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Social-life factors associated with participation in screening and further assessment of colorectal cancer: A nationwide ecological study in Japanese municipalities

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ABSTRACT

The burden of colorectal cancer in developed countries is high, and it is a major public health concern in Japan. Improving the quality of evidence on colorectal cancer screening participation and further assessment participation rates is important to reduce this burden. This study examined the social-life factors that influence colorectal cancer screening programs in Japan, particularly the effects of the proportion of elderly people and social capital, using a municipality-level national database and existing health reports. Data from a national municipality-based study were analyzed to identify social-life factors associated with participation in colorectal cancer screening and further assessment. Administrative data on the Japanese municipal screening programs were drawn from the Report on Regional Public Health Services and Health Promotion Services 2017. Available data used as predictors of interest for all 1719 municipalities as of 2017 were from the national census, statistical reports on the land area by prefecture and municipality, municipal financial surveys, a survey of physicians, dentists and pharmacists, and other databases. The mean rate of participation in colorectal cancer screening was 13.8%, and that of further assessment was 73.6%. Multiple linear regression analyses of the two outcomes showed that the proportion of elderly people was most significantly positively associated with colorectal cancer screening programs ($\beta = 0.51$ for participation, $\beta = 0.13$ for further assessment participation), and the proportion of single-elderly-person households was most significantly negatively associated ($\beta = -0.45$ and -0.19, respectively). It is suggested that the health behaviors required for participation in colorectal cancer programs in Japanese elderly populations are greatly affected by family members.

1. Introduction

Colorectal cancer is one of the most common cancers, causing 390,000 deaths annually in women and 470,000 in men worldwide (Bray et al., 2018; Ferlay et al., 2019). The socioeconomic burden of colorectal cancer is particularly high in developed countries, and it is a major public health concern in Japan, where it is the leading cause of cancer death in women and the third in men (Center for Cancer Control and Information Services, 2020a). Because of rapid population aging, the financial burden for treating this cancer is becoming an increasing problem in Japan. Malignant neoplasms account for approximately 10% of Japan's national medical care expenditures, and colorectal cancer costs increased by 23% from 2009 to 2018 (Japanese Ministry of Health, Labor and Welfare, 2020a). However, colorectal cancer is preventable and screening using the fecal occult blood test reduced mortality in several randomized controlled trials. This cancer screening test is one of the most effective ways to reduce mortality according to established medical evidence (Bibbins-Domingo et al., 2016). Improving the quality of cancer screening programs through fecal occult blood testing is important to reduce the burden of colorectal cancer.

The cancer screening program in Japan started in 1983 as a municipal program based on the "Law of Health and Medical Services for the Elderly," and the colorectal cancer screening program started in 1992. Currently, cancer screening in Japan is divided into workplace-based screening, conducted mainly by companies employing secondary and tertiary industry workers, and municipal screening programs, conducted

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by municipalities for all other residents. The government has provided evidence-based guiding principles for cancer screening for both municipal and workplace-based screening programs. For colorectal cancer screening, a fecal occult blood test is recommended once per year for men and women over 40 years old. Also, breast cancer, cervical cancer, gastric cancer, and lung cancer screenings are recommended by the government (Japanese Ministry of Health, Labor and Welfare, 2016a, 2018). Almost all municipalities, which are the organizers of municipal screening programs, conduct all five cancer screening programs following the government guiding principles; all municipalities provide colorectal cancer screening programs. All information on municipal screening programs is reported to the government and made public (Japanese Ministry of Health, Labor and Welfare, 2020b). In Japan, the national health insurance system does not reimburse cancer screening for able-bodied persons. Municipal screening programs are financed mainly by municipalities, and the co-payment by examinees varies among municipalities. Fecal occult blood tests are usually provided free of charge or at a low cost (less than 1000 yen) (Japanese Ministry of Health, Labor and Welfare, 2021). The government recommends the use of individual invitations to receive cancer screenings, and approximately 85% of municipalities are implementing it (Center for Cancer Control and Information Services, 2020b). The remaining municipalities are informing their residents via PR magazines and websites. Residents are required to undergo cancer screenings at screening sites or medical institutions designated by the municipality. Japan's municipal screening program is a nationally established population-based program, but it is not yet highly organized and is still in the process of implementing quality assurance. Notable, data on workplace-based screening are not collected and managed comprehensively, and the national results for which the government has accurate data are limited to municipal screening programs (Machii et al., 2018; Sagawa et al., 2019). The lack of clear separation of the population eligible for municipal screening programs and workplace-based screening is also a limitation for quality assurance of cancer screening in Japan. The government has constructed a working group to identify the eligible population and participation rates, but these remain unresolved (Japanese Ministry of Health, Labor and Welfare, 2016b).

In Japan, a national target rate of participation in cancer screening of 50% was set in 2007, and a target rate of participation in further assessments of 90% was added in 2018 (Japanese Ministry of Health, Labor and Welfare, 2007). This is a common goal among the five cancer screening programs. The term "participation rate" refers to the percentage of individuals who receive the primary screening test (fecal occult blood tests for colorectal cancer screening). "Further assessment participation rate" refers to the percentage of individuals with a positive screening result who undergo the next test to confirm the diagnosis. In the case of colorectal cancer screening, further assessment refers to colonoscopy for those with a positive fecal occult blood test. Even if an individual participates in screening, the effectiveness of cancer screening will not be realized unless those with a positive result undergo further assessment. The Japanese government periodically conducts a comprehensive survey of living conditions, which is a sampling and self-reporting questionnaire survey of the entire population. In this survey, the overall cancer screening participation rates for both municipalities and workplaces are estimated every 3 years. The 50% target participation rate was not achieved in the latest 2019 survey, except in men with gastric cancer and men with lung cancer (Japanese Ministry of Health, Labor and Welfare, 2020c). The survey did not determine the rate of participation in further assessments. According to the data from the municipal screening programs, the 90% target for further assessments was not met for any of the five cancers.

Studies have been conducted in many countries to improve cancer screening participation rates through interventions (Baron et al., 2010; Community Preventive Services Task Force, 2006). The reasons for low screening participation rates vary by country and region. The World Health Organization (WHO) suggests that the first step is to understand why participation is low in a region before trying an evidence-based initiative (WHO Regional Office for Europe, 2020).

Factors associated with a low participation rate in cancer screening include socioeconomic disparities, ethnicity, and access to medical facilities (Baron et al., 2010). On the other hand, the influence of social relationships on cancer screening participation has not been examined sufficiently. Especially in Japan, which is nearly homogeneous ethnically, the influence of social relationships may be relatively large.

Recently, a growing body of research has suggested the influence of social capital on health (De Silva et al., 2005; Murayama et al., 2012; Nyqvist et al., 2013; Choi et al., 2014). Social capital has been defined in various ways. According to Coleman, "It is not a single entity, but a variety of different entities having two characteristics in common: They all consist of some aspect of social structure, and they facilitate certain actions of individuals who are within the structure" (Coleman, 1990). In another influential definition, Putnam defined social capital as "features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit" (Putnam, 1995). In this paper, we use Kawachi's simple definition from the field of public health, "the resources available to individuals and groups through membership in social networks" (Villalonga-Olives & Kawachi, 2015).

Social support has also been defined in various ways, but Gray defined it as "social support not as an element of social capital itself, but as an outcome of social capital" and the help derived from friends and associates is their "output" (Gray, 2009). Social support is related to a variety of health conditions, including coronary artery disease and cancer (Goodwin et al., 1996; Lett et al., 2005; Uchino, 2009). However, the direction of causality is not entirely clear; it is not known whether social support promotes health, or whether health is necessary to obtain social support. On the other hand, the causal relationship between participation in cancer screening and health outcomes is clear. It is valuable to identify factors associated with participation in cancer screening. Research on social support in elderly people is also limited. Isolation or a lack of companionship is one of the most important factors affecting decreased quality of life, and its prevalence has been reported to increase sharply in people over the age of 75 years (Demakakos, 2006).

A specific example of "resources" in cancer screening is "the acquisition of useful information," such as the date, location, and local government cost of screening. The spread of useful information may influence cancer screening behavior at the population level. There are several reports on the impact of social capital in communities and populations on cancer screening participation behavior. A U.S. study of 2668 men and women aged 18–70 years reported that people with higher neighborhood social awareness were more likely to be screened for cancer and this effect was the strongest for colorectal cancer screening (Leader & Michael, 2013). A study of 2586 black U.S. women aged 40 years and older reported that individual perceptions of high social capital, especially collective efficacy, in their neighborhoods were associated with higher mammography screening participation (Dean et al., 2014).

Japanese research on the association between social relationships and cancer screening participation is limited. In Japan, a survey of 1192 men and women aged 40–69 years reported that high levels of family and neighborhood relationships and participation in community events were associated with higher cancer screening participation rates (Taguchi & Natsuhara, 2015). Hatano et al. conducted an ecological study on the 2007 data of all municipalities in Japan (Hatano et al., 2013). A linear multiple regression analysis was conducted, using population density, proportion of elderly, average household income, municipal debt/budget ratio, physician/population ratio, and public health nurse/population ratio as independent variables, and colorectal cancer screening participation rate, gastric cancer screening participation rate, voter turnout, and influenza vaccination rate as dependent variables. Hatano et al. found that gastric cancer screening participation and voter turnout (a surrogate measure of social capital) were negatively associated with population density, and considered that the lack of social capital in urban areas negatively affected screening participation rates.

Based on these studies and recent cancer screening research, we conducted an ecological study to examine the factors, particularly the proportion of elderly people and household structure (e.g., whether the person lives alone), that influence colorectal cancer screening programs in Japan. This was an ecological study, and it is difficult to directly measure social capital and social support. As alternative indicators, we refer to the indicators in this study as "social-life factors," which include age, sex, socioeconomic status, and social environment.

Although Hatano et al. reported the association between municipal social-life factors and screening participation rates, they did not cover the rate of further assessment participation; moreover, they examined limited factors and dealt with old screening information from 2007 (Hatano et al., 2013). To our knowledge, this study is the first to examine the effects of demographics, finances, household structure, and the healthcare system on colorectal cancer screening (including both the screening participation and further assessment participation rates), using data covering the entire country, and not based on sampling or estimates.

2. Method

2.1. Research design

This ecological study used all municipalities in Japan as the unit of analysis. Various municipal social-life factors, described in the following paragraphs, were used as independent variables. The rates of colorectal cancer screening participation and further assessment participation by municipality were used as dependent variables. We used data on participation in screening and further assessments from 2017, the most recently available data at the time of the analysis. The data for independent variables were also from 2017. Concerning a few independent variables for which data were not available for 2017, we used data from 2016 or 2015. An ethics review was not required because all of the data used were openly provided by the Japanese government, no personal data were handled, and no analysis was performed that could identify individuals.

2.2. Data sources

Rates of participation in screening and further assessments were determined by aggregating data on Japanese municipal screening programs from the Report on Regional Public Health Services and Health Promotion Services 2017 (Japanese Ministry of Health, Labor and Welfare, 2020b). The screening data were administrative data collected by municipalities from medical institutions and reported to the government. Data were used for all people aged 40 years and older who were eligible for screening and included in the report. We used data on predictors of interest for all 1735 municipalities as of 2017 from the "National census," "Annual report on internal migration in Japan derived from basic resident registration," "Statistical reports on the land area by prefectures and municipalities in Japan," "Municipal taxation status survey," "Municipal Financial Survey," "Survey of Medical Institutions," and "Survey of Physicians, Dentists, and Pharmacists" compiled by the Statistics Bureau of the Ministry of Internal Affairs and Communications (2020). The predictors of interest used were "total population," "elderly population," "total number of households," "number of nuclear families," "number of single-elderly-person households," "annual number of people moving in and out of the municipality, " "total habitable area," "gross taxable income of municipality residents, " "gross municipal expenditures," "total number of workers," "number of primary, secondary and tertiary workers," "number of hospitals," "number of clinics," and "number of physicians."

Studies with a similar design conducted at the municipal level are limited. We comprehensively selected variables used in previous ecological research in Japan and variables related to "population," "household," "medical care," and "labor" from the data source for use as independent variables. From these data sources, this study used data only from the municipal units.

The total population and numbers of nuclear family households, single-elderly-person households, workers, and primary, secondary, and tertiary workers were based on 2015 data, and the number of physicians was based on 2016 data, the most recent available. The analysis of all other predictors of interest was based on data from 2017 in conjunction with those from the municipal screening programs.

The details of all data sources are summarized in Supplementary Table 1.

2.3. Variables and excluded records for analysis

The following variables were determined by dividing each value by the total population: "proportion of elderly," "annual municipal expenditure per capita," "proportion of workers per population," "hospital ratio," "clinic ratio," "physician ratio," "annual moving-in rate," and "annual moving-out rate." The following variables were determined by dividing each value by the total number of households: "proportion of nuclear families," "proportion of single-elderly-person households," and "average income per household." The "average income per household" is simply the "gross taxable income of municipality residents" divided by the total number of households. Due to data limitations, household structure could not be considered. The proportions of workers in primary, secondary, and tertiary industries were determined by dividing the number of workers in each industry by the total number of workers. As any one of these three variables can be explained by the other two, only the proportions of primary and secondary workers were used in the multiple regression analysis to avoid multicollinearity. The population density was determined by dividing the total population by the total habitable area. Municipalities with data missing for any reason were excluded from the analysis.

2.4. Statistical analysis

The mean, maximum, minimum, and quartiles of all variables were calculated. Multiple regression and correlation analyses were conducted using each predictor of interest and municipality as independent variables and the screening and further assessment participation rates as dependent variables. For the screening participation rate, we also conducted analyses using separate data for men and women. We considered it reasonable to include all independent variables in the analysis to adjust for confounding and to compare with previous studies. Therefore we used a forced-entry regression analysis method. Unstandardized partial regression coefficients (B), standard errors, standardized partial regression coefficients (β), *P*-values, multiple correlation coefficients (R), coefficients of determination, and adjusted coefficients of determination (R-squared) were calculated. Tolerance and the variance inflation factor (VIF) were calculated as indicators of collinearity, with Tolerance > 0.1 and VIF < 10 as thresholds for multicollinearity. As a measure of autocorrelation, we calculated Durbin–Watson values according to the order of Japanese municipal codes, which are generally numbered from north to south, with geographically neighboring municipalities being close in number. This was because the indicators of cancer screening may be similar among neighboring municipalities, and we considered it necessary to check whether there were any effects of such similarities. In the correlation analysis, the correlation coefficients (r) and *P*-values were calculated. Sensitivity analyses were performed for two age groups: 40–69 years and over 65 years. The 40–69-year age group was set as the reference in the analyses of other countries, and the over 65-year age group as a target from which workers were generally excluded. In cases where the screening and further assessment participation rates did not follow a normal distribution, an analysis to confirm the validity of the results was conducted after performing necessary variable transformations to approximate a normal distribution. We considered a two-sided *P*-value of less than 0.05 to indicate statistical significance in all analyses. We did not calculate sample size because this study covered all fixed municipalities in Japan. In multiple regression analysis, it is generally desirable to have a sample of a least 15 for each independent variable (Green, 1991; Siddiqui, 2013). In this study, there were 114.6 municipalities per independent variable. All statistical analyses were performed using EZR ver. 1.40 (Kanda, 2013), the graphical user interface of R ver. 3.5.2 (The R Foundation for Statistical Computing, Vienna, Austria), and the Statistical Package for the Social Sciences (SPSS) for Windows, ver. 27 (IBM, Armonk, NY, USA).

3. Results

3.1. Basic results

The data excluded from this analysis were as follows. For seven municipalities, data were missing because the population was reduced to zero after the government created an evacuation zone following the nuclear accident in 2011. Nine municipalities had zero positive participants in the fecal occult blood test screening. This can happen in rural municipalities with small populations. The rate of participation in further assessments could not be calculated for these municipalities. We excluded a total of 16 municipalities from the analysis, leaving 1719 municipalities. Table 1 summarizes the predictors of interest for the municipalities. The interquartile range for colorectal cancer screening participation rate was 9.3–17.6% (7.9–15.7% for men, 10.4–19.3% for women) and that for the further assessment participation rate was 67.1–82.8% (63.8–81.6% for men, 70.0–85.7% for women). The independent variables with relatively high variance were total population and population density. The variance of the proportion of primary industry workers was higher than those of secondary and tertiary industry workers. We also summarized the values of the independent variables for each participation rate quartile (Supplementary Table 2).

3.2. Multiple regression analysis

The screening participation rate was significantly and positively associated with the proportion of elderly people ($\beta = 0.51$), annual moving-in rate ($\beta = 0.24$), population density ($\beta = 0.07$), annual municipal expenditure per capita ($\beta = 0.17$), proportion of primary industry workers ($\beta = 0.20$), and clinic ratio ($\beta = 0.06$) (Table 2). It was significantly and negatively associated with the total population ($\beta = -0.09$), proportion of nuclear families ($\beta = -0.22$), proportion of single-elderly-person households ($\beta = -0.45$), and hospital ratio ($\beta = -0.10$). The further assessment participation rate was significantly and positively associated with the proportion of elderly people ($\beta = 0.13$), proportion of secondary industry workers ($\beta = 0.08$), and hospital ratio ($\beta = 0.07$) and significantly and negatively associated with the proportion of single-elderly-person households ($\beta = -0.19$), population density ($\beta = -0.14$), and proportion of workers per population ($\beta = -0.09$).

The proportion of elderly people produced the highest positive standardized partial regression coefficients among the significant factors for both the screening participation ($\beta = 0.51$) and further assessment participation ($\beta = 0.13$) rates, and the highest negative factor was the proportion of single-elderly-person households ($\beta = -0.45$ and -0.19, respectively). The hospital ratio and population density had a positive/negative reversal of β between screening participation and further assessment participation rates. The adjusted coefficient of determination was 0.31 for the participation rate and 0.06 for the further assessment participation rate. There was no multicollinearity based on Tolerance (0.13–0.82) or the VIF (1.2–7.6). There was no strong autocorrelation among the Japanese municipal codes according to the Durbin–Watson values.

A linear multiple regression analysis was conducted to identify the factors associated with the participation rate using separate data for men and women (Supplementary Tables 3 and 4). Municipalities with zero positive further assessments were added in three and five cases for men

Table 1
Basic characteristics of municipalities (N = 1719).

	Mean	S.D.	Min	25%	Median	75%	Max
Colorectal cancer screening, %							
Participation rate							
Total	13.8	6.2	2.2	9.3	12.9	17.6	53.3
Men	12.3	6.1	1.6	7.9	11.3	15.7	50.1
Women	15.2	6.5	1.5	10.4	14.3	19.3	60.9
Further assessment participation rate							
Total	73.6	14.2	0.0	67.1	75.9	82.8	100.0
Men	71.3	15.8	0.0	63.8	73.4	81.6	100.0
Women	76.0	15.2	0.0	70.0	78.3	85.7	100.0
Population							
Total population	73777.4	189019.8	370	8417	25,278	64,660	3,724,844
Population density, per km^2*	1384.6	2531.6	11.6	246.3	500.5	1238.4	22380.2
Proportion of elderly people, %**	31.7	7.1	15.1	26.5	31.2	36.3	60.5
Annual moving-in rate, %	3.2	1.5	0.9	2.2	2.8	3.7	18.0
Annual moving-out rate, %	3.5	1.3	1.8	2.7	3.2	3.9	15.9
Households, %							
Proportion of nuclear families	56.1	6.6	28.6	51.9	56.2	60.2	76.9
Proportion of single-elderly-person households**	12.6	4.5	3.8	9.4	11.7	15.1	31.3
Finance, million-yen							
Average income per household	3.13	0.85	1.20	2.55	3.12	3.62	11.82
Annual municipal expenditure per capita	0.71	0.59	0.25	0.40	0.52	0.79	9.66
Employment and Industry, %							
Proportion of workers per population	48.4	4.1	33.3	45.8	48.5	50.8	71.5
Proportion of primary industry workers***	11.0	10.3	0.0	2.9	7.9	16.2	77.0
Proportion of secondary industry workers***	25.2	8.1	1.5	19.2	25.0	30.9	51.6
Proportion of tertiary industry workers***	61.3	8.9	19.7	55.2	61.0	67.9	92.9
Healthcare, per 100,000 population							
Hospital ratio	6.6	7.0	0.0	0.0	5.3	9.1	69.0
Clinic ratio	76.7	51.7	0.0	55.1	69.9	86.5	982.8
Physician ratio	165.9	183.0	0.0	75.7	132.5	198.8	3068.2

* Per habitable area.** Elderly persons are defined as those aged 65 years and older.*** Proportion of the total number of workers.

Table 2
Results of multiple linear regression analyses and correlation for colorectal cancer screening participation and further assessment participation rate in municipalities (N = 1719).

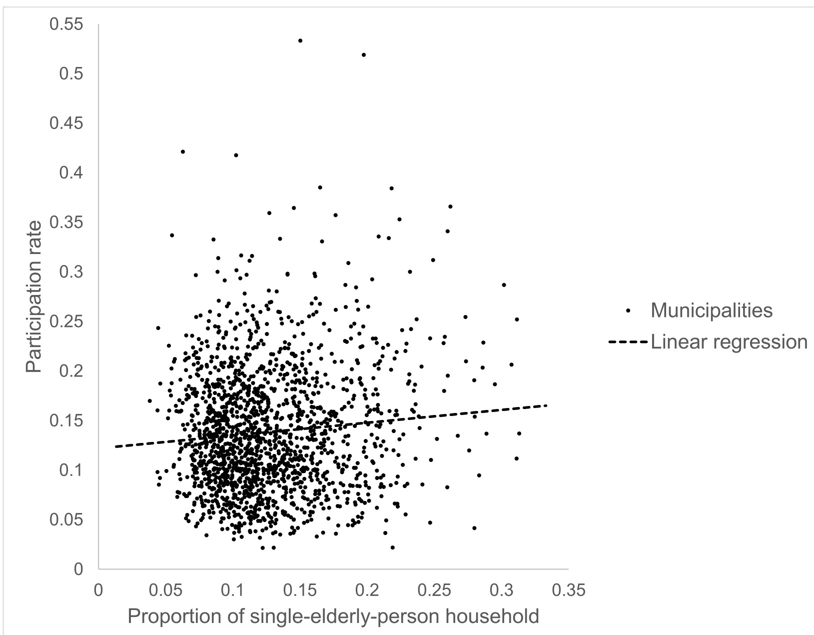
–	Participation rate								Further assessment participation rate							
–	Unstandardizedcoefficients		Standardizedcoefficients		Collinearitystatistics		Correlation		Unstandardizedcoefficients		Standardizedcoefficients		Collinearitystatistics		Correlation	
Independent variables	B	Std. Error	β	P	Tolerance	VIF	r	P	B	Std. Error	β	P	Tolerance	VIF	R	P
(Constant)	0.18	0.04	–	<0.001	–	–	–	–	0.86	0.10	–	<0.001		–	–	–
Population																
Total population	-2.8×10^{-8}	7.7×10^{-9}	−0.09	<0.001	0.74	1.3	−0.18	<0.001	6.6×10^{-9}	2.0×10^{-8}	0.01	0.744	0.74	1.3	−0.10	<0.001
Population density, per km^2*	1.8×10^{-6}	7.7×10^{-7}	0.07	0.022	0.41	2.4	−0.16	<0.001	-7.6×10^{-6}	2.0×10^{-6}	−0.14	<0.001	0.41	2.4	−0.21	<0.001
Proportion of elderly people**	0.45	0.05	0.51	<0.001	0.15	6.9	0.28	<0.001	0.27	0.12	0.13	0.030	0.15	6.9	0.12	<0.001
Annual moving-in rate	1.01	0.23	0.24	<0.001	0.13	7.6	−0.03	0.180	−0.03	0.61	0.00	0.958	0.13	7.6	−0.18	<0.001
Annual moving-out rate	−0.82	0.25	−0.17	0.001	0.15	6.9	0.01	0.657	−0.25	0.68	−0.02	0.715	0.15	6.9	−0.16	<0.001
Households																
Proportion of nuclear families	−0.21	0.03	−0.22	<0.001	0.56	1.8	−0.38	<0.001	4.0×10^{-2}	6.7×10^{-2}	0.02	0.551	0.56	1.8	0.02	0.338
Proportion of single-elderly-person households**	−0.63	0.07	−0.45	<0.001	0.15	6.7	0.09	<0.001	−0.59	0.19	−0.19	0.002	0.15	6.7	0.02	0.317
Finance																
Average income per household	2.9×10^{-3}	2.4×10^{-3}	0.04	0.242	0.36	2.8	−0.09	<0.001	-1.3×10^{-2}	6.5×10^{-3}	−0.08	0.051	0.36	2.8	−0.11	<0.001
Annual municipal expenditure per capita	1.7×10^{-2}	3.2×10^{-3}	0.17	<0.001	0.44	2.3	0.36	<0.001	-4.8×10^{-3}	8.5×10^{-3}	−0.02	0.571	0.44	2.3	−0.01	0.638
Employment and Industry																
Proportion of workers per population	−0.06	0.05	−0.04	0.181	0.40	2.5	0.27	<0.001	−0.30	0.13	−0.09	0.018	0.40	2.5	0.01	0.575
Proportion of primary industry workers	0.12	0.02	0.20	<0.001	0.32	3.1	0.36	<0.001	8.4×10^{-2}	5.7×10^{-2}	0.06	0.140	0.32	3.1	0.07	0.005
Proportion of secondary industry workers	0.01	0.02	0.02	0.599	0.43	2.3	−0.04	0.102	0.14	0.06	0.08	0.022	0.43	2.3	0.11	<0.001
Healthcare, per population																
Hospital ratio	-8.3×10^{-4}	2.0×10^{-4}	−0.10	<0.001	0.82	1.2	−0.10	<0.001	1.4×10^{-3}	5.2×10^{-4}	0.07	0.007	0.82	1.2	0.08	0.001
Clinic ratio	6.6×10^{-5}	3.1×10^{-5}	0.06	0.034	0.60	1.7	0.15	<0.001	-2.2×10^{-5}	8.3×10^{-5}	−0.01	0.788	0.60	1.7	−0.08	<0.001
Physician ratio	-8.4×10^{-6}	8.0×10^{-6}	−0.03	0.304	0.70	1.4	−0.13	<0.001	-1.2×10^{-5}	2.2×10^{-5}	−0.02	0.585	0.70	1.4	−0.08	0.002
R	0.56								0.27							
R-squared	0.31								0.07							
Adjusted R-squared	0.31								0.06							
Durbin-Watson***	1.36								1.74							

* Per habitable area.** Elderly persons are defined as those aged 65 years and older.*** Analyzed according to Japan's municipal codes.VIF: variance inflation factor.

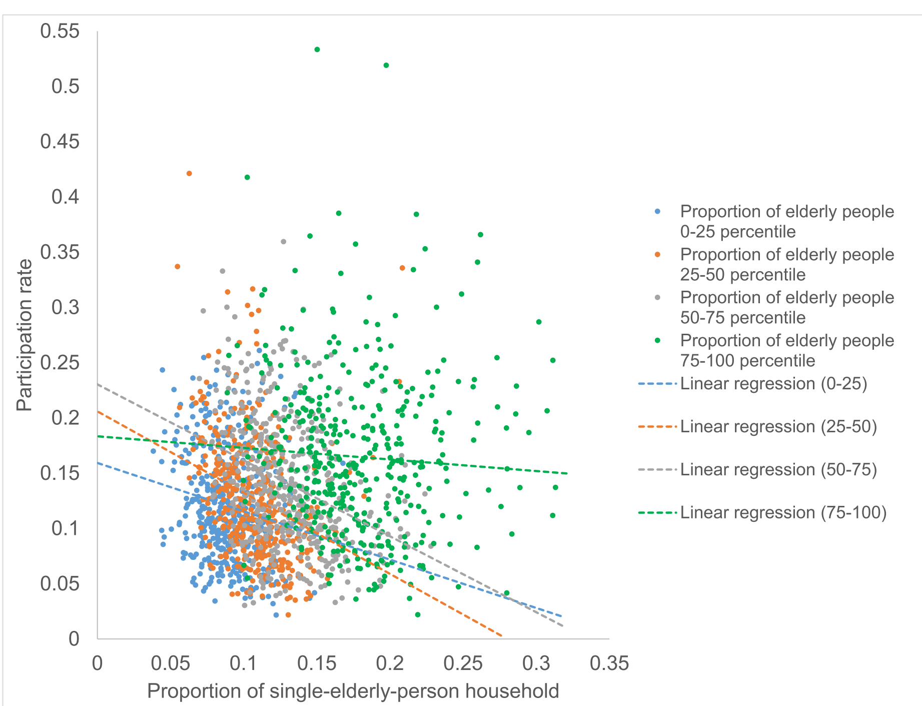
and women, respectively. All 1716 municipalities for men and 1714 municipalities for women were included in the analysis. The trends were generally similar between men and women. For both men and women, the standardized regression coefficients indicated the strongest negative relationships between the proportion of single-elderly-person households and both the screening and further assessment participation rates. On the other hand, the difference in the proportion of elderly people was no longer statically significant for the further assessment participation rate in women. The standardized regression coefficients for participation rate were slightly lower for women overall, with an adjusted R-squared value of 0.36 for men versus 0.26 for women.

3.3. Correlation analysis

Table 2 shows the results of the correlation analysis. The proportion of single-elderly-person households was slightly positively correlated with the screening participation (r = 0.09) but not the further assessment participation rate. The other factors with positive/negative trends were consistent with those identified in the multiple regression analysis. Scatterplots of the screening participation rates and proportion of single-



A



B

Fig. 1. Scatterplots of the colorectal cancer screening participation rates and the proportion of single-elderly-person households by municipality (N = 1719)
Figure. 1A: Simple scatterplot and regression line for all municipalities.
Figure. 1B: The municipalities in 1A was divided into four groups based on the percentile of the proportion of elderly people, and one regression line per group was added to the plot.

elderly-person households in 1719 municipalities were created based on the results of the multiple regression and correlation analyses (Fig. 1). Fig. 1A is a simple scatterplot and regression line for all municipalities. Fig. 1B divides 1A into four groups by the percentile of the proportion of elderly people and adds the regression line for each group. Fig. 1A shows a slight positive correlation, whereas Fig. 1B shows negative correlations from the regression lines drawn for each group.

3.4. Sensitivity analysis

Sensitivity analyses were performed for two age groups: 40–69 years and over 65 years (Supplementary Table 5). The 40–69 age group was set as a comparable target to match the analyses of other countries, and the over 65 age group as a target from which workers were generally excluded. There was no difference in the trend of the results in either analysis. The kurtosis and skewness of the distributions did not follow normal distributions exactly, as values for the participation rates were 2.39 and 1.04, and those for the further assessment participation rates were 4.06 and −1.45, respectively. Therefore, analyses were performed with logarithmic, exponential, and power transformations to achieve a near-normal distribution (Supplementary Table 5). There was no difference in the trend of the results in any analysis.

4. Discussion

4.1. General and specific discussion

To our knowledge, this is the first report to investigate the detailed effects of social-life factors on colorectal cancer screening participation and further assessment participation rates in municipalities across Japan. The Japanese colorectal cancer screening program was found to be significantly and negatively associated with the proportion of single-elderly-person households. The unstandardized partial regression coefficients associated with the screening participation and further assessment participation rates were −0.63 and −0.59, respectively, implying that the respective indices tended to decrease by 6.3 and 5.9 percentage points as the proportion of single-elderly-person households increased by 10 percentage points. The proportion of elderly people was positively associated with the screening participation and further assessment participation rates.

To confirm the influence of social-life factors on men and women, we also conducted an analysis of the factors according to sex. In women, the difference in the proportion of elderly people was no longer statistically significant, and the adjusted R-squared value was lower (0.26) than the value in men (0.36). Thus, the associations with the factors evaluated in this study appear to be relatively weak in women. However, there was no positive/negative reversal of the standardized regression coefficients in men or women. The standardized regression coefficients for the proportion of single-elderly-person households were negative and the largest for both the participation and further assessment participation rates in both men and women.

A previous Japanese study analyzing only the screening participation rate did not include the proportion of single-elderly-person households as a factor; the proportion of elderly people exhibited a positive trend with participation rate, although not statistically significant, which is consistent with our results (Hatano et al., 2013). Fig. 1A and B shows that the proportion of elderly people is a confounding factor in the relationship between the proportion of single-elderly-person households and screening participation rates. Drawing four regression lines for the subgroups of the proportions of elderly people in Fig. 1B showed that the negative association of the proportion of single-elderly-person households was hidden in the background. Because the effect of the proportion of single-elderly-person households was absorbed by the proportion of elderly people, Supplementary Table 2 also did not show a negative association between the proportion of single-elderly-person households and the screening participation rates. Although further studies are needed, our results suggest that factors such as older age and singleness are potential negative factors in cancer screening programs regardless of country or cancer type, as there are reports of lower rates of cervical cancer screening participation among single older Swiss women (Burton-Jeangros et al., 2017).

The Japanese Cabinet Office conducted the "National Survey of Lifestyle Preferences," a two-stage random sampling survey of 5000 men and women aged 15–80 years nationwide in Japan in 2012 (Japanese Cabinet Office, 2012). In the survey, the percentage of respondents who answered that they were "familiar" with their neighbors was 25.7–37.0% among 40–59-year-olds, compared with 42.8–59.1% among 60–79-year-olds. Participation in community events at least several times per year, including health activities, was 24.1% in the 40–65-year age group and 40.7% in the 65–79-year age group. These community activities of the elderly in Japan may also affect cancer screening participation. One interpretation of our results is that a community constructed among the elderly can facilitate the spread of useful information about cancer screening, but some single persons may be affected by isolation.

The adjusted coefficient of determination for the multiple regression analysis of the screening participation rates was 0.31, which is higher than the value of 0.07 reported in (Hatano et al., 2013). This is thought to result from the increased explanatory power of the multivariate analysis due to the inclusion of many significantly associated independent variables. This coefficient was 0.06 for the further assessment participation rate, which was lower than for the participation rate. Although our analysis found no information that explains this directly, the following interpretation is possible. All persons who had positive screening results were participants in the cancer screening program. The explanatory power of the municipality factor may have been reduced due to the selection of a population with active health behaviors compared with the entire population. Nevertheless, it is noteworthy that the strongest significant negative effects of the proportion of single-elderly-person households were seen in both the screening and further assessment participation rates. This indicates that social relationships have broad effects on cancer screening programs.

In men and women, a similar trend was observed for the relationship between the proportion of single-elderly-person households and participation in cancer screening. Although little is known about the relationship between cancer screening participation and social isolation in elderly Japanese, Mitsuhashi et al. (2006) reported a significant association between the provision and receipt of social support and preventive checkups among older men, but no such association was found among women. A similar association between the proportion of single-elderly-person households and the screening participation rate was found in our study. It is important to conduct future studies to examine the association between social support and health outcomes related to cancer screening participation in elderly Japanese.

Several other predictors of interest were also identified that were significantly associated with the screening and further assessment participation rates. The proportion of nuclear families had the second-largest negative association with the participation rate. Similar to single-elderly-person households, nuclear families may have a more limited access to information on cancer screening. The screening participation rates were positively associated with the annual moving-in rates and negatively associated with moving-out rates. These results are difficult to interpret, but municipalities with more new move-ins may provide information about government services to residents more actively (and the opposite if there are more move-outs). Interestingly, population density and the hospital ratio exhibited positive/negative reversal of β between the screening participation and further assessment participation rates. The results of this study show that rural residents tend to be more willing to undergo further assessment than to participate in screening. This may be due to the close relationship between residents and their family physicians in rural communities, which means that they have a system in place to consult immediately if they receive a positive cancer screening result. The hospital ratio may have contributed to the increase in participation in further assessments because it is difficult for clinics alone to provide advanced detailed examinations compared with screening tests. Screening is performed using a fecal occult blood test kit, while colonoscopy, which is a more intensive method of evaluation, requires more equipment and endoscopists. Medical institutions are undergoing reorganization in rural areas where the population is declining. Specialized medical services that require specialists and equipment, such as colonoscopy, tend to be concentrated in central hospitals (Yasaka et al., 2020).

4.2. Points to note for data interpretation

There were at least three limitations to this study. First, it used the municipality as the unit of analysis. Using a group as a unit of analysis makes it impossible to analyze the effects of differences in individual predictors of interest on the "screened" and "not screened" categories. Most of the previous studies conducted logistic regression analyses for each individual using the binary variable "screened" and "not screened" as outcomes, with the results shown as odds ratios (Leader & Michael, 2013; Dean et al., 2014, 2015). The present study used multiple regression analysis with the outcome a continuous variable, and screening participation rates across the municipalities, which limits comparability with previous studies. In addition, because this was a cross-sectional ecological study, the temporal pre/post relationship is unknown, and the presence of unidentified confounding factors cannot be ruled out, so caution must be exercised when discussing causal relationships. However, observational studies are essential and effective in the search for further underlying predictors of interest.

Second, the cancer screening data used were limited to municipal screening programs and did not include workplace-based screening. Cancer screening in Japan is divided into workplace-based screening, which is mainly conducted by companies employing secondary and tertiary industry workers, and municipal screening programs conducted by municipalities for all other residents. Data on workplace-based screening are not collected and managed comprehensively, and the national data for which the government has accurate numbers are limited to municipal screening programs (Machii et al., 2018; Sagawa et al., 2019). In this study, we used only data on municipal screening programs. The low screening participation rate of 13.8% in Table 1 is because the numerator does not include information on workplace-based screening. Although bias could be avoided by excluding the subjects of workplace-based screening from the denominator, this was impossible because the actual numbers were not known. According to the 2019 "Comprehensive survey of living conditions" (Japanese Ministry of Health, Labor and Welfare, 2019), colorectal cancer screening participation rates were reported as 47.8% in men and 40.9% in women. However, this survey does not distinguish between municipal and workplace-based screening. The validity of the data was limited because this survey involved sampling and self-reporting. Fundamental improvements to the information collection system are needed to ensure the quality assurance of cancer screening programs in Japan.

Third, the indicators are limited and should be interpreted carefully when discussing social capital. The variables used in the analysis do not necessarily represent social connections directly, and social interactions that form social capital at the population level do not always correspond to municipal boundaries.

Despite these limitations, this study has practical strengths. The use of the municipality as the unit of analysis is also an advantage of this study. Mass screening in Japan is conducted on a municipal basis, and it was appropriate to use municipalities as a spatial division of analysis to obtain valuable results in terms of administrative measures. The fact that both the independent and dependent variables included in the analysis are hard measures that do not depend on individual self-assessment also supports the results of this study. In particular, the inclusion of the dependent variables of both screening participation and further assessment participation rates revealed factors such as the proportion of elderly people and household structure, which are directly related to the macro outcome of the community's overall cancer screening program.

The lack of inclusion of information on workplace-based screening is a major limitation of this study. The lack of data was not unique to this study; it is a limitation of cancer screening data in Japan. This study eliminated much of the bias that may be caused by this setting by including the proportion of workers and the proportions of primary, secondary, and tertiary workers as variables. Sensitivity analysis was also conducted for people aged 65 years and older, assuming they are retired, but no difference in trend was found. The pattern of the regression coefficients for the screening participation and further assessment participation rates were generally consistent, indicating that there was no significant bias in the study setting or that the analysis appropriately eliminated the bias. This is because the further assessment participation rate did not have a bias due to the exclusion of workplace-based screening data, because both the denominator and numerator used to calculate the rate represented people who participated in municipal screening programs.

4.3. Practical considerations and future implications

Our ultimate goal is to improve the overall quality of cancer screening by changing the behavior of the population through interventions. Although this study does not propose an intervention, it provides a foundation for effective efforts in each of the municipalities that are the delivery units for cancer screening in Japan by identifying local factors relevant to the overall screening program. For example, we believe that it could be used as a classification tool to predict the success or failure of an intervention. Policymakers could prioritize Reminder and Recall (Baron et al., 2010; Community Preventive Services Task Force, 2006), a direct approach to individuals rather than community-based interventions, in areas with a high proportion of single elderly and low screening participation rate. Much research has already accumulated on improving the rate of participation in cancer screening, and short-term results are expected with appropriate interventions. In the long term, support for building social capital for the single elderly will be important for both cancer screening and all other health promotions.

This study has internal validity for Japan because the analysis was conducted for all municipalities in Japan. On the other hand, it is difficult to assess the external validity for other countries based on this study alone. Similarly designed studies performed in other countries and other cancer types would be valuable as comparisons.

In conclusion, a study of municipalities across Japan found that the proportion of single-elderly-person households was significantly and negatively associated with the rates of colorectal cancer screening and further assessment participation, and the proportion of elderly people was significantly and positively associated. The results suggest that social connections play an important role in the cancer screening programs. Interpreting this result, health behaviors are promoted by communities built among older people, but some single older people are isolated from this framework. These findings should be confirmed prospectively using individual data.

CRediT authorship contribution statement

Noriaki Takahashi: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, and, Visualization. **Mutsuhiro Nakao:** Conceptualization, Methodology, Writing – review & editing, Supervision, and, Project administration.

Declaration of competing interest

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Appendix A. Supplementary data

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