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ORIGINAL PAPER

Inequality within a community at the neighborhood level and the incidence of mood disorders in Japan: a multilevel analysis

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Abstract

Purpose This study analyzes whether income inequality within a community at the neighborhood level is associated with incidence of mood disorder in Japan.

Methods A retrospective cohort study was performed using the data of 116,658 National Health Insurance beneficiaries aged between 20 and 69 in Chiba City, Japan. To evaluate income inequality within a community, the Gini coefficient within a 30-min walking distance from an individual's residence was calculated using income distribution estimated by the National Census and the Housing and Land Survey 2013. Incidence of mood disorder was determined through insurance claims submitted from April 1, 2013, to March 31, 2016. A multilevel logistic analysis with three levels—the individual, household, and residential district—was performed to evaluate the association.

Results Income inequality within a community at the neighborhood level was not associated with incidence of mood disorder in the models with and without equivalent household income (p for trend = 0.856 and 0.947, respectively). No difference was observed in the impact of the Gini coefficient among income levels, lower versus higher income groups (p for interaction between Gini coefficient and household income = 0.967). In contrast, lower equivalent income at the household level was significantly associated with higher incidence of mood disorder (p for trend < 0.001).

Conclusions While we confirmed that lower income at the household level itself had an adverse effect on mental health, income inequality within a community at the neighborhood level was not a significant factor for incidence of mood disorder in Japan.

Keywords Gini coefficient · Income inequality · Mood disorder · Equivalent income · Multilevel analysis

Introduction

Both individual socioeconomic status and income inequality within a community have been recognized as important factors in determining an individual's health [1, 2]. Although the means by which income inequality within a community has significant health effects have yet to be determined, several potential avenues have been proposed. First, the greater the degree of income inequality in a residential area, the greater the prevalence of the poor residents (poverty is a well-known adverse factor in health) [1, 3]. Second, inequality in a variety of social and institutional infrastructures in a community due to differential investment may be another link; this is known as "the neo-materialist hypothesis" [4, 5]. Third, known as "the social capital hypothesis," the level of income inequality is inversely associated with the interpersonal trust level, and this is followed by adverse health influences [4–6]. Finally, deprived individuals tend to be vulnerable to the perception

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of their living place as denoting their position in society and may thus have exaggerated psychosocial responses that lead to adverse impact on their health or mental well-being; this is known as "the status anxiety hypothesis" [4].

Subramanian et al. have noted the importance of geographical scale—such as the country, state, municipality, and neighborhood levels—in evaluating the contextual effect of inequality [7]. However, it is not clear which exact levels of geographical scale are actually important. In previous studies with a relatively large scale, like a country or state, the adverse effects on health produced by inequality within the regions have consistently been identified in both cross-sectional [8–11] and longitudinal [12–16] study designs. In contrast, the results of the studies undertaken at the municipal level were inconsistent; some reported significant association between higher inequality and poor health outcomes [17, 18], others found no significant association [6, 19–21], while another identified a paradoxical association [22]. There are notably few studies focusing on inequality on a much smaller scale, such as at the neighborhood level. Analyzing factors at the parish level, Osler et al. reported no significant association between income inequality and all-cause mortality [23]. However, a significant drawback of this study is that it did not employ a multilevel analysis—the method considered essential in distinguishing the effects of individual and contextual factors [7]. To date, several cross-sectional studies using a multilevel analysis have evaluated the impact of income inequality at the neighborhood level. Ichida et al. reported a significant association between higher income inequality and poor self-rated health among the elderly [24]. Fone et al. found no association between income inequality and the prevalence of common mental disorders [25]. We believe that longitudinal studies with a multilevel analysis are indispensable in analyzing the association.

Although Japan has been perceived as one of the more wealthy and egalitarian countries [26], its relative poverty rate increased significantly between 1995 and 2010. In 2013, Japan was found to have the sixth highest rate of relative poverty among the 20 Organization for Economic Cooperation and Development (OECD) countries after Israel, Mexico, Turkey, Chile, and the United States [27]. These facts accelerated our interests in the impact of income inequality in Japanese population. The aim of this study is to identify the impact of regional income inequality at the neighborhood level determined by the Gini coefficient on the incidence of mood disorders in Japan using multilevel analysis.

Methodology

Study design

This is a retrospective cohort study using integrated data from health insurance claims, individual income from tax records, and residential areas, accumulated and administrated by Chiba City, a satellite urban city of Tokyo. For this study, we utilized data from April 1, 2012, to March 31, 2016.

Subjects

Our subjects were beneficiaries of the National Health Insurance (NHI) in Chiba City, Japan. All residents in Japan, except for those on public assistance, are required to enroll in the public health insurance system. There are two major public health insurance systems for individuals under 75 years. One is for employees of the government and companies and the other is NHI, which is managed by the municipalities and is meant for self-employed workers including farmers and fishers, retirees, and the unemployed. Under Japan's universal health care insurance coverage, all patients are able to visit any medical facility they want and receive the same care regardless of the insurance plan they have. Medical care facilities submit medical fee claims to each patient's health care insurer, such as NHI. Therefore, municipalities, which are in charge of NHI, completely administer their beneficiaries' insurance claim data, including diagnoses by their doctors.

The total population of Chiba City was 962,988. The number of beneficiaries of NHI was 263,511, 27.4% in fiscal year 2012. A total of 159,812 beneficiaries aged 20 to 69 years enrolled in the NHI in the period of April 1, 2012, to March 31, 2013. However, 204 were excluded because their residential areas were not identified. Of the remaining 159,608 beneficiaries, 116,658 subjects were enrolled in NHI for 3 years (April 1, 2013 to March 31, 2016), ensuring that the data were thoroughly trackable during this period (follow-up rate of 73.1%), and were analyzed in this study.

Main outcome

The main outcome was the incidence of a mood disorder between April 1, 2013, and March 31, 2016. Subjects who made insurance claims encoded with "0504" at least once during the period were determined as individuals who had incidence of a mood disorder. According to the International Classification of Diseases for the Use of Social Insurance established by the Ministry of Health, Labour and Welfare in Japan [28], this encoded number indicates a mood disorder and is equivalent to F30–F39 of the International Statistical Classification of Diseases-10 (ICD-10). It includes manic episodes, bipolar affective disorder, depressive episodes, recurrent depressive disorder, persistent mood disorders, and other mood disorders, including unspecified ones. Individuals with incidence may possibly include both those with a first episode and those with a recurrence. We were not able to distinguish between the two.

Household income

Individual income data from January 1 to December 31, 2012, were obtained from tax records provided by Chiba City Hall. Each individual's data were accompanied by a number identifying his/her household. Household income was calculated by adding individual income to the corresponding household number. Household size was calculated by counting individuals with the same household number. Equivalent household income was calculated by household income divided by the square root of the total number of household members [29]. We divided the subjects into four categories by quartile of equivalent income in 83,594 households, as the linearity between income and incidence of mood disorders was not necessarily guaranteed.

Gini coefficient and mean income at the neighborhood level

We obtained registered residential data on the town and district (the *chome* level) in which the subjects lived on April 2, 2012. The district is the smallest unit used in National Census data. We calculated the center of gravity for each district and assumed that all subjects lived at these points. We identified 492 districts within the target area. We defined the neighborhood level of the area as that within a 30-min walking distance from the subject's residential point. Regional income inequality at each neighborhood level was measured as a Gini coefficient [7]. The average household income was also calculated. To determine these measures, we used the Arc GIS version 10.4.1 geographic information system (GIS) with the Arc GIS Network Analysis extension and road network data for Chiba Prefecture provided by ESRI Inc.; we assumed the walking speed to be 4.8 km/h.

To calculate the Gini coefficient and average household income, it is necessary to cite the income distribution of the entire population living in each district. However, as the available subjects in this study were limited to the beneficiaries of NHI, data for the income distribution of the whole population in Chiba City could not be obtained. Alternatively, we obtained income distribution data for each district (i.e., each chome level) from ZENRIN Inc. in Fukuoka, Japan; these data were estimated using the 2013 National Census and 2013 Housing and Land Survey, as provided by the Statistics Bureau of Japan. We also assumed that all individuals lived at the gravity point of the district. The following procedure to calculate the Gini coefficient was employed. We began to draw the area within the 30-min walking distance from each subject's residential point using GIS. Next, we searched the gravity points of residents within this 30-min walking distance. Third, we added up the income distributions of these gravity points, and finally used the tallied income distribution to calculate the Gini coefficient and average income. We categorized the Gini coefficient and income average into four groups using quartiles in 492 districts, as the linearity between Gini coefficient and incidence of mood disorders was not necessarily guaranteed.

Other data

We divided the subjects into four age categories: 20–39, 40–49, 50–59, and 60–69 years of age. A categorical variable for household type was discerned as follows: single, one adult and children, two or more adults and children, and two or more adults only; here "children" denotes those younger than 18 years old. As explained in the context of calculating the Gini coefficient, we used GIS to determine the numbers of medical institutions and the population within the 30-min walking distance of each subject's residential point. The location information of the medical institutions was downloaded from the website of the Institute for Health Economics and Policy [30], which provides information for 95,762 medical institutions (excluding dental clinics). The population figures for each district were obtained from the 2010 National Census, which was included in the ArcGIS data-collection standard pack (ESRI Inc., Redland, CA). We constructed categorical variables for the number of medical institutions and the population within the 30-min walking distance using quartiles in 492 districts.

Statistical analysis

The median, 25th, and 75th percentiles were shown for continuous variables, number, and percentage, as well as categorical variables. The association between the Gini coefficient and incidence of mood disorder during the 3 years (2013–2016) was analyzed using a multilevel logistic regression analysis—a three-level model with two random intercept equations. Levels 1, 2, and 3 were at the individual ($n = 116{,}658$), household (number of clusters = 83,594), and residential district (number of clusters = 492) levels, respectively.

Model 1 was adjusted for sex and age. Model 2 was adjusted for household type, number of residents, number of medical institutions, and average income within a 30-min walking distance from each individual's district point in addition to the same adjusted variables in Model 1. Model 3 was adjusted equivalent income in addition to the same adjusted variables in Model 2. We also analyzed the cross-level interaction between the Gini coefficient and equivalent household income with the same adjusting variables in Model 2. All available variables that may be confounding factors were utilized as adjusting variables. Results were considered statistically significant when the two-sided p value was < 0.05. All statistical analyses were performed

Table 1 Characteristics of subjects, households, and districts

Individual level	
Number of subjects[a]	116,658
Sex[a]	
Men	56,322 (48.3)
Women	60,336 (51.7)
Age (years)[b]	61 (45, 66)
Household level	
Number of households[a]	83,594
Equivalent income (million JPY)[b]	1.02 (0.22, 1.84)
Household type[a]	
Single	29,580 (35.4)
One adult and children	2299 (2.8)
Two or more adults and children	6087 (7.3)
Two or more adults only	45,628 (54.6)
District level	
Number of districts[a]	492
Area (km^2)[b]	9.48 (8.62, 10.41)
Population size[b,c]	58,480 (35,206, 82,103)
Number of medical institutions[b,d]	37 (25, 75)
Average income (million JPY)[b,c]	4.85 (4.66, 5.14)
Gini coefficient[b,c]	0.368 (0.352, 0.376)

As of January 24, 2018, US $1 was the equivalent of JPY 109.93

[a]Number (percentage) is shown

[b]Median (25th and 75th percentiles) is shown

[c]The 2013 National Census and 2013 Housing and Land Survey were used in our calculation

[d]The location information of the medical institutions by the Institute for Health Economics and Policy was used in our calculation

using STATA software version 14 (Stata Corp LP, College Station, TX).

Results

Table 1 shows the characteristics of the subjects, households, and districts. At the individual level, men made up 48.3% and median (25th and 75th percentiles) age was 61 (45, 66). At the household level, the equivalent income was JPY 1.02 (0.22, 1.84) million. At the district level: the land area was 9.48 (8.62, 10.41) km^2, the population was 58,480 (35,206, 82,103), number of medical institutions was 37 (25, 75), average income was JPY 4.85 (4.66, 5.14) million, and the Gini coefficient was 0.368 (0.352, 0.376). Of the subjects included in this study, 5888 (5.1%) had a mood disorder at some point in the 3-year period.

The result of the multilevel logistic regression analysis is shown in Table 2. The Gini coefficient was not associated with the incidence of mood disorders in all models (p for linear trend = 0.795 in Model 1, 0.856 in Model 2, and 0.947 in Model 3). Moreover, interaction between equivalent income and Gini coefficient was not significant (p for joint test of the interaction = 0.967), indicating that the impact of the Gini coefficient did not differ across groups with different income levels. However, lower equivalent income at the household level was associated with higher incidence of a mood disorder (p for linear trend < 0.001).

Table 2 Association between the Gini coefficient and the incidence of mood disorders using multilevel logistic regression analysis

	Number of subjects	Number of incidences	Incidence rate (%)	Model 1			Model 2			Model 3		
				OR	95% CI	p value	OR	95% CI	p value	OR	95% CI	p value
Gini coefficient												
Quartile 1	26,668	1357	5.1	1.00			1.00			1.00		
Quartile 2	36,809	1850	5.0	0.98	0.90–1.08	0.728	0.94	0.84–1.06	0.299	0.95	0.84–1.06	0.355
Quartile 3	27,967	1359	4.9	0.95	0.86–1.04	0.279	0.93	0.82–1.05	0.228	0.94	0.83–1.06	0.279
Quartile 4	25,214	1322	5.2	1.00	0.91–1.10	0.977	0.99	0.87–1.13	0.900	1.00	0.88–1.14	0.994
Equivalent income												
Quartile 1	24,574	1598	6.5	–			–			1.00		
Quartile 2	29,915	1551	5.2	–			–			0.80	0.74–0.87	< 0.001
Quartile 3	31,346	1410	4.5	–			–			0.69	0.63–0.75	< 0.001
Quartile 4	30,823	1329	4.3	–			–			0.63	0.58–0.69	< 0.001
AIC				46,033			45,878			45,762		

Model 1 is adjusted for sex and age at the individual level

Model 2 is adjusted for household type at the household level and number of residents, number of institutions, and average income within a 30-min walking distance at district level in addition to the same adjusted variables in Model 1

Model 3 is adjusted for equivalent income at the household level in addition to the same adjusted variables in Model 2

AIC Akaike's Information criterion, *CI* confidence interval, *OR* odds ratio

Discussion

This longitudinal study reveals that the Gini coefficient at the neighborhood level in Chiba City, Japan, is not associated with the incidence of mood disorders. Previous longitudinal studies evaluating income inequality at country and state levels reported an association between higher income inequality within regions and higher mortality rates resulting from all causes [12, 13], suicide and injury [16], higher incidence of depression [14], and heart attack [15]. Moreover, most cross-sectional and ecological studies of inequality at these levels have indicated a significant association between higher inequality and poor health [8–10, 31]. In contrast, with some exceptions [17, 18, 22, 24], many studies on inequality at the relatively smaller regional level found no significant association between inequality within regions and health [6, 19–21, 23, 25, 32–34]. Indeed, Bokerman et al. [35] and Fone et al. [25] have suggested that income inequality within a small population is often immaterial for health outcomes. Our results are in accordance with this suggestion.

This prompts the question of why inequality at an extensive regional level—such as the country or state level—has a negative effect on health but does not at a smaller level. One possible explanation is the similarity of institutional infrastructure among communities at a smaller district level, given that the target area is relatively narrow in these studies. For example, the subjects in our study lived in one city. As such, the social resources would be similar among districts. In contrast, the social resources—such as education, health insurance systems, health services, and food availability—in different countries and states would be correspondingly diverse. Countries and states with higher inequality might just have poor social resources, resulting in the poor health of its citizens. The other possible explanation is that individuals in a modern society with developed means for transmitting information—such as television and the internet—perceive their position by comparing themselves with the people living in a large region rather than with their neighbors. However, considering "the social capital hypothesis" in which higher income inequality within a community is associated with the erosion of social cohesion, resulting in an increased risk of social isolation, stress, and poor health, inequality within small regions should be important. Ichida et al. have shown that high social capital at a small spatial unit is significantly associated with good self-rated health and claimed that social capital in small communities plays an important role in enhancing health [24]. Nonetheless, our study reveals no association between income inequality at the neighborhood level and the incidence of mood disorders using a multilevel analysis. Thus, we cannot provide additional evidence to support this hypothesis.

In addition, our study reveals no significant cross-level interaction between the Gini coefficient at the district level and equivalent income at the household level—indicating no difference in the impact of inequality within communities on the incidence of mood disorders between individuals with lower and higher income. Some studies have suggested different effects of income inequality within communities according to income. Kahn et al., for example, have noted that high and medium income inequality were associated with an increased prevalence of depressive symptoms in the poorest group, but not in other groups [36]. Kennedy et al. have shown that the association of income inequalities was the strongest among lower income groups [3]. These studies were cross-sectional and did not employ a multilevel analysis. Subramanian et al. have argued that testing "cross-level interactions"—clarifying to whom income inequality is particularly detrimental—is particularly indispensable for a multilevel analysis [7]. We found no significant interaction between the Gini coefficient at the district level and equivalent income at the household level using a multilevel analysis.

In contrast to income inequality within a community, lower equivalent income at the household level was significantly associated with higher incidence of mood disorders in this study. This result is in accordance with a number of previous studies [6, 14, 15, 23, 34]. Indeed, Santiago et al. defined persistent poverty as "toxic for one's psychological health" [37]. We also ascertained that poverty is one of the potent causes for poor health.

This study has several advantages. The first of these is its data accuracy, since we used municipal administration data and identified individual incomes from tax records, residential areas from the resident registry, and the incidence of mood disorders as determined by health insurance claims. In studies that depend on self-reported questionnaires, some people do not respond. Indeed, Hirai et al. reported that subjects with lower income are less likely to response to a mail survey, especially in regard to items about income; and differences in response rates among various income groups induce bias [38]. Second, we calculated the Gini coefficient within a 30-min walking distance from each subject's residential point using GIS. Previous studies on income inequality at the neighborhood level used country-specific units for regions—such as *kyuuson*, which is approximately the same as a primary school district, in Japan [24]; Nomenclature of Units for Territorial Statistics 4 (NUTS 4) in Finland [32]; community districts in New York City [39]; and Lower Super Output Area (LSOA) in Wales [25]. Using a country-specific unit is not applicable to international comparisons. In contrast, an area within walking distance from the subject's residential point can be evaluated in any country using GIS. Moreover, the units for regions used in the previous studies [24, 25, 32, 39] have a fundamental drawback in

that these fixed geographical or administrative boundaries divides areas. Although people may live without being conscious of these boundaries, income inequality was evaluated using areas within these geographical or administrative boundaries. In contrast, the unit used in this study allows for the overlap of each region and is more representative of the neighborhood feeling that people have. Thus, we believe that our method to determine the district unit using GIS would be robust, especially for international comparisons in future studies.

This study also has several limitations. First, the target area of this study was one city, resulting in minor variations of income inequality at the neighborhood level. Indeed, the maximum and minimum Gini coefficient within a 30-min walking distance from a subject's residential point were 0.332 and 0.391, respectively. Generalizability is therefore also limited. Second, we could not follow all subjects during the 3 years (follow-up rate was 73.1%), and the reasons why they withdrew from NHI in Chiba City were unclear. Plausible reasons for doing so include their moving to another municipality, changing to another health insurance, or death. A comparison between the individuals who had been beneficiaries of NHI in Chiba City during the follow-up period and those who withdrew from the insurance is provided in Online Resource 1. The fact that subjects who had been beneficiaries of NHI during the follow-up period were apparently older than those who withdrew from the insurance prompted us to assume that the main reasons for withdrawal were a physical move and change of health insurance provider, but not death. Third, the potential confounding factors that we adjusted were limited. It is well known that the other confounding factors, such as marital status [9, 14], education [9, 11, 14, 21, 25], and past life events [14], are associated with mental health. We could not rule out the possibility that these factors might lead to a bias in the results. Fourth, our subjects were only the beneficiaries of NHI, comprising self-employed workers, retirees, and unemployed people as mentioned above. Therefore, the impact of inequality at the neighborhood level on mood disorders among the employees could not be analyzed in this study.

In conclusion, this longitudinal study using multilevel analysis shows that income inequality at the neighborhood level is not associated with the incidence of mood disorders and confirms that a lower income level at the household level in itself can have a harmful impact on mental health. Thus, political measures focusing on poverty alleviation could be a way to reduce mental health issues. Moreover, we believe that our method to determine a geographic unit would be robust, versatile, and applicable in making international comparisons in future studies.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethics statement As this was an observational study using existing data collated by Chiba City, consent was not obtained from each subject enrolled in this study. All personal information (e.g., names and telephone numbers) was removed from the records, and all data were anonymized before being provided. The study protocol was approved by the Research Ethics Committee of the Graduate School of Medicine, Chiba University (Approval Number 1724). The study was carried out in accordance with the principles of the Declaration of Helsinki and the Ethical Guidelines for Medical and Health Research Involving Human Subjects.

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