Development and validation of a rurality index for healthcare research in Japan: a modified Delphi study

Makoto Kaneko, Takaaki Ikeda, Machiko Inoue, Kemmyo Sugiyama, Manabu Saito, Ryuichi Ohta, Upul Cooray, Evelyn Vingilis, Thomas R Freeman, Maria Mathews

ABSTRACT

Objectives Rural–urban healthcare disparities exist globally. Various countries have used a rurality index for evaluating the disparities. Although Japan has many remote islands and rural areas, no rurality index exists. This study aimed to develop and validate a Rurality Index for Japan (RIJ) for healthcare research.

Design We employed a modified Delphi method to determine the factors of the RIJ and assessed the validity. The study developed an Expert Panel including healthcare professionals and a patient who had expertise in rural healthcare.

Setting The panel members were recruited from across Japan including remote islands, mountain areas and heavy snow areas. The panel recruited survey participants whom the panel considered to have expertise.

Participants The initial survey recruited 100 people, including rural healthcare providers, local government staff and residents.

Primary outcome measures Factors to include in the RIJ were identified by the Expert Panel and survey participants. We also conducted an exploratory factor analysis on the selected factors to determine the factor structure. Convergent validity was examined by calculating the correlation between the index for physician distribution and the RIJ. Criterion-related validity was assessed by calculating the correlation with average life expectancy.

Results The response rate of the final survey round was 84.8%. From the Delphi surveys, four factors were selected for the RIJ: population density, direct distance to the nearest hospital, remote islands and whether weather influences access to the nearest hospital. We employed the factor loadings as the weight of each factor. The average RIJ of every zip code was 50.5. The correlation coefficient with the index for physician distribution was −0.45 (p<0.001), and the correlation coefficients with the life expectancies of men and women were −0.35 (p<0.001) and −0.12 (p<0.001), respectively.

Conclusion This study developed the RIJ using a modified Delphi method. The index showed good validity.

INTRODUCTION

Rural–urban healthcare disparities exist globally, regardless of a country’s level of development. These disparities pose challenges to policymakers, healthcare providers and the public. People who live in rural areas have more chronic diseases compared with those living in urban areas. Furthermore, rural areas have fewer healthcare providers owing to difficulties in recruiting and retaining a workforce. In response to these issues, various countries have developed a rurality index for evaluating rural–urban health disparities and developing evidence-based policies. Rural indices, such as the Rurality Index of Ontario (RIO) in Canada and the Modified Monash Model in Australia have been used successfully in clinical research and policymaking. There are no universal measures or approaches for developing a rurality index because rurality is context-specific. For instance, RIO was developed using population density, time to the nearest basic referral centre and time to the nearest advanced referral centre. However, remote islands were not considered. Yet, Scotland’s rurality index, ‘clinical peripherality’, considers remote islands because Scotland has several remote islands. Therefore, each country or region must develop a rurality index based on their specific contexts.

Definitions of rural area in Japan

Japan has many remote islands in which 683,000 people (0.5% of the overall population) live. Additionally, 11 million people live in rural ‘depopulated areas’ (11% of the overall population and 58% of all the...
areas.\textsuperscript{8} Japan has some areas that experience heavy snowfall, and people living in these areas have limited access to healthcare during the winter months. As a consequence, Japan developed several definitions of ‘rural’. ‘Depopulated area’ is determined by the municipality’s income, demand and population decline rate.\textsuperscript{9} ‘Disadvantaged area’ is defined similarly to the depopulated area or by several acts of legislation addressing remote islands or areas that experience heavy snowfall, such as the ‘Remote Islands Development Act’ and the ‘Act on Special Measures concerning Countermeasures for Heavy Snowfall Areas’.\textsuperscript{10} The Act on Special Measures concerning Countermeasures for Heavy Snowfall Areas determines heavy snowfall areas and special heavy snowfall areas. ‘Special Heavy Snowfall Areas,’ which account for approximately 20\% of all land in Japan, represent areas in which heavy snow can hinder transportation and disrupt the daily lives of the residents.\textsuperscript{10} 11 This Act was legislated in 1962 and has been reviewed 10 times, with the last update in 2007. However, the above definitions of ‘rural’ have been used mainly for deciding the national government’s subsidy to residents and local governments but not for Japan’s healthcare system.

Healthcare system in Japan

In Japan, the governance of medical care is under the Ministry of Labour, Health and Welfare, which is responsible for policy setting and administration.\textsuperscript{12} Local governments are responsible for the delivery of primary, secondary and tertiary care.\textsuperscript{12} Generally, in Japanese settings, primary care means patient care in the outpatient setting, and secondary care refers to hospitalised care. Tertiary care plays a significant role in providing advanced medical care, such as organ transplantation or surgical procedures for rare congenital diseases.\textsuperscript{13} Although the administrative distinction between primary, secondary and tertiary care is defined above, there is no patient registration system for primary care facilities and a patient can access a secondary care hospital without a referral from a primary care physician.\textsuperscript{12} Therefore, from a patient’s perspective, the boundary between primary and secondary/tertiary care is ambiguous and some patients use not a clinic but a hospital as their usual source of care.\textsuperscript{12,14}

Primary care service areas comprise approximately 1700 districts (eg, cities, towns and villages), secondary care service areas comprise 344 jurisdictions and tertiary care service areas comprise 52 areas.\textsuperscript{14} The provisioning system for emergency care is essentially based on the population of each secondary care service area.\textsuperscript{14} Japan’s ‘rural area’ in healthcare policy has been mainly based on population and the distance to the nearest medical institution; the area is called ‘non-doctor districts’.\textsuperscript{15} However, the indicator is dichotomous: ‘non-doctor districts’ or not and does not describe gradation between rural and urban. Also, because of depopulation in these rural areas, maintaining rural medical facilities has become difficult. Therefore, updating the definition of ‘rural area’ in Japanese healthcare is warranted. Such a rurality index can be indispensable for a country as it can provide healthcare policymakers as well as researchers with a single, consistent operational definition and gradient of rurality by which to assess rural–urban healthcare disparities and to identify rural regions in need of appropriate healthcare services.

AIMS

The aim of this study was to develop and validate a Rurality Index for Japan (RIJ) for use in Japanese healthcare policy development and research. As a first step toward developing an RIJ, we conducted a scoping review in 2020.\textsuperscript{6} The review identified frequently used variables, methods for calculating indices and validation measures used in previous rurality indices over the past 30 years.\textsuperscript{6} In this study, we developed and validated an RIJ based on the results of our scoping review\textsuperscript{6} and the consensus of healthcare providers, policymakers and residents using the Delphi method.

METHODS

Study design

We employed a modified Delphi method in this study. The Delphi method is suitable for establishing consensus for the research problem, which can benefit from subjective judgements on a collective basis.\textsuperscript{16} The Delphi method facilitates anonymity in responses, gathers expert opinions, employs sequential questionnaires without face-to-face discussions and uses frequency distributions to identify patterns of agreement through two or more rounds of surveying.\textsuperscript{16} The approach is used widely in medical and health services research.\textsuperscript{17} The modified Delphi method, unlike the original Delphi, offers a research team the opportunity to discuss opinions between survey rounds.\textsuperscript{18}

Procedure and statistical analysis

Figure 1 shows the flow chart of the process of development and validation of the RIJ. This study included three Phases and three Rounds of data collection under Phase 1. Briefly, in Phase 1, Round 1, we convened an Expert Panel. In Round 2, the Expert Panel identified potential factors for the RIJ based on a previously conducted scoping review.\textsuperscript{6} In Round 3, the Expert Panel developed a survey including the identified potential factors. They recruited 100 participants with expertise in rural healthcare and conducted three sets of surveys. In Phase 2, we developed the formulation of the RIJ based on the results of Phase 1. We subsequently conducted content, factorial, convergent and criterion-related validity assessments on the results as part of Phase 3. These Phases are described in detail below.

Phase 1: modified Delphi methods for identifying and rating factors to be considered in RIJ

Round 1: developing an Expert Panel

The first step was to identify and convene an Expert Panel to oversee all aspects of the study. The initial Expert Panel
consisted of five general practitioners who had practiced in rural areas of Japan. Four were members of the committee of rural and remote medicine in the Japan Primary Care Association. The other was a professor of family medicine and a director of a rural family medicine residency programme. To make the Expert Panel more representative, the five physicians, based on their knowledge and existing relationships, recruited the following other members who had engaged in rural practice and had expertise in rural healthcare: a nurse who had worked on a remote island, a public health nurse who practised on a remote island and had educational experience in rural healthcare, and a nurse practitioner who had worked in a rural area. To include patient perspectives, the panel invited a patient who was a leader of a patient group for developing a sustainable healthcare system for rural areas. The panel members were recruited from rural areas across Japan including remote islands, mountain areas and heavy snow areas.

The first meeting was held with the Expert Panel on 20 April 2021 online. At this meeting, the initial discussion of the Expert Panel was on the determination of a unit of analysis for the rurality index in Japan. The consensus was to employ the zip code as a minimum unit for the index because the zip code is suitable for describing location information and other administrative districts, such as cities or towns that can include both rural and urban areas in one district.

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**Phase 2: Development of formulation of the RIJ**

To normalise the included factors
- Mini-max normalisation

To determine the factor structure and weight
- Exploratory factor analysis

**Phase 3: Validation test**

<table>
<thead>
<tr>
<th>Content validity</th>
<th>Discussion on domains by the Expert Panel</th>
</tr>
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<tr>
<td>Factorial validity</td>
<td>Factor analysis</td>
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<td>Convergent validity</td>
<td>Correlation between the RIJ and the index for physician distribution</td>
</tr>
<tr>
<td>Criterion-related validity</td>
<td>Correlation between the RIJ and average life expectancy</td>
</tr>
<tr>
<td>Determining cut-off value</td>
<td>Receiver Operating Characteristic curve and Youden index</td>
</tr>
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</table>

**Figure 1** Flow chart of the process of development and validation of the Rurality Index for Japan.

For Round 2, the Expert Panel convened through a video conferencing meeting that was recorded. The second meeting was held on 8 July 2021. At the meeting, the first author began with a summary of the scoping review findings. According to our previous scoping review, the frequently used variables in the existing rurality indices are population (size or density), travel distance/time to emergency care and/or referral centre, as well as resource availability, such as the number of physicians (primary care physicians and specialists). Subsequently, the Expert Panel reviewed all the factors one by one and discussed other potential factors based on their expertise considering the Japanese healthcare context.

For example, Japan has many remote islands, and sometimes, a patient can only access a secondary hospital by travelling by a ship or an aeroplane. Additionally, in Japan, secondary hospitals play a significant role as referral centres, and they provide out-of-hours care for patients who potentially require admission after hours.

Therefore, travel distance or time to a secondary hospital must be considered. Access to medical facilities may also be affected by the weather. After the discussion, the Expert Panel developed a list of potential factors for the RIJ. They assessed content validity through discussions on domains and subdomains to be included in the survey.

Round 3: online surveys (modified Delphi methods)

The Expert Panel recruited stakeholders for the Round 3 survey through snowball sampling. The Expert Panel identified stakeholders who had expertise in rural healthcare. Previous literature on the methodology for the Delphi method provided no agreement on sample size for the survey and many published Delphi studies employed 10–100 or more participants. Therefore, in this study,
the Expert Panel recruited 100 stakeholders as potential participants. The inclusion criteria for survey participants were rural healthcare providers, government officers and residents that the Expert Panel considered would have opinions about rural health based on their knowledge and experience: for example, a resident who is a member of a committee for developing a sustainable healthcare system for rural areas. The Expert Panel also included local government officers who had been engaged in healthcare policy in rural areas because perspectives from an administrator in rural areas were important to use in the development of the index for healthcare policy. There were no specific exclusion criteria; the reason is that we aimed to include diverse perspectives from not only healthcare providers but also rural residents. Nine Expert Panel members recruited 10 participants each, and one member (MK) recruited 20 participants. The Expert Panel members were recruited from rural areas across Japan including remote islands, mountain areas and heavy snow areas. Although the study did not obtain information on the survey participants’ regional demographics in detail, the Expert Panel members had local connections with the participants. Thus, the survey participants would have various regional backgrounds.

An Expert Panel method was used to develop the survey. The initial draft of the survey was developed by one of the Expert Panel members (MK), and the Expert Panel reviewed and revised subsequent versions of the survey. Three consecutive online surveys were conducted from August 2021 through October 2021 to obtain a consensus on the factors included in the RIJ. The participants of the online survey received an email invitation from a member of the Expert Panel. The email invitation contained a link to the online survey. Participants were asked to rate the importance of each factor using a 6-point Likert scale (1=not important at all; 6=extremely important) and offer written feedback/suggestions. Consensus on factors that should be included in the rurality index was set a priori and defined as at least 80% agreement (we regarded 5 or 6 as agreement) based on recommendations and consensus levels used in the previous Delphi studies.

The demographic characteristics of the survey participants and the level of consensus for each factor were examined using descriptive statistics, including frequencies and percentages. Comments/suggestions on survey items were transcribed into a single report for review and discussed by the Expert Panel. There were three surveys. Following the first survey, the expert panel reviewed the results and feedback from survey participants. The second survey retained the factors that had met the 80% agreement threshold, and proposed factors that had been revised based on the feedback. Only participants who responded to the first survey were invited to complete the second survey. The third survey incorporated the results and feedback from the second survey. Participants who responded to the second survey were invited to complete the third survey.

Phase 2: formulation of the RIJ based on the results of Phase 1
To normalise the included factors, we employed min-max normalisation. We also conducted exploratory factor analysis through the Promax rotation using the identified four factors to determine the factor structure. We employed a Scree Plot to determine the number of factors. We used the calculated value from the factor loading as the weight of each factor.

Phase 3: validation test
Factorial validity was verified using the results obtained from the exploratory factor analysis conducted in Phase 2. Convergent validity was examined by calculating the Pearson correlation coefficient between the index for physician distribution per 100,000 people and the developed rurality index. The index for physician distribution was developed from the standardised number of physicians and the population and standardised consultation ratio in each region. This index has been used to describe the uneven distribution of doctors in secondary or tertiary healthcare service areas. Therefore, in this study, we evaluated the correlation between the RIJ and the index for physician distribution in each secondary healthcare service area. Criterion-related validity was assessed by calculating the correlation between average life expectancy in each municipality and the rurality index because a previous study reported that rurality is negatively correlated with life expectancy and there are no other suitable rurality indices in Japan by which to evaluate criterion-related validity. We also calculated the cut-off of the RIJ using ‘depopulated area’ and ‘disadvantaged area,’ which are the existing definitions of rurality in Japan, as the reference standards. The cut-off was determined using the Youden index. All statistical analyses were conducted using StataCorp. 2017. Stata Statistical Software: Release 15. College Station, Texas, USA: StataCorp LLC.

Patient and public involvement
This study invited residents in rural areas as stakeholders and participants of the Delphi survey. The residents were invited to comment on the study design and consulted on the relevance of the research. The study protocol was performed following the Declaration of Helsinki. Informed consent was obtained from all study participants.

RESULTS
In Phase 1, out of 100 potential participants, 85 responded to the survey (response rate: 85%, median age: 45 years, men: 55.3%, women: 43.5% and prefer not to answer: 1.2%). The participants’ demographic characteristics in the first, second and third surveys are shown in Table 1. Table 2 shows the list of potential factors determined by the survey participants and through the results of the first and second surveys. The changes of the term or
combining the factors determined by the Expert Panel are also described in Table 2. Specifically, at the start of the first survey, 16 factors were listed. Four factors reached 80% agreement and the others did not reach 80% agreement. As shown in Table 2, three of the four factors were related to a remote island issue and were combined into one factor, ‘remote island’, based on the Expert Panel’s discussion. At the end of the first survey round, only two factors remained: remote islands and direct distance to the nearest secondary or tertiary hospital. (‘Secondary or tertiary hospital’ means secondary or tertiary emergency care hospital.) Thus, the Expert Panel decided further discussion was necessary to modify the other factors’ expression. Through the Expert Panel members’ discussion, legal terms such as ‘disadvantaged areas’ and ‘heavy snowfall areas’ were changed because the meaning of the terms might be difficult to understand for the participants. The changes in the items are shown in Table 2. In the second round of surveying, only participants who had completed the first round were asked to complete the second survey round. After the second survey, three factors reached 80% agreement: direct distance to the nearest secondary or tertiary hospital from the centre of each zip code area, remote islands and whether weather influences access to the nearest secondary or tertiary hospital. The Expert Panel combined ‘distance to the nearest hospital which provides care for patients with acute stroke’ and ‘Distance to the nearest hospital which provides care for patients with an acute heart attack’ into ‘Distance to the nearest secondary or tertiary hospital’ because it is difficult to know whether each secondary hospital offers care for acute stroke or heart attack from public data. Although population density is the most frequently used factor for rurality indices in previous studies, it was not included at that stage. Therefore, the Expert Panel discussed the issue and conducted the third survey. The third survey proposed two models: a three-factor (distance, island and weather) model and a four-factor model (three-factor model plus population density). In the third survey, we requested the participants to choose either one.

In the third survey, the response rate was 84.8% and 71.4% of the participants selected the four-factor model involving distance, island, weather and population density. Therefore, we included the following four factors into the RIJ: population density in each zip code, direct distance to the nearest secondary or tertiary hospital from the centre of each zip code area (Euclidean distance), remote islands and whether weather, such as typhoons or heavy snowfall, influences access to the nearest secondary or tertiary hospital. Because the line between secondary and tertiary care is ambiguous in Japan and because the survey participants regarded care for acute diseases, such as stroke, heart attacks and obstetrical delivery, as important, we included both secondary and tertiary hospitals. We also defined a remote island as an island other than the four main islands in Japan (Hokkaido, Honshu, Shikoku and Kyushu) and an island without a secondary or tertiary hospital. Additionally, the Expert Panel defined areas in which ‘access to a secondary or tertiary hospital is affected by the weather’ as ‘special heavy snowfall areas’ based on the Act on Special Measures concerning Countermeasures for Heavy Snowfall Areas because in Japan, access to healthcare services in such areas is mainly hindered by typhoons and heavy snowfall, and typhoons may already be accounted for by the factor of ‘remote islands’. The Expert Panel regarded the zip code areas in special heavy snowfall areas’ were changed because the meaning of the terms might be difficult to understand for the participants.

<table>
<thead>
<tr>
<th>Demographic characteristics</th>
<th>First survey N=85 n (%)</th>
<th>Second survey N=66 n (%)</th>
<th>Third survey N=56 n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response rate (%)</td>
<td>85</td>
<td>77.6</td>
<td>84.8</td>
</tr>
<tr>
<td>Age (year)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–29</td>
<td>4 (4.7)</td>
<td>3 (4.6)</td>
<td>2 (3.6)</td>
</tr>
<tr>
<td>30–39</td>
<td>30 (35.3)</td>
<td>22 (33.3)</td>
<td>14 (25.0)</td>
</tr>
<tr>
<td>40–49</td>
<td>28 (32.9)</td>
<td>21 (31.8)</td>
<td>16 (28.6)</td>
</tr>
<tr>
<td>50–59</td>
<td>12 (14.1)</td>
<td>11 (16.7)</td>
<td>10 (17.9)</td>
</tr>
<tr>
<td>60–69</td>
<td>5 (5.9)</td>
<td>4 (6.1)</td>
<td>6 (10.7)</td>
</tr>
<tr>
<td>70–79</td>
<td>6 (7.1)</td>
<td>5 (7.6)</td>
<td>8 (14.3)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>47 (55.3)</td>
<td>36 (54.5)</td>
<td>29 (51.8)</td>
</tr>
<tr>
<td>Female</td>
<td>37 (43.5)</td>
<td>29 (43.9)</td>
<td>27 (48.2)</td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>1 (1.2)</td>
<td>1 (1.5)</td>
<td>0</td>
</tr>
<tr>
<td>Others</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High school</td>
<td>7 (8.2)</td>
<td>5 (7.6)</td>
<td>4 (7.1)</td>
</tr>
<tr>
<td>College</td>
<td>11 (12.9)</td>
<td>10 (15.2)</td>
<td>11 (19.6)</td>
</tr>
<tr>
<td>University</td>
<td>46 (54.1)</td>
<td>38 (57.6)</td>
<td>31 (55.4)</td>
</tr>
<tr>
<td>Masters</td>
<td>16 (18.8)</td>
<td>11 (16.7)</td>
<td>7 (12.5)</td>
</tr>
<tr>
<td>Doctorate</td>
<td>5 (5.9)</td>
<td>2 (3)</td>
<td>3 (5.4)</td>
</tr>
<tr>
<td>Occupation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doctor</td>
<td>43 (50.6)</td>
<td>33 (50)</td>
<td>28 (50)</td>
</tr>
<tr>
<td>Nurse</td>
<td>8 (9.4)</td>
<td>7 (10.6)</td>
<td>4 (7.1)</td>
</tr>
<tr>
<td>Public health nurse</td>
<td>4 (4.7)</td>
<td>3 (4.5)</td>
<td>3 (5.4)</td>
</tr>
<tr>
<td>Local government staff</td>
<td>2 (2.4)</td>
<td>1 (1.5)</td>
<td>2 (3.6)</td>
</tr>
<tr>
<td>Others (rural residents, academic faculty, etc)</td>
<td>21 (24.7)</td>
<td>16 (24.2)</td>
<td>11 (19.6)</td>
</tr>
<tr>
<td>Not employed</td>
<td>7 (8.2)</td>
<td>6 (9.1)</td>
<td>8 (14.3)</td>
</tr>
</tbody>
</table>

*Although the participants who did not join the second survey were not invited to the third survey, in some categories (e.g., 60–69 years old), the number of participants in the third survey was higher than that in the second survey. This might be explained by the wrong input of the participants or participant ageing between surveys.
For all the 113952 zip codes in Japan, we calculated population density and direct distance to the nearest secondary or tertiary hospital. We identified every zip code as snowfall areas and those without a secondary or tertiary hospital as the areas in which ‘access to a secondary or tertiary hospital is affected by the weather’.

### Table 2 Percentages of agreement in potential factors for the Rurality Index for Japan

<table>
<thead>
<tr>
<th>Potential factors</th>
<th>Percentages of agreement</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First survey</td>
<td>Second survey</td>
</tr>
<tr>
<td>Population density</td>
<td>77.6</td>
<td>68.2</td>
</tr>
<tr>
<td>Distance to the nearest secondary or tertiary hospital</td>
<td>83.5</td>
<td></td>
</tr>
<tr>
<td>Distance to the nearest hospital which provides care for patients with acute stroke</td>
<td>74.1</td>
<td>83.4</td>
</tr>
<tr>
<td>Distance to the nearest hospital which provides care for patients with an acute heart attack</td>
<td>76.5</td>
<td>86.4</td>
</tr>
<tr>
<td>Distance to the nearest hospital which provides care for pregnant women for delivery</td>
<td>72.9</td>
<td>77.3</td>
</tr>
</tbody>
</table>
| Disadvantaged area                                                               | 57.6          |               | Changed into ‘population decline rate’*
| Heavy snowfall area                                                              | 49.4          |               | Combined with ‘Whether weather such as heavy snow influences access to the nearest secondary or tertiary hospital’ |
| Remote island                                                                    | 90.6          |               | Included                    |
| Remote island with a clinic or hospital                                         | 92.9          |               | Combined into ‘remote island’ |
| Bridge between remote island and main island                                    | 81.2          |               | Combined into ‘remote island’ |
| Whether weather such as heavy snow influences access to the nearest secondary hospital  | 75.2          | 83.3          | Included                    |
| Availability of public transportation to the nearest secondary hospital          | 70.6          | 59.1          | Rejected                    |
| Availability of emergency helicopter to the nearest secondary hospital          | 65.9          | 78.8          | Rejected                    |
| Availability of house call                                                      | 41.2          | 53.0          | Rejected                    |
| Community General Support Centre                                                | 27.1          | 50.0          | Rejected                    |
| Availability of care management for elderly                                     | 34.1          | 78.8          | Rejected                    |
| Additional factors from the second survey by the steering team discussion        |              |               |                            |
| Population decline rate                                                         | 54.5          |               | Rejected                    |
| Proportion of people aged 65 years and over                                     | 68.2          |               | Rejected                    |
| Proportion of people aged 15–29 years                                           | 59.1          |               | Rejected                    |
| Comments                                                                         |              |               |                            |
| Distance to the nearest pharmacy.                                               |              |               |                            |
| Availability of CT/MRI.                                                          |              |               |                            |
| Physician/population ratio.                                                      |              |               |                            |

Community General Support Centre: The centre provides community-based-integrated care, including living arrangements, social care and daily life support services. Care management: Care management means coordination by licensed care managers of the different services provided by different providers to accommodate geographically dispersed home settings. The definition of the disadvantaged area included the population decline rate.

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Figure 2  (A) The Rurality Index for Japan by zip code. (B) The Rurality Index for Japan by the municipality. (C) The Rurality Index for Japan by secondary healthcare service area.
code associated with a remote island and special heavy snowfall areas. Two common factors were extracted based on the initial explanatory factor analysis. Factor loadings were rotated using the Promax rotation to interpret the factors. Therefore, population density and special heavy snowfall areas were classified into one group labelled ‘population/climate factors’. In addition, direct distance to the nearest secondary or tertiary hospital and remote islands were grouped as ‘distance factors’. Exploratory factor analysis through the Promax rotation revealed the factor loading of each factor as follows: population density: −0.3; direct distance to the nearest secondary or tertiary hospital: 0.46; remote islands: 0.47, and special heavy snowfall areas: 0.3. We employed the factor loadings as the weight of each factor and created a pre-conversion RIJ as follows:

$$\text{Pre-conversion RIJ} = \text{population density} \times (-0.3) + \text{direct distance to the nearest secondary or tertiary hospital} \times 0.46 + \text{remote island} \times 0.47 + \text{special heavy snowfall areas} \times 0.3$$

We calculated the pre-conversion RIJ and converted the score into integers. The total scores were ranked on a scale of 1–100, and they were used as the RIJ. Higher scores represented increased levels of rurality.

The average rurality index for every zip code in Japan was 50.5 (SD: 28.9), and the average rurality index in depopulated areas was 75.7 (SD: 20.6), and that in disadvantaged areas was 66.9 (SD: 24.9). We also calculated the rurality index for every municipality and secondary healthcare service area using an average of the pre-converted RIJ for each area. We created the maps based on the RIJ for every zip code, municipality and secondary care service area. The maps are shown in figure 2A–C. In the figures, areas with higher rurality are depicted in red colour. Because ‘Special Heavy Snowfall Areas’ are located in the northern areas of Japan, that part is presented in a darker red colour. Also, remote islands without secondary or tertiary hospitals are shown in a darker red colour. Around Tokyo or other big cities are described in a greener colour. The Expert Panel agreed that the maps were consistent with clinical realities based on the visual inspection.
We also examined the correlation between the RIJ and the index for physician distribution in each secondary healthcare service area or the average life expectancy in each municipality. The correlation coefficient of the RIJ through the index for physician distribution was $-0.45$ ($p<0.001$). The correlation coefficients of the RIJ through the life expectancies of men and women were $-0.35$ ($p<0.001$) and $-0.12$ ($p<0.001$), respectively. The scatter plots are shown in figure 3A–C.

We used receiver operating characteristic (ROC) curves to plot the sensitivity (true-positive rate) against the specificity (false-positive rate) of the pre-conversion RIJ using the depopulated areas and disadvantaged areas as the reference standards. The Youden value indicates the optimal cut-off value. The cut-off value of the pre-conversion RIJ for depopulated areas is 0.00197, the sensitivity at the cut-off is 0.65, the specificity at the cut-off is 0.84 and the area under the curve at the cut-off is 0.83. For disadvantaged areas, the cut-off value is 0.00147, the sensitivity at the cut-off is 0.74, the specificity at the cut-off is 0.79 and the area under the curve at the cut-off is 0.84. The ROC curves are shown in the online supplemental figure S1A,B.

**DISCUSSION**

**Summary of the findings**

We developed the RIJ using a modified Delphi method. This is the first study to create a rurality index for healthcare in Japan. The index comprises four factors: population density in each zip code, direct distance to the nearest secondary or tertiary hospital from the centre of each zip code area, remote islands and whether weather, such as typhoons or heavy snowfall influences access to the nearest secondary or tertiary hospital. The RIJ showed good factorial, convergent and criterion-related validities. The RIJ can be used to redefine ‘rural area’ in the Japanese healthcare setting and to examine rural–urban disparity. Also, the RIJ can be used not only for describing the disadvantages of rural practice but also the advantages of it such as comprehensive care or a broader scope of practice.

**Comparison with existing literature**

Two of the included factors, population density and distance to the nearest secondary or tertiary hospital, were consistent with previously developed rurality indices in other countries or regions. Our previous scoping review revealed that population density is the most frequently used factor, whereas distance and time are the second most frequently used factors. Another common factor is resource availability, such as the number of physicians, including primary care physicians and specialists, or the physician/population ratio. However, in Japan, the boundary between primary care and secondary care is unclear, and defining a primary care provider is difficult. Therefore, such resource availability may not have been identified as a factor of rurality in a Delphi method used in this study.

Inherently, rurality is dependent on the context of each country or region. The remaining two factors, remote islands, and weather might reflect the Japanese context. Similarly, Scotland includes remote islands in their rurality index, and as such, their index might be similar to that used in Japanese contexts. Moreover, because climate change can affect access to healthcare, the inclusion of weather in a rurality index might become important for other countries.

The RIJ showed acceptable validity. We assessed factorial, convergent and criterion-related validities. In previous studies, only 29% of all indices examined validity. Content validity is crucial owing to its context-specific nature, and conducting validation using different aspects is a major strength of our study.

**Limitations of the study**

First, we employed direct distance rather than actual distance to assess the distance from each zip code to the nearest hospital owing to the difficulty of measuring the actual distance. However, direct distance and actual distance are relatively correlated. Therefore, the use of direct distance should not skew the index. Second, we did not consider the availability and frequency of public transportation, such as ships or aeroplanes. These factors are important for rural residents, especially islanders. Because information on the availability and frequency of public transportation might change often, employing it in the rurality index for all of Japan is difficult, and it may result in inconsistencies over time. However, in Japan, public transportation is mainly used in metropolitan areas compared with rural prefectures. Therefore, the lack of or the frequency of public transportation, as they pertain to the RIJ, might not affect most rural areas. Third, the figures for the included factors may change over time. For example, the special snowfall areas also may change due to global warming. Therefore, we shall update the data and share the new RIJ on our website to ensure easy access for researchers and policymakers.

**Implication of the study**

As expected, this study revealed that the RIJ negatively correlates with physician distribution and life expectancy among men and women. Because there is currently no index for describing the degree of rurality in Japan, the RIJ can be used to evaluate rural–urban discrepancies related to health outcomes and the health workforce. The RIJ can also be used to determine the required scope of practice in each rurality level, as is the case in Australia.

**CONCLUSIONS**

In this study, we developed a rurality index in Japan (RIJ) using a modified Delphi method. The index showed good factorial, convergent and criterion-related validities. The RIJ can be a useful tool for assessing rural–urban disparity,
workforce recruitment and retention policies, as well as accessibility to other healthcare resources in rural areas throughout Japan.

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**Contributors**

MK designed the study and participated in the implementation, data collection, data analysis and writing of the manuscript. MK also serves as the guarantor. MI, KS, MS, RO, UC, EV, TRF and MM contributed to the design of the study and critically reviewed the manuscript. All authors had full access to the data and take responsibility for the integrity of the data and the accuracy of the analysis.

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**Competing interests**

None declared.

**Patient and public involvement**

Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

**Patient consent for publication**

Consent obtained directly from patient(s).

**Ethics approval**

This study involves human participants and was approved by the Ethics Committee of Yokohama City University (approval number: B210100001).

**Provenance and peer review**

Not commissioned; externally peer reviewed.

**Data availability statement**

Data are available upon reasonable request. The data sets are available from the corresponding author on reasonable request.

**Supplemental material**

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Sensitivity: 0.65
Specificity: 0.84

Area under ROC curve = 0.8279
Sensitivity: 0.74
Specificity: 0.79

Area under ROC curve = 0.8397