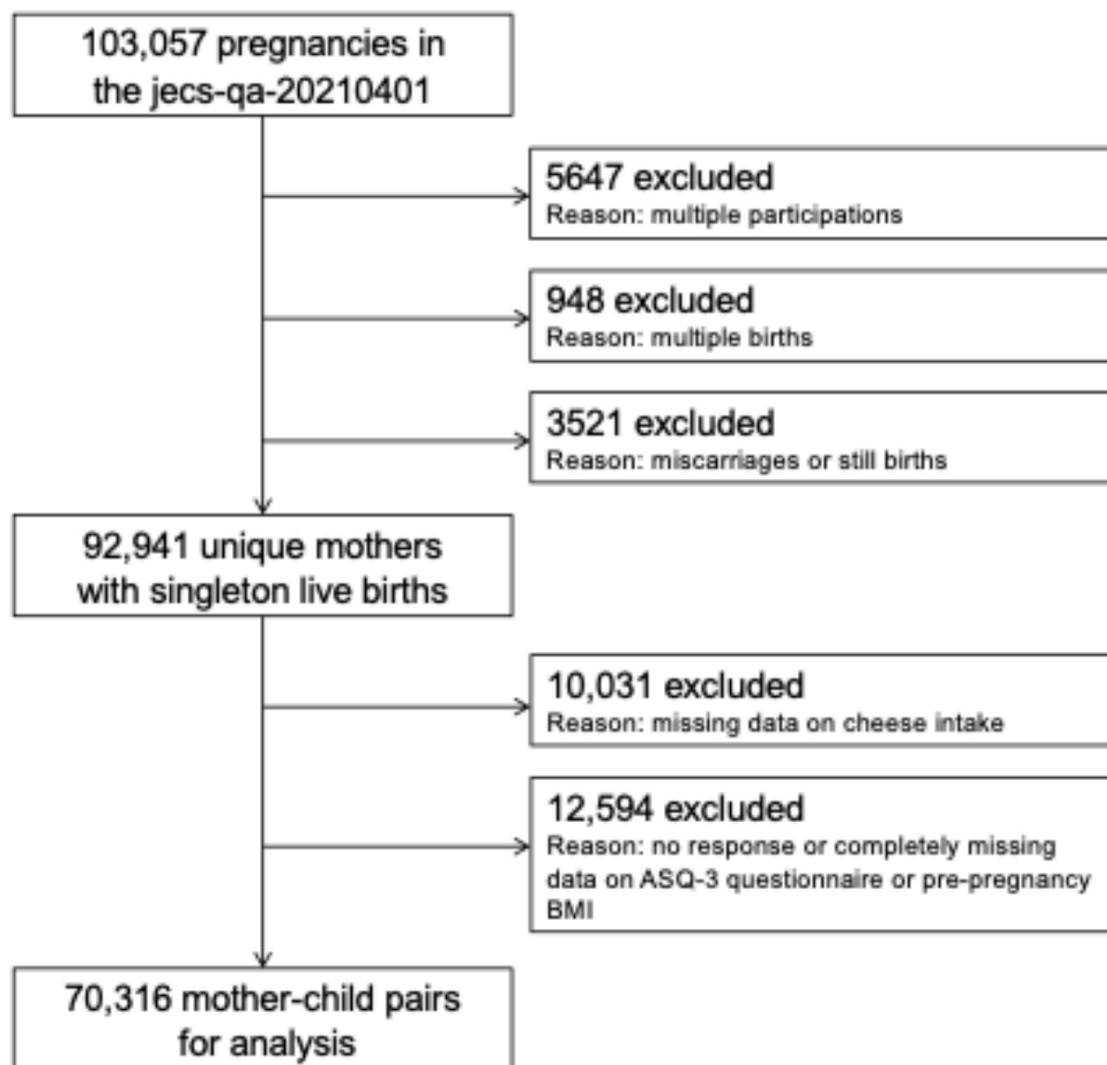


Figure 1

Participant flow chart