Tohoku J. Exp. Med., 2019, **249**, 265-273

Determinants of Vaccination Coverage for the Second Dose of Measles-Rubella Vaccine in Tokyo, Japan

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In Japan, some measles outbreaks were initiated by a tourist from oversea and foreign workers recently. Moreover, rubella outbreak emerged since July 2018 mainly in the South Kanto, and the outbreak is currently ongoing in 2019. It is important to maintain a high measles-rubella combined vaccine (MR) coverage for measles-rubella control. Vaccination coverage for the second dose of MR (MR2) is 90.8% in Tokyo in 2016, which was the third worst among all prefectures in Japan. The purpose of this study was to clarify determinant factors of vaccination coverage for MR2 in Tokyo. Data were obtained for 49 wards and cities in Tokyo in 2016. We regressed vaccination coverage of MR2 on the times of notification by mail, the proportion of households receiving welfare payments, and the proportion of non-Japanese elementary school students. In addition to the simplest specification, five factors were included separately as explanatory variables: the proportion of public health nurses; the ratio of the number of pediatric medical facilities to the number of preschool and elementary school children; the moving-in rate; the proportion of households with a single parent; and the proportion of households with husband and wife both working. Results show that a high proportion of households receiving welfare payments, notification by two or more letters, and moving-in rate or a lower proportion of non-Japanese elementary school students improve coverage. In conclusion, the health authorities can exert efforts to reduce burden of time spent for vaccination and provide sufficient information to improve coverage.

Keywords: information shortage; measles-rubella combined vaccine; notification by mail; time cost; vaccination coverage
Tohoku J. Exp. Med., 2019 December, **249** (4), 265-273.

Introduction

In Japan, the total number of notified measles cases was 11,013 in 2008, when measles became a notifiable disease, however the annual number has been 35-732 cases since 2009. In 2018, a total 279 cases of measles were notified and there were the largest number of cases since the achievement of measles elimination in March 2015. It included an outbreak initiated by a tourist from overseas in Okinawa prefecture, an outbreak initiated by foreign workers in Fukuoka prefecture and outbreaks that spread through medical facilities (National Institute of Infectious Diseases and Tuberculosis and Infectious Diseases Control Division, Ministry of Health, Labour and Welfare, Japan 2019a).

A nationwide rubella epidemic occurred between 2012 and 2013, however the number of cases decreased between 2014 and 2017. Conversely, in 2018, the number of cases increased rapidly from around July and August, mainly in the South Kanto area including Tokyo, and 2,946 cases were notified finally. The outbreak is currently ongoing in 2019 (National Institute of Infectious Diseases and Tuberculosis and Infectious Diseases Control Division, Ministry of Health, Labour and Welfare, Japan 2019b).

It is therefore important to maintain a high measles-rubella combined vaccine (MR) coverage for measles-rubella control. Since 2006, routine immunization in Japan has included two doses of MR. Children receive the first dose of MR (MR1) at one year of age. The second dose of MR (MR2) is administered within 1 year before elementary school entrance at 5-6 years old. Actually, MR2 is recommended as a second opportunity to seroconvert to children who did not do so with the first dose (World Health Organization 2019).

The vaccination coverage of MR1 in Japan is usually very high: greater than 95% (National Institute of Infectious Diseases and Tuberculosis and Infectious Diseases Control Division, Ministry of Health, Labour and Welfare, Japan 2019a). However, the coverage for MR2 is lower. In 2016,

Received September 6, 2019; revised and accepted November 25, 2019. Published online December 17, 2019; doi: 10.1620/tjem.249.265.
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the respective nationwide vaccination coverages for MR1 and MR2 were 97.2% and 93.1%. The target of 95% vaccination coverage was achieved for MR1. However, further efforts must be undertaken to achieve that target for MR2. Japan has no requirement for MR2 vaccination to enter elementary school. However, the guidelines for preventing measles, as established in 2007 by The Ministry of Health, Labour and Welfare (MHLW) ask municipalities to recommend that children without MR1 or MR2 undergo MR vaccination at a health checkup before entrance to elementary school. Greater policy efforts must be undertaken to encourage MR2 vaccination. To do so efficiently, reasons why MR2 vaccination coverage is so low must be identified.

There are 62 municipalities in Tokyo, accounting for about 13.5 million population, or about 10% of all of Japan. Each municipality provides routine immunization services. Children receive MR2 at medical facilities with no cost burden of MR to recipients. In 2016, the respective vaccination coverages for MR1 and MR2 in Tokyo were 98.0% and 90.8%. Tokyo's vaccination coverage for MR2 in 2016 was the third from the lowest among all prefectures in Japan. Such low vaccination coverage might lead to a measles or rubella outbreak in Tokyo. Actually, some outbreaks of measles have occurred sporadically in Tokyo. They were caused initially by cases of people who had contracted it from abroad, even after measles elimination was confirmed by the Measles Elimination Accreditation Committee, the Western Pacific Regional Office, World Health Organization (WHO) in March 2015. In Tokyo, efforts are strengthened through confirmation of vaccine history, including MR2, and recommendations of vaccination for children who did not receive vaccines at a health checkup before entrance to elementary school. Those efforts have been advanced through cooperation among public health authorities and educational authorities.

To date, many factors associated with vaccination coverage have been discussed in the literature: income (Klevens and Luman 2001; Smith et al. 2004; Wu et al. 2008; Sakai et al. 2015; Hagemann et al. 2017), physician density (Smith et al. 2011), caregiver education (Wei et al. 2009), and a recommendation or reminder from a physician or public health authorities (Anderberg et al. 2011; Vannice et al. 2011; Stockwell et al. 2012; Gargano et al. 2013; Busso et al. 2015; Sakai. 2018). We integrated these factors to assess two factors that are putatively associated with vaccination coverage for MR2: time cost, which is defined as burden of time spent for vaccination, and information about MR2. The high time cost and shortage of information are expected to be negative factors hindering vaccination coverage.

No report of the literature describes a study with statistical investigation of factors related to the vaccination coverage of MR2 in Japan. The purpose of this study was to clarify the determinants of vaccination coverage for MR2 in Tokyo using the variables presented above. If some robust association can be made among them, then we recommend better policy to raise MR2 coverage based on the obtained results to eliminate rubella in the near future and to keep elimination status for measles in Japan.

Methods

Subject

Subjects were residents of 23 wards and 26 cities in Tokyo, Japan. The study area covered all urban areas in Tokyo, covering 99.4% of the entire Tokyo population. Rural areas, including isolated islands, were excluded from this study.

Vaccination coverage

Vaccination coverage of MR2 was calculated as the number of children who had been administered MR2 during April 2016-March 2017, divided by the target population. Data of annual MR2 vaccination coverage by local governments in Japan were published by the central government. Vaccination coverage was calculated from the vaccination register.

Determinant factors

1) Time cost

i) Households receiving welfare payments

A household receiving welfare payments is defined as one which has received public assistance. This system has two purposes (The Ministry of Health, Labour and Welfare, Japan 2018): guarantee of a minimum standard of living and promotion of self-reliance. For the former, it provides assistance for those who have difficulty paying for living expenses despite using all their assets including all income and assistance from relatives and earning ability, depending on the level of necessity. For the latter, officers visit their home several times a year according to the status of the recipient household and provide vocational guidance for recipients who can be employed. Therefore, in general, households receiving welfare payments have low income, however they can communicate frequently and easily with public officials.

The proportion of households receiving welfare payments was used as a variable. It was defined as the number of households receiving welfare payments divided by the total number of households in the ward or city.

ii) Households with a single parent

The proportion of households with a single parent was used as a variable. It was defined as the number of households with a single parent divided by the total number of households in the ward or city.

iii) Households with husband and wife both working

The proportion of households with husband and wife both working was used as a variable. It was defined as the number of households with husband and wife both working divided by the total number of households in the ward or city.

iv) Pediatric medical facilities

The ratio of the number of pediatric medical facilities to the number of preschool and elementary school children was used as a variable. It was defined as the number of pediatric medical facilities divided by the total number of preschool children who attend nursery school, kindergarten or kodomoen (a hybrid of nursery school and kindergarten), and elementary school students in the ward or city.

2) Information

i) Notification by mail

Notification by mail for vaccination of MR2 from the ward or city was defined as surface mail messages sent to households in which recipients reside. Sometimes some wards or cities sent additional notifications to parents with children who do not complete the vaccination on time. Other media such as posters, public relations magazines or through radio, TV program, homepages or SNS were not included as notification by mail. Notification from medical facilities was also excluded. Times of notification by mail were variable and were summarized as none, one letter, and two or more letters.

ii) Non-Japanese elementary school students

The proportion of non-Japanese elementary school students was used as a variable. The proportion of non-Japanese elementary school students was defined as the number of non-Japanese elementary school students divided by the total number of elementary school students in the ward or city.

iii) Public health nurses

The proportion of public health nurses was used as a variable. It was defined as the number of public health nurses divided by the total population in the ward or city.

iv) Moving-in rate

The moving-in rate was used as a variable. It was defined as the number of people moving into the ward or city divided by the total population of the ward or city.

3) Data collection

We used 2016 statistical data for each local government published by the Tokyo Metropolitan Government (TMG), population estimates, and household estimates from the 2015 Census. We also used data of the survey conducted of local governments by TMG in Tokyo in 2017 to ascertain how many times the local government sent notification by mail to ask unvaccinated children to receive MR2 during April 2016-March 2017.

Statistical analysis

We regressed vaccination coverage of MR2 on times of notification by mail, the proportion of households receiving welfare payments, and the proportion of non-Japanese elementary school students. Variables for times of notification by mail were set as a dummy variable for once and as a dummy variable for two or more letters, with no notification being the reference. Hereinafter, we designate this specification as specification (1). Specification (1) is a base specification. We also examined addition of the proportion of public health nurses, the ratio of the number of pediatric medical facilities to the number of preschool and elementary school children, the moving-in rate, the proportion of households with a single parent, and the proportion of households with husband and wife both working to specification (1) to check the robustness of the result in specification (1). We designate these specifications as (2)-(6). Specification (2) includes "Proportion of public health nurses" as an explanatory variable in addition to explanatory variables in (1). Also, (3) includes "Ratio of the number of pediatric medical facilities to the number of preschool children and elementary school students". Similarly, (4), (5), and (6) respectively include the "Moving-in rate", "Proportion of households with a single parent", and "Proportion of households with husband and wife both working".

The estimation method was weighted least squares method weighted by the target population in the ward or city. We adopted 5% as the significance level for inference.

Ethics

All data used for this study were published data. For that reason, no ethical review was required for this study.

Results

Table 1 presents summary statistics of variables used for estimation. The average vaccination coverage of MR2 remained at 91.0%; its worst was 82.5%. The average key explanatory variables other than the number of mail notifications were the proportion of households receiving welfare payments (3.2%) and the proportion of non-Japanese elementary school students (1.2%). However, the highest of those figures were, respectively, 7.3% and 4.4%. Fig. 1 depicts the distribution of times of notification by mail. The most frequent times of notification were two letters; it included 24 cities or wards. One ward and one city sent notification messages three times. One city sent notifications four times.

Table 2 presents estimation results by (1)-(6) specifications. The proportions of households receiving welfare payments and of non-Japanese elementary school students were all significant in all specifications. A higher proportion of households receiving welfare payments in a ward or city had higher vaccination coverage in MR2. The estimated coefficients varied from 0.89 in (1) to 1.26 in (4). If the proportion rises by one standard deviation of the proportion of households receiving welfare payments, 0.013, then the vaccination coverage rises by 1.2-1.6 percentage points. However, the higher proportion of non-Japanese elementary school students in a ward or city had lower vaccination coverage in MR2. The estimated coefficients varied from –2.13 in (1) to –2.50 in (4). If the proportion rises by one standard deviation of the proportion of non-Japanese elementary school students, 0.010, then the vaccination coverage declines by 2.1-2.5 percentage points.

Regarding variables of times of notification by mail, only two or more letters was found to be significant among the four specifications. The estimated result indicates that a ward or city giving notification by two or more letters had higher vaccination coverage than a ward or city which sent no notification at all by 1.9-2.4 percentage points. No significant difference was found between one-time notification by mail and no notification.

Among other explanatory variables in (2)-(6), only the moving-in rate was found to be significant. For a moving-in rate that is higher by one standard deviation (0.018), vaccination coverage was higher by 0.9 percentage points. Other variables were not significant: the proportion of public health nurses, the ratio of the number of pediatric medical facilities to the number of preschool children and elementary school students, the proportion of household with

Table 1. Summary statistics.

	Average	Standard deviation
Vaccination coverage of MR2	0.9097	0.0294
Proportion of households receiving welfare payments	0.0325	0.0133
Proportion of non-Japanese elementary school students	0.0122	0.0098
Proportion of public health nurses	0.0002	0.0000
Ratio of the number of pediatric medical facilities to the number of preschool children and elementary school students	0.0018	0.0006
Moving-in rate	0.0596	0.0180
Proportion of households with a single parent	0.0108	0.0033
Proportion of households with husband and wife both working	0.1239	0.0331

MR2 denotes a second dose of measles-rubella combination vaccine administered within 1 year before elementary school entrance: 5-6 years old. The proportion of households receiving welfare payments is defined as the number of households receiving welfare payments divided by the total number of households in the ward or city. The proportion of non-Japanese elementary school students is defined as the number of non-Japanese elementary school students divided by the total number of elementary school students in the ward or city. The proportion of public health nurse is defined as the number of public health nurses divided by the total population in the ward or city. The ratio of the number of pediatric medical facilities to the number of preschool children and elementary school students is defined as the number of pediatric medical facilities divided by the total number of preschool children who attend nursery school, kindergarten or kodomoen, which is a hybrid of nursery school and kindergarten, and elementary school students in the ward or city. The moving-in rate is defined as the number of those moving into the ward or city divided by the total population. The proportion of households with a single parent is defined as the number of households with a single parent divided by the total number of households in the ward or city. The proportion of households with husband and wife both working is defined as the number of households with husband and wife both working divided by the total number of households in the ward or city. The data sample was all wards or cities in Tokyo, Japan in 2016; the number of the sample was 49.

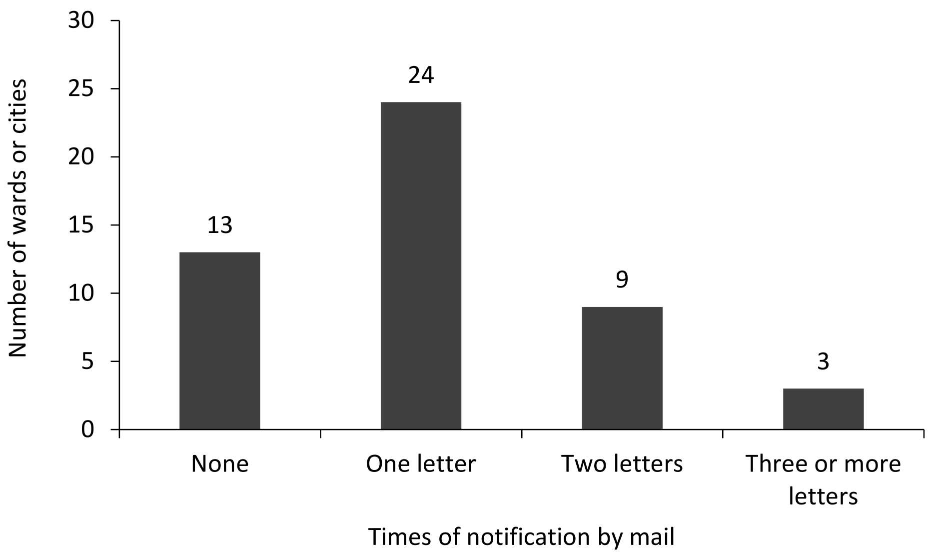

Fig. 1. Distribution of times of notification to unvaccinated people by mail.

The notification was sent to unvaccinated people to administer the second dose of measles-rubella vaccine (MR2) from local government of wards or cities (n = 49) in Tokyo during April 2016-March 2017.

The bars indicate the number of cities or wards which times of notification by mail were none, one letter, two letters or more than three letters and corresponding number were described at the top of bars. "Three or more letters" included one ward and one city with three times and one city with four times. Notification by mail is limited to individual notification by mail from a ward or city to household with age 5-6 children who are eligible for MR 2.

Table 2. Estimation results of vaccination coverage of the second dose of measles-rubella vaccine.

	Estimated coeff.					
Specification	(1)	(2)	(3)	(4)	(5)	(6)
Notification by one letter	0.0119	0.0108	0.0129	0.0132	0.0154	0.0127
Notification by two or more letters	0.0193*	0.0170	0.0200*	0.0178	0.0236*	0.0199*
Proportion of household receiving welfare payments	0.8909*	0.9157*	0.9603*	1.2599*	1.1302*	0.9580*
Proportion of non-Japanese elementary school students	–2.1313*	–2.1817*	–2.3091*	–2.5000*	–2.3020*	–2.2540*
Proportion of public health nurse		110.5277				
Ratio of the number of pediatric medical facilities to the number of preschool children and elementary school students			7.5074			
Moving-in rate				0.5016*		
Proportion of households with a single parent					–2.2800	
Proportion of households with husband and wife both working						–0.0825
Constant	0.8960*	0.8816*	0.8815*	0.8584*	0.9110*	0.9045*
Coefficient of determination	0.4546	0.4697	0.4711	0.5023	0.4969	0.4598

The second dose of measles-rubella combination vaccine is administered within 1 year before elementary school entrance which is 5-6 years old. The proportion of households receiving welfare payments is defined as the number of households receiving welfare payments divided by the total number of households in the ward or city. The proportion of non-Japanese elementary school students is defined as the number of non-Japanese elementary school students divided by the total number of elementary school students in the ward or city. The proportion of public health nurses is defined as the number of public health nurses divided by the total population in the ward or city. The ratio of the number of pediatric medical facilities to the number of preschool children and elementary school students is defined as the number of pediatric medical facilities divided by the total number of preschool children who attend nursery school, kindergarten, or kodomoen, which is a hybrid of nursery school and kindergarten, and elementary school students in the ward or city. The moving-in rate is defined as the number of people moving into the ward or city divided by the total population. The proportion of households with a single parent is defined as the number of households with a single parent divided by the total number of households in the ward or city. The proportion of households with husband and wife both working is defined as the number of households with husband and wife both working divided by the total number of households in the ward or city. The data sample was all wards or cities in Tokyo, Japan in 2016; the number of samples was 49. Specification (1) is base specification. Specification (2) includes "Proportion of public health nurse" as explanatory variable in addition to explanatory variables in (1). (3) includes "Ratio of the number of pediatric medical facilities to the number of preschool children and elementary school students." Similarly, (4), (5) and (6) include "Moving-in rate," "Proportion of households with a single parent" and "Proportion of households with husband and wife both working," respectively.
*indicates significant.

single parent, and the proportion of households with husband and wife both working.

Discussion

We found a significant effect of time cost incurred through households receiving welfare payments and a shortage of information associated with non-Japanese elementary school students, moving-in rate, and partially for notification by two or more letters. The absolute value of the effect for one standard deviation was the highest for non-Japanese elementary school students, followed by welfare households. The moving-in rate was found to have the weakest effect among the three significant continuous variables. The effect of notification by two or more letters compared with no notification at all was comparable to that of changing non-Japanese elementary school students by one standard deviation.

In general, high-income caregivers are burdened by higher time cost when bringing children to medical facilities for vaccination. Therefore, we expect higher vaccination coverage in households receiving welfare payments and lower coverage in households with husband and wife both working. Although caregivers in households with single parents might not have high income, their responsibility for family finances is apparently important: their time cost might be higher than that of caregivers in households with two parents, even given equal incomes. Additionally, if many pediatric medical facilities are available for a given population in a ward or city, then transportation costs and times are expected to be less burdensome: time cost to administer vaccines might therefore be lower. For that reason, vaccination coverage might be expected to be high in such a ward or city.

Regarding information insufficiencies, notification by mail from a ward or city might give some information. However, non-Japanese people living in Tokyo are adversely affected by language barriers, and might not know the MR2 system. Therefore, they might have lower vaccination coverage. A household moving into a ward or city might receive some general guidance about living there, including information about MR2 received from ward or city officers when moving there. Therefore, they might have more information about MR2 than caregivers who have long lived in the ward or city. Additionally, if many public health nurses are available for a population in a ward or city, then they might provide information about MR2 other than notification by mail. Vaccination coverage might be expected to be high in such a ward or city.

Nevertheless, the time cost and shortage of information were not exclusive. For that reason, a variable might have two aspects. For example, we inferred that welfare households were affected strongly by the lower time cost. Furthermore, communication with welfare households and local government officers might be more frequent, as described earlier in comparison with non-welfare households. Consequently, welfare households might have more information related to MR2. We inferred non-Japanese elementary school students as an indicator for shortage of information. However, households with non-Japanese elementary school students might be adversely affected more by lower income than Japanese households. If so, then the time cost for caregivers of non-Japanese elementary school students might be lower. Therefore, vaccination coverage can be expected to be higher. Estimation results suggest that the effect of a shortage of information is much greater than that of time cost. Regarding the moving-in rate, if a household moving into a ward or city has higher income than others, then time cost effect might decrease the vaccination coverage. Estimation results suggest that the effect of less shortage of information is much greater than the time cost effect.

Optimal times of notification are noteworthy. The obtained results demonstrated consistently that notification once by mail has no particular effect. Notification by two or more letters has a greater effect than no notification, however it was not significant in two specifications, (2) and (4) in Table 2. Only three wards and cities sent notification by three or more letters. Therefore, we did not compare two letters with three or more letters.

Many researchers have examined associations between vaccination coverage and income. However, their findings were mixed. Some studies have found positive association (Klevens and Luman 2001; Wu et al. 2008; Sakai et al. 2015). Other researchers found negative association (Smith et al. 2004; Wei et al. 2009; Smith et al. 2011). One report from a study using cross-national panel data and individual panel data in the US described that it was positive for lower income households and then negative in higher income households (Sakai 2018). Generally speaking, income has two effects on demand in economic theory. One is an income effect, which raises demand for normal goods. Even if there were no out-of-pocket expense for vaccination itself, transportation costs might be considerable, especially in economically developing countries. In this sense, income is expected to be positively associated with the vaccination coverage if vaccination is a normal good. Another effect of income is time cost. As described earlier, the time cost is higher if income is high. Therefore, income and vaccination coverage are expected to be negatively associated. From this perspective, our obtained results demonstrating higher vaccination coverage in households receiving welfare payments indicate that time cost matters, even in households receiving welfare payments. Alternatively, lower vaccination coverage in households with non-Japanese elementary school students might reflect a severe shortage of information rather than an income effect or a lower time cost.

Regarding a shortage of information, many studies (Wei et al. 2009; Anderberg et al. 2011; Vannice et al. 2011; Stockwell et al. 2012; Gargano et al. 2013; Busso et al. 2015; Sakai. 2018) have found a significant effect of recommendation from physicians or reminders from public health authorities about vaccination coverage. We also found consistent results for notification by two or more letters, the proportion of non-Japanese elementary school students, and the moving-in rate. A study in Germany found from annual cross-sectional parent surveys that nursery school attendance was positively associated with vaccination coverage and that caregivers' school education was negatively associated (Hagemann et al. 2017). From the perspective of our hypothesis, their findings can be interpreted as follows: attendance at nursery schools might represent information sharing among caregivers and nurse teachers. Therefore, caregivers whose children attend nursery school probably have more information than others. Additionally if nursery school attendance is associated with lower income than others, then those caregivers face lower time cost, which affects vaccination coverage. If caregivers' level of school education attainment is higher, then they might access information easily and therefore face less of a shortage of information. That result implies higher vaccination coverage associated with higher education. However, such was not the case. Probably, higher education is associated with higher income and therefore higher time cost. Actually, the latter effect compensated the former; education was associated negatively with vaccination coverage.

For studies described in reports of the literature, the density of pediatric facilities was presumed to be an important factor affecting vaccination coverage. An earlier study for MR1 in Japan revealed that the pediatrician density increased odds by 1.012 for vaccination coverage of MR1 (95% confidence interval, 1.010-1.015) among 1,700 municipalities in Japan in 2010 (Sakai et al. 2015). However, the present study found no significant result in this regard. To elucidate the differences, three points of difference between the two studies can be explained. First, that earlier study specifically addressed variation in vaccination coverage nationwide. By contrast, we specifically examined variation in Tokyo. Therefore, variation in vaccination coverage or pediatric density was much less in our study than in the earlier one. In other words, the earlier research specifically examined a wider variation. Therefore, they found a significant effect of pediatric density. A second point of difference was the definition of density. We defined it as pediatric facilities per child, however the earlier study defined it as pediatric physicians per child. Large hospitals have many physicians. Therefore, the facility density is apparently better as a measure of accessibility. Thirdly, the most important difference was probably the number of samples. They used 1,700 samples; we used only 49. Actually, if we were to extend the data size by 40 times with the same distribution, then all explanatory variables we examined would be significant with a p value of 0.000.

Based on the obtained results, what policy or actions can be recommended? First, because non-Japanese elementary school students showed a negative effect, some policy to resolve the shortage of information in households with non-Japanese elementary school students appears to be necessary. Nevertheless, announcements in English are done already. Announcements in Chinese, Korean, Spanish, Tagalog, and other languages are expected to be necessary. Moreover, primarily, residents might not understand the system of routine immunization because their respective countries of origin have different programs. Therefore, other approaches must be pursued for households other than notification by mail, including home visitation or some explanation to their community. Secondly, notification by two or more letters was optimal, as described above. Therefore, wards and cities using fewer than two notifications are strongly recommended to send notification with a frequency of two or more letters. Thirdly, to reduce time cost, potential policies might engender change in the ability to receive vaccines even on Sundays or holidays or at night under cooperation with medical associations.

A program was launched by MHLW in March 2019 to raise the MR1 and MR2 vaccination coverage. It required prefectures to evaluate those coverage rates and propose improvement measures to raise them to be higher than 95% in all municipalities under their jurisdiction. Results obtained from the present study are expected to be useful for those propositions and to contribute to raising the vaccination coverage of MR1 and MR2 in all municipalities.

This study has some limitations. The first and the most important point is that this study is a kind of ecological study. The associations presented herein should not be interpreted as causal relations. Reverse causality, which we did not presume, cannot be ruled out. For example, low vaccination coverage might engender higher numbers of notifications sent by mail. To demonstrate clear causality, a trial with random assignment of factors such as income or information must be conducted, however such a study would be impossible or very difficult to conduct. Initially, the best we can do is to accumulate data and obtain some findings. Reverse causality might be resolved by panel data using several years of data from the same wards and cities.

A second limitation is that, because this study was a cross-sectional study, the estimated coefficients do not indicate marginal effects of marginally changed factors from the current situation. Only a ward or city with a higher welfare household proportion, for example, might be inclined to have higher vaccination coverage. In other words, even if the proportion of welfare households rises, then vaccination coverage might not rise by the estimated coefficient. Factors such as the time cost or a shortage of information and municipality cannot be separated as individual fixed effects. We cannot change or affect municipality individual fixed effect by policy. Therefore, we must exclude these effects to predict or estimate policy effects. To address this shortcoming, we need panel data consisting of our data used in several years. Although it cannot be resolved immediately, data accumulation can resolve this difficulty.

A third limitation is that even though the coverage of population under consideration was approximately one-tenth of the national population, we cannot generalize the results for all of Japan. Estimation results might differ among regions.

A fourth point is that even though we identified a significant effect of time cost and a shortage of information, we must be reminded that these two factors were defined or assumed to be related to the observable variables such as households receiving welfare payments or non-Japanese elementary school students as described above. In this sense, the observable variables we used might be understood as proxy variables for time cost or a shortage of information. The present study does not show that these two factors can be measured precisely by the observable variables. It might not be a constructive discussion to assess how proxy variables that we used represent the two factors.

A fifth point is that several epidemiological variables presumably affected the vaccination coverage. The outbreak situations of measles or rubella might be an important factor to determine vaccination coverage. The measles outbreak occurring in 2016 was the smallest after elimination of certification by WHO in March 2015. Similarly, a rubella outbreak occurred in 2012-2013, however the rubella outbreak in 2016 was moderate. However, a rubella outbreak occurred again in 2018 in Japan. The US Centers for Disease Control and Prevention issued a level 2 alert on October 22, 2018 for travelers to recommend that pregnant women not travel to Japan (Matsunaga and Kon 2019). Extension of the study period to include 2018 might affect the vaccination coverage.

A sixth and final point is unrelated to the present study, however is instead related to the system used to estimate MR1 or MR2 vaccine coverage. This information was collected from municipalities and published by MHLW. Therefore, vaccination coverage data used by this study were official. In Japan, the caregivers of children have the primary responsibility of routine immunization for their children. However, municipalities, not prefecture or central governments, have the obligation for administration of immunization policy, including the coverage rate. The denominators of the official coverage rate were defined as the number of targeted children in April 1 of each year. Targeted children for MR2 were children who would be five years old as of April 2. However, the official coverage rate ignores the vaccination status of children who moved into or out of the municipality. Children moving in were not included in the denominator. Vaccinated children moving out were not excluded from the numerator and denominator. For example, if many unvaccinated targeted children move out and none move into an area, the coverage rate might be much less than 100%. Moreover, unvaccinated children moving into an area, being then vaccinated in the municipality, are included in the numerator of the official coverage rate, however are not included in the denominator. Moreover, children who receive MR vaccinations outside of the routine immunization system were ignored. The respective precisions of these estimates of vaccination coverage might be lower for municipalities with active immigration.

In conclusion, we show the effect of time cost and of a shortage of information as described above in the present study. Namely, the higher vaccination coverage was observed for a higher proportion of households receiving welfare payments, notification by two or more letters, and a higher moving-in rate. Results also show that the proportion of non-Japanese elementary school students is negatively associated with vaccination coverage. Although health authorities cannot control the proportion of households receiving welfare payments, the moving-in rate or the proportion of non-Japanese elementary school students directly, they can exert efforts to reduce time cost and provide sufficient information. Particularly, local governments that conduct no notification by mail are strongly recommended to send notification by two or more letters to improve vaccination coverage. We hope that the results reported herein will constitute important evidence at the council for vaccination policy in MHLW.

Acknowledgments

We acknowledge all people working to enhance measles-rubella control at public health centers in Tokyo, Japan.

Conflict of Interest

The authors declare no conflict of interest.

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