

# Determinants of self-paid rotavirus vaccination status in Kanazawa city, Japan, including socioeconomic factors, parents' perception, and children's characteristics

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## Research article

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## Abstract

**Background:** Japan's National Immunization Program does not cover rotavirus vaccine and no government subsidies are available. This study aimed to measure the uptake of and determinants that influenced self-paid rotavirus vaccination, including socioeconomic status and relative poverty.

**Methods:** We conducted a cross-sectional study at health check-ups for all children aged 18 months in Kanazawa city, Japan, between December 2017 and July 2018. Community nurses collected information on self-paid vaccination history, parents' perceptions of and recommendations for rotavirus vaccine, and socioeconomic status, in interviews using a standardized questionnaire. We used multivariable logistic regression to assess vaccine uptake and possible determinants.

**Results:** In total, 1,282 participants were enrolled. The estimated rotavirus vaccine coverage was 69.9%. Rotavirus vaccine uptake was positively correlated with the following: parents' perceptions that rotavirus gastroenteritis is serious and that the rotavirus vaccine is effective; pediatrician's recommendations; information from the city office, articles in magazines and on the Internet; and parents' education level. Lower household income was negatively correlated with rotavirus vaccination. The high price of vaccine, fear about adverse reactions to the vaccine, number of household members and siblings, and children's characteristics were not correlated with rotavirus vaccination. Poverty was negatively correlated with rotavirus vaccination, even after adjustment for other determinants (adjusted odds ratio 0.49, 95% confidence interval: 0.26–0.90).

**Conclusion:** Parents' perceptions, socioeconomic status, and relative poverty are determinants of vaccination. This study suggests that appropriate information about rotavirus vaccine, subsidies for those of lower socioeconomic status, and national recommendations are necessary to achieve higher coverage.

## Background

Rotavirus has strong infectivity. It is difficult to prevent infection by hand washing or hygiene, and it is the leading etiology for diarrhea mortality among children aged 5 years and under<sup>1</sup>; therefore, the World Health Organization (WHO) recommended rotavirus vaccines for inclusion in national immunization programs (NIP) in 2009.<sup>2</sup> Two live oral vaccines are available: a monovalent human rotavirus vaccine (Rotarix<sup>®</sup>, GlaxoSmithKline Biologicals, Rixansart, Belgium)<sup>3</sup> and a pentavalent bovine-human reassortant vaccine (RotaTeq<sup>®</sup>, Merck & Co., Inc., Rahway, NJ, USA).<sup>4</sup> However, rotavirus vaccine is not part of the NIP in many countries, especially in Asia.<sup>5</sup>

In the US, there was a well-known risk for intussusception associated with an earlier rotavirus vaccine (RRV-TV, Rotashield, Wyeth Laboratories), which was approved in 1998 and stopped in 1999.<sup>6</sup> Qualitative research reported that safety concerns and lack of knowledge about rotavirus gastroenteritis (RVGE) were barriers to vaccination when the new rotavirus vaccine (RotaTeq<sup>®</sup>) was approved in 2006.<sup>7</sup> In Canada, rotavirus vaccination is recommended for all infants, although not all provinces have publicly funded programs. A Canadian study reported that increased knowledge and more positive attitudes toward the vaccine among parents increased the coverage of rotavirus vaccine.<sup>8</sup> Few previous studies have evaluated the influence of parents' socioeconomic factors on vaccine uptake, although one study reported lower parental socioeconomic status and parental concerns about vaccine safety were determinants of vaccination.<sup>9</sup>

In Japan, Rotarix<sup>®</sup> and RotaTeq<sup>®</sup> became available on the private market in November 2011 and July 2012, respectively. Although several studies reported the high effectiveness of these vaccines<sup>10, 11</sup> and their impact on reducing hospitalization from RVGE,<sup>12-15</sup> rotavirus vaccine has not yet been included in Japan's NIP. In addition, vaccination uptake in Japan is unclear because Japan has no vaccination registry. A study in Japan reported voluntary vaccination

was positively correlated with annual household income and positive maternal opinion of voluntary vaccination, but negatively correlated with the number of children.<sup>16</sup> However, specific determinants of rotavirus vaccination were not evaluated. As of 2019, rotavirus, mumps, and influenza vaccines are self-paid vaccines for children in Japan. In general, newer vaccines, such as rotavirus vaccine, are more expensive compared with those that have been used for many decades, such as the mumps and influenza vaccines. The price per full course of rotavirus vaccine was estimated at US \$283, which included the doctor's technical fee for administering the vaccine (around US \$33 per shot).<sup>17</sup> In contrast, the first dose of mumps vaccine and first two doses of influenza vaccine were estimated at US \$100–\$150 and US \$70, respectively.<sup>18</sup> The high price of the rotavirus vaccine may be a barrier to vaccination. However, the impact of socioeconomic factors on vaccination uptake has not been evaluated, especially considering household income. Previous studies reported associations between socioeconomic deprivation and vaccine uptake.<sup>19,20</sup> Relative poverty, which is commonly defined as an equivalized household income less than 50% of the national median, is also associated with children's health.<sup>21</sup> According to the Comprehensive Survey of Living Conditions conducted by Japan's Ministry of Health, Labour and Welfare, the relative poverty rate increased from 13.5% in 1991 to 15.7% in 2015.<sup>22</sup> Therefore, it is necessary to evaluate the influence of relative poverty and socioeconomic factors on rotavirus vaccine uptake.

This study aimed to measure the uptake of rotavirus vaccine and determinants that influenced self-paid rotavirus vaccination, including socioeconomic factors, relative poverty, parents' perceptions, and children's characteristics.

## Methods

### Study design and setting

This cross-sectional study was conducted at the 18-month child health check-up in Kanazawa city, Japan, between December 2017 and July 2018. Kanazawa city is the largest city in Japan's Hokuriku region. In 2018, the total population was about 465,000 people and there were around 3,800 births. The Japanese government provides a nationwide continuum of maternal, newborn, and child healthcare, the central component of which is the maternal and child health handbook.<sup>23</sup> When pregnant women register, the local government provides them with a maternal and child health handbook; all services then start and follow a standard schedule. Pregnant women bring the handbook to their maternity clinic of choice for antenatal care, and their doctor records antenatal care results for them and their fetus in the handbook. After giving birth, all data regarding childbirth are recorded in the handbook and mothers receive a birth certificate from the doctor that they take to local government to register the birth. Local governments then provide all registered infants with health information, healthcare advice, and vouchers for child health check-ups and immunizations that are included in the NIP. The main contents of the maternal and child health handbook are described in detail elsewhere.<sup>24</sup> Child health and development check-ups (birth to age 6 years) and immunization status are recorded in the handbook, regardless of whether they are included in the NIP. Local governments provide health check-ups for all children aged 18 months under the Maternal and Child Health Act. Kanazawa city has three welfare and health centers that provide health check-ups for all children aged 18 months. The annual reports of the health and welfare services for children in Kanazawa city indicate that the participation rate in health check-ups for children aged 18 months was around 98.9%.<sup>25</sup>

At the time of the children's health check-up, trained community nurses informed parents about this study and obtained consent for study participation. Then parents were interviewed using a standardized questionnaire that investigated factors that potentially influence rotavirus vaccine uptake. The questionnaire covered parents' perceptions about RVGE and the rotavirus vaccine, recommendations received or information obtained about rotavirus vaccine, and socioeconomic factors (e.g., number of household members and siblings, parental age and education level, mothers'

employment). In addition, data were collected on the child's birth weight, birth order, underlying diseases (food allergies, atopic dermatitis, nasal allergy, asthma, heart disease, and respiratory disease), and daycare service use. Immunization status was ascertained from the maternal and child health handbook, in which all vaccination history must be recorded in Japan as per the Maternal and Child Health Act.

For a significant effect size of 50%, and assuming vaccination uptake of 50%, a percentage of factors associated with vaccination among unvaccinated subjects of 20%, two-sided significance of 0.05, and power of 0.8, this study required 1,124 participants. We obtained written informed consent from all participating parents. The Institutional Review Board associated with Saga University approved this study (No. 30-33).

## Definition and estimation for coverage of rotavirus vaccine

Ensuring that vaccination indicators (e.g., vaccine coverage and uptake) are clearly and consistently defined is important for effective communication of outcomes.<sup>26</sup> According to the US Centers for Disease Control and Prevention, childhood vaccination coverage is defined as the percentage of children in the target population who received a dose of a recommended vaccine.<sup>27</sup> Vaccine uptake is most commonly defined as the absolute number of people who received a specific dose; that is, the numerator in the vaccine coverage calculation. In Japan, rotavirus vaccine is recommended to start at 2 months of age and should be completed before 6 months; therefore, all children in this study had passed the recommended age range. We defined vaccine uptake as the number of children who had received a specific dose of rotavirus vaccine. To estimate rotavirus vaccine coverage, we estimated the target population using the following formula. Estimated total number of target population = number of children (parents) who completed the interview for this study / (answered proportion × proportion of children that participated in Kanazawa city health check-ups, 98.9%). Then, we estimated rotavirus vaccine coverage as rotavirus vaccine coverage (%) = number of children who had received at least one dose of rotavirus vaccine / estimated total number of target population × 100.

## Evaluating equivalent household income and relative poverty rate

We recorded annual household income using five categories: less than ¥2,000,000; ¥2,000,000–3,999,999; ¥4,000,000–5,999,999; ¥6,000,000 or more; and unknown. To estimate the mid-point of an open-ended income category, we used formulas described by Parker et al.<sup>28</sup> These formulas are based on Pareto's law of income distribution, which states that the logarithm of the percentage of units with an income in excess of a certain value is a negatively sloped linear function of the logarithm of that value. According to this theory, the median income for the top-coded category =  $10^{(0.301/v) \cdot (X)}$ , where  $X$  = lower value of the top-coded/open-ended category and  $v = c-d/b-a$ . Where  $a$  = the log of the lower limit of the interval preceding the top-coded/open-ended category;  $b$  = log of the lower limit of the top-coded/open-ended category;  $c$  = the log of the sum of the frequencies in the top-coded category and the category preceding it; and  $d$  = the log of the frequencies in the top-coded category.

We equalized household income using the square root of household scale, which means that household income was divided by the square root of household size.<sup>29</sup> For example, a household of four persons has needs twice as large as one composed of single person. The relative poverty rate was defined as the proportion of children whose equivalent household income was less than 50% of the median of all surveyed children, following the definition of the Organisation for Economic Co-operation and Development (OECD).<sup>30</sup>

## Statistical analysis

We first assessed correlations in parents' perception of rotavirus vaccine and RVGE, socioeconomic factors, and children's characteristics between vaccinated and unvaccinated children. Odds ratios (OR) and 95% confidence intervals (CI) were calculated using a univariate logistic regression model. Next, multiple logistic analysis was performed to investigate correlations between rotavirus vaccination status and potentially influential factors, adjusted for possible confounders. For equivalent income and relative poverty rate analyses, we excluded cases where data for household income and household size were not available, and performed additional analyses using complete data. Median household equivalent income was compared by rotavirus vaccine uptake status using the Mann-Whitney U-test. We evaluated associations between relative poverty and rotavirus vaccine uptake and uptake of other self-paid vaccines using multiple logistic regression analysis with adjustment for possible confounders. All analyses were conducted using SAS version 9.4 (SAS Inc, Cary, NC).

## Results

In total, 1,303 children attended the 18-month health check-up, and data for 1,282 children were gathered (participation rate 98.4%). Of these children, 664 (52.0%) were boys. Table 1 shows parents' perceptions and factors possibly related to rotavirus vaccine uptake. We found that 73% of parents believed RVGE was a serious disease, 66% believed rotavirus vaccine was effective, 33% worried about adverse reactions to the rotavirus vaccine, and most (90%) thought that the rotavirus vaccine was expensive. Parents were more likely to have received a recommendation from a pediatrician to vaccinate their child for rotavirus than from an obstetric doctor. Parents were more likely to get information from city reports than from magazines or the Internet. An analysis of socioeconomic factors showed that about 60% of children lived in households with four or more members and two siblings. More fathers than mothers had a university-level education. About 70% of mothers were employed, and about 40% of families had an annual income lower than \$4,000,000. About 10% of children were born weighing less than 2500 g, about 30% had any primary diseases, and about 60% used daycare services.

Table 1  
 Parents' perceptions and factors potentially related to rotavirus vaccine uptake (n = 1,282)

	Agree (%)	Disagree (%)	Uncertain (%)
<b>Perception</b>			
I believe that RVGE is a serious disease	936 (73.0)	89 (6.9)	257 (20.0)
I believe that the rotavirus vaccination is effective	846 (66.0)	45 (3.5)	391 (30.5)
I worry about adverse reactions to the rotavirus vaccine	455 (35.5)	601 (46.9)	226 (17.6)
I think that the rotavirus vaccine is expensive	1149 (89.6)	122 (9.5)	11 (0.9)
	Yes (%)	No (%)	Missing (%)
<b>Recommendation</b>			
Obstetric doctor recommended the rotavirus vaccine	125 (9.8)	1150 (89.7)	70 (0.5)
Pediatrician recommended the rotavirus vaccine	579 (45.2)	696 (54.3)	7 (0.5)
I read information about rotavirus vaccine in a city report	838 (65.4)	436 (34.0)	8 (0.6)
I read information about rotavirus vaccine in magazines and on the Internet	478 (37.3)	797 (62.2)	7 (0.5)
<b>Socioeconomic status</b>			
Household members $\geq$ 4	765 (59.7)	517 (40.3)	
Siblings $\geq$ 2	712 (55.5)	570 (44.5)	
Father's age < 30 years	214 (16.7)	1033 (80.6)	35 (2.7)
Mother's age < 30 years	290 (22.6)	987 (77.0)	5 (0.4)
Father's education level $\geq$ university	700 (54.6)	582 (45.4)	
Mother's education level $\geq$ university	454 (35.4)	828 (64.6)	
Mother has job	878 (68.5)	404 (31.5)	
Household income below \4,000,000	470 (36.7)	812 (63.3)	
<b>Children's characteristics</b>			
Birth weight < 2500 g	116 (9.0)	1166 (91.0)	
First child	601 (46.7)	675 (52.6)	6 (0.5)
Have primary diseases	360 (28.1)	871 (67.9)	51 (4.0)
Daycare use	714 (55.6)	529 (41.3)	39 (3.0)
RVGE, rotavirus gastroenteritis.			

	Agree (%)	Disagree (%)	Uncertain (%)
Self-paid vaccine uptake			
Rotavirus vaccine	921 (71.8)	347 (27.1)	14 (1.1)
Mumps vaccine	679 (53.0)	587 (45.8)	16 (1.2)
Influenza vaccine	645 (50.3)	629 (49.1)	8 (0.6)
RVGE, rotavirus gastroenteritis.			

Among the 1,282 participating children, 935 had received at least one dose of rotavirus vaccine; however, the vaccination status of 14 children (1.5%) was not recorded in their maternal and child health handbook. Therefore, 1,268 children were included in the analysis to assess determinants influencing rotavirus vaccine uptake. In total, 921 children had received at least one dose of any rotavirus vaccine. Of these children, 565 (61.3%) were vaccinated with Rotarix®; 351 were fully vaccinated and four children had received only one dose. Similarly, of the 356 (38.7%) children that were vaccinated with RotaTeq®, 351 were fully vaccinated and five children had received two doses. The rotavirus vaccine coverage, which was defined as the percentage of children who had received at least one dose of rotavirus vaccine in the target population, was estimated as  $921 / [1282 / (0.984 \times 0.989)] \times 100 = 69.9\%$ .

Table 2 shows determinants influencing rotavirus vaccine uptake. Factors positively correlated with rotavirus vaccine uptake in the crude model were parents' belief that RVGE was serious and that the vaccine was effective, recommendation from a pediatrician, parents' education level, and information about rotavirus vaccine from city reports, magazines, and the Internet. Larger numbers of household members and siblings and lower household income were negatively correlated with vaccine uptake. Factors positively correlated with rotavirus vaccine uptake in the multivariate model were belief that RVGE was serious and vaccination was effective, recommendation from a pediatrician, information about rotavirus vaccine from city reports, and mother's age and education level. However, there was a negative correlation between lower household income and vaccine uptake.

Table 2

Parents' perceptions of rotavirus vaccine, rotavirus gastroenteritis, recommendation for vaccination, socioeconomic status, and children's characteristics by rotavirus vaccine uptake (n = 1,268)

	Vaccinated (n = 921)	Unvaccinated (n = 347)	Crude OR (95% CI)	aOR <sup>a</sup> (95% CI)	aOR <sup>b</sup> (95% CI)
Perception					
I believe that RVGE is a serious disease	731 (80.1%)	184 (53.3%)	3.59 (2.75– 4.69)	N/A	2.74 (1.99– 3.79)
I believe that the rotavirus vaccination is effective	720 (78.2%)	115 (33.3%)	7.27 (5.53– 9.56)	N/A	5.27 (3.87– 7.16)
I worry about adverse reactions to the rotavirus vaccine	333 (36.2%)	116 (33.6%)	1.12 (0.87– 1.46)	N/A	
I think that the rotavirus vaccine is expensive	829 (90.0%)	309 (90.1%)	1.06 (0.70– 1.61)	N/A	
Recommendation					
Obstetric doctor recommended the rotavirus vaccine	99 (10.8%)	25 (7.3%)	1.55 (0.98– 2.45)	N/A	
Pediatrician recommended the rotavirus vaccine	462 (50.2%)	108 (31.3%)	2.23 (1.72– 2.90)	N/A	2.19 (1.59– 3.01)
I read information about rotavirus vaccine in a city report	642 (69.7%)	185 (53.9%)	1.99 (1.55– 2.57)	N/A	1.73 (1.26– 2.37)
I read information about rotavirus vaccine in magazines and on the Internet	382 (41.5%)	90 (26.1%)	2.72 (1.25– 5.92)	N/A	1.29 (0.93– 1.79)
Socioeconomic status					
Household members per 1 member	3.8 [1.0]	4.4 [1.3]	0.41 (0.31– 0.54)	1.08 (0.90– 1.28)	1.08 (0.89– 1.32)
Siblings per 1 member	1.6 [0.7]	2.2 [1.0]	0.36 (0.28– 0.48)	0.58 (0.32– 1.07)	0.54 (0.27– 1.08)

CI, confidence interval; OR, odds ratio; aOR, adjusted odds ratio; RVGE; rotavirus gastroenteritis.

<sup>a</sup> Adjusted for household member, siblings, mother's age, parental educational level, household income, and first child.

<sup>b</sup> Further adjusted for perceptions of RVGE, vaccine effectiveness, pediatrician's recommendation, and information from city reports, magazines, and the Internet.

	Vaccinated (n = 921)	Unvaccinated (n = 347)	Crude OR (95% CI)	aOR <sup>a</sup> (95% CI)	aOR <sup>b</sup> (95% CI)
Father's age per 1 year	35.1 [5.7]	35.0 [6.4]	1.00 (0.98– 1.02)		
Mother's age per 1 year	33.5 [4.9]	32.7 [5.3]	1.03 (1.01– 1.06)	1.06 (1.03– 1.09)	1.06 (1.02– 1.09)
Father's education level ≥ university	541 (58.7%)	151 (43.5%)	1.85 (1.44– 2.37)	1.28 (0.96– 1.71)	1.16 (0.83– 1.60)
Mother's education level ≥ university	377 (40.9%)	72 (20.8%)	2.65 (1.98– 3.54)	2.09 (1.50– 2.92)	2.15 (1.48– 3.14)
Mother's employment	631 (68.5%)	237 (68.3%)	1.01 (0.77– 1.32)		
Household income below \4,000,000	301 (32.7%)	162 (46.7%)	0.55 (0.43– 0.71)	0.62 (0.47– 0.82)	0.72 (0.52– 0.99)
Children's characteristics					
Birth weight < 2500 g	82 (8.9%)	31 (8.9%)	1.00 (0.65– 1.54)		
Birth order per 1 order	1.6 [0.7]	2.1 [0.9]	0.46 (0.40– 0.54)	0.64 (0.35– 1.17)	0.74 (0.37– 1.48)
Having primary diseases	264 (29.9%)	92 (27.6%)	1.12 (0.84– 1.48)		
Daycare use	518 (57.9%)	187(56.0%)	1.08 (0.84– 1.39)		
CI, confidence interval; OR, odds ratio; aOR, adjusted odds ratio; RVGE; rotavirus gastroenteritis.					
<sup>a</sup> Adjusted for household member, siblings, mother's age, parental educational level, household income, and first child.					
<sup>b</sup> Further adjusted for perceptions of RVGE, vaccine effectiveness, pediatrician's recommendation, and information from city reports, magazines, and the Internet.					

Table 3 lists reasons for parents not vaccinating their children for rotavirus. The most common reason was “Rotavirus vaccine is not included in the NIP” (37.3%), followed by “Parents have to pay for uptake” (30.4%). Among 105 parents who said they did not vaccinate because of the price, 44 (41.9%) parents might have vaccinated if the vaccine was free and 52 (49.5%) might have vaccinated if it was less than \5,000 (Additional file 1).

Table 3  
Reasons for not vaccinating children (n = 347)

<b>Rotavirus vaccine is not included national immunization program</b>	<b>129</b>	<b>(37.3%)</b>
Parents have to pay up to \30,000 (approximately US \$300) for uptake	105	(30.4%)
Suspicious about the vaccine's effectiveness	20	(5.8%)
Worry about adverse reactions	15	(4.3%)
Nobody recommended	14	(4.1%)
Missed the opportunity	11	(3.2%)
I don't think that RVGE is serious	11	(3.2%)
I did not know about the rotavirus vaccine	8	(2.3%)
Rotavirus vaccine is not necessary, because our child does not use daycare.	6	(1.7%)
Others	28	(8.1%)
RVGE, rotavirus gastroenteritis.		

Information about household income was available for 991 of the 1,282 participants (Additional file 2). The estimated mid-point income for the upper open-ended category was \9,272,912. After excluding participants with missing data for number of household members and siblings, we used data for 990 participants to calculate household equivalent income and relative poverty rate. The median household equivalent income (using the per square root scale) was \2,886,751. The median household equivalent income was significantly higher among those who were vaccinated (\2,886,571) than those who were unvaccinated (\2,500,00) ( $P < 0.05$ ). The poverty line, which was a half of the median household equivalent income, was estimated as \1,443,375; 65 participants (6.6%) were defined as having relative poverty.

Table 4 shows relative poverty and self-paid vaccine uptake status. Relative poverty status was negatively correlated with vaccine uptake, even after adjusting for parents' education level and other possible influencing factors (adjusted OR: 0.49, 95% CI: 0.26–0.90). Relative poverty was also negatively correlated with mumps vaccine uptake (crude OR: 0.50, 95% CI: 0.30–0.84), although this was not significant after adjusting for parental educational level. Relative poverty was not correlated with influenza vaccine uptake.

Table 4  
Relative poverty status and self-paid vaccine uptake (n = 990)

	Poverty (n = 65)	Not poverty (n = 925)	Crude OR (95% CI)	Model 1 <sup>a</sup> aOR (95% CI)	Model 2 <sup>b</sup> aOR (95% CI)
Rotavirus vaccine					
Unvaccinated	30	225	1.00 (reference)	1.00 (reference)	1.00 (reference)
Vaccinated	35	700	0.38 (0.23–0.62)	0.48 (0.29–0.81)	0.49 (0.26–0.90)
Mumps virus vaccine					
Unvaccinated	40	404	1.00 (reference)	1.00 (reference)	
Vaccinated	25	521	0.50 (0.30–0.84)	0.60 (0.35–1.02)	
Influenza vaccine					
Unvaccinated	39	455	1.00 (reference)	1.00 (reference)	
Vaccinated	26	470	0.67 (0.40–1.13)	0.80 (0.47–1.35)	
OR, odds ratio; aOR, adjusted odds ratio; CI, confidence interval.					
<sup>a</sup> Adjusted for parents' education level.					
<sup>b</sup> Further adjusted for parents' perceptions and recommendation, which were significantly correlated with rotavirus vaccine uptake (Table 1).					

## Discussion

To our knowledge, this was the first study from Asia to assess self-paid rotavirus vaccine uptake and determinants of vaccine uptake. Although the rotavirus vaccine was not included in the NIP and was considered expensive (the price for two doses of Rotarix<sup>®</sup> and three doses of RotaTeq<sup>®</sup> equaled about ¥30,000 or US \$300) in Japan, vaccine coverage in Kanazawa city was estimated as 69.9%. We found a negative association between lower household income and rotavirus vaccine uptake, even after adjusting for possible determinants. In terms of the influence of socioeconomic factors on rotavirus vaccination, ecological studies suggest that the most deprived areas have the lowest coverage and higher rates of hospitalization for acute gastroenteritis caused by rotavirus.<sup>20, 31, 32</sup> However, ecological studies were not able to evaluate socioeconomic factors and vaccine uptake with consideration of the influence of parental perceptions, recommendations received, and other individual-level determinants. Although some cross-sectional studies evaluated the influence of socioeconomic factors and other determinants on rotavirus vaccine uptake,<sup>9, 33, 34</sup> few studies evaluated household income and vaccine uptake.<sup>9, 33</sup> MacDonald et al. conducted a retrospective population-based cohort study of Canadian children born between January 1, 2008 and December 31, 2013, and found that income had a strong influence in urban areas, but not in rural regions where coverage was lower overall.<sup>34</sup> Our results may support the idea posed in that study that household income influences self-paid vaccination uptake when vaccine coverage is increased, although the vaccination coverage in our study was higher than in the Canadian study (1%–4%). Our study showed that the higher the coverage of self-paid vaccine, the stronger the negative correlation with household income. We found that vaccine

coverage for rotavirus was 69.9%, mumps was 52.2%, and influenza was 49.3%, with socioeconomic factor-adjusted ORs for household income and vaccine uptake being 0.63 (Table 2), 0.69, and 0.92 (Additional file 3), respectively.

The pivotal point of this study was that we evaluated relative poverty and self-paid vaccine uptake. Relative poverty is reported to be significantly associated with child health and wellbeing.<sup>21</sup> According to the Comprehensive Survey of Living Conditions conducted by Japan's Ministry of Health, Labour and Welfare, the relative poverty rate of children in 2015 was 13.9%, which was 14th highest among 35 OECD countries.<sup>22</sup> Therefore, evaluations of relative poverty and child health-related issues in Japan are important. To our knowledge, this is the first study to show a significant negative correlation between relative poverty and rotavirus vaccine uptake. In contrast, the uptake of other self-paid vaccines (mumps and influenza) was not correlated with relative poverty. Although the reason for this was not clear, the higher price of rotavirus vaccine than other self-paid vaccines may explain this discrepancy. About one-third of parents of unvaccinated children said they did not get the rotavirus vaccine for their children because of its price. The price of rotavirus vaccine in Japan is much higher than in other high-income countries. The WHO reported the price range for rotavirus vaccine progressively increased with increasing income/procurement level, but there was a considerable range within each segment, particularly for higher income groups.<sup>35</sup> In that report, the average price of one dose was reported as US \$25 in high-income countries. The vaccination price per full course of rotavirus vaccine in Japan was estimated at US \$283, which included the doctor's fee for administering the vaccine (around US \$33 per shot).<sup>17</sup> This was the highest price among the high-income countries studied. Therefore, affordable price setting for such vaccinations is required.

Various factors have been reported as determinants of rotavirus vaccine uptake (other than household income and relative poverty) in industrialized countries.<sup>8, 9, 33, 34, 36, 37</sup> Similar to those reports, we found that rotavirus vaccine uptake was positively correlated with parents' perception of RVGE and vaccine effectiveness, pediatricians' recommendations, information from the city office, and higher maternal age and education level. MacDonald et al. reported that the likelihood of vaccination increased with a decreased number of children in the household.<sup>22</sup> Those authors hypothesized that this may be because of logistical problems in accessing services and decreasing awareness or perceived importance among parents because their older children had not had opportunity for vaccination.<sup>34</sup> However, we did not detect such correlations. This may be because the siblings of children in our study had opportunity to receive rotavirus vaccination, so parents had knowledge about the vaccine.

This study had some limitations. First, we conducted this study in an urban area of Japan and did not include a rural area; therefore, study participants are unlikely to be representative of all Japanese children. The relative poverty rate in this study was 6.6%, which was lower than that for all of Japan (15.7%) in 2016. The low relative poverty rate in this area might have influenced vaccine coverage and determinants. In addition, the convenience of access to vaccination may differ between urban and rural areas. Geographical accessibility is a factor that influences vaccine hesitancy.<sup>38</sup> Further studies in rural areas are needed to clarify this point. Second, there is potential for recall bias for parents' perceptions and receiving recommendation, because those items were measured after vaccination. However, we ascertained vaccination status from the maternal and child health handbook, and questions relating to current socioeconomic factors were answered. Therefore, we consider that the correlation between self-paid vaccine uptake and socioeconomic factors was not affected by recall bias.

## Conclusions

This study found that rotavirus vaccine coverage is high in an urban area in Japan, and that parents' perceptions, recommendations, socioeconomic factors, and relative poverty are associated with vaccine uptake. This study suggests that appropriate information about rotavirus vaccine, subsidies for those with lower socioeconomic status, national recommendations, and affordable vaccinations are necessary to achieve further higher coverage.

## Additional Files

All included in one file

**Additional file 1.** Affordable price among parents who did not vaccinate their children because of the high price

**Additional file 2.** Household income categories and their medians.

**Additional file 3.** Socioeconomic status and characteristics of children by self-paid vaccine uptake.

## Abbreviations

CI = confidence interval; NIP = National Immunization Program; OECD, Organisation for Economic Co-operation and Development; OR = odds ratio; RVGE = rotavirus gastroenteritis; WHO, World Health Organization.

## Declarations

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### Authors' contributions

MH, TK, and YH contributed to the study design. MH and KA managed the data. All authors participated in the analysis and interpretation of the data. MH drafted the manuscript. All authors involved in the critical revision of draft and approved the final manuscript version.

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### Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

### Ethics approval and consent to participate

This study was approved by the Institutional Review Board associated with Saga University (No. 30-33), which conformed to the ethical guidelines of the Helsinki Declaration.

### Consent for publication

Not applicable.

### Competing interests

M.H. received lecture fees from GlaxoSmithKline/JapanVaccine, Merck Sharp and Dohme, and Sanofi Pasteur Inc. All other authors have no conflicts of interest relevant to this article to disclose.

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