Systematic scoping review of factors and measures of rurality: toward the development of a rurality index for health care research in Japan

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Abstract

Background

Rural-urban health care disparities are an important topic. Hence, assessing rurality and evaluation of health outcomes based on rurality are indispensable. However, there is no universal measure of rurality and Japan has no index to evaluate rurality for health care research. This study aimed to conduct a systematic scoping review to identify the important factors and methods of measuring rurality to inform the future development of a rurality index in Japan.

Methods

For our review, we searched six bibliographic databases (MEDLINE, PubMed, CINAHL, ERIC, Web of Science and the Grey Literature Report) and official websites of national governments such as Government and Legislative Libraries Online Publications Portal (GALLOP), from 1 January 1989 to 31 December 2018. We extracted relevant variables used in the development of rurality indices, the formulas and reliability/validity measures.

Results

We identified 17 rurality indices in 7 countries. These indices mainly aimed to assess access to health care or to decide incentives for health care providers. Frequently used
variables for the indices were population size/density, travel distance/time to emergency care or referral centre. Many indices did not examine reliability and validity.

Conclusions

While the concept of rurality and concerns about barriers to access to care for rural residents is shared by many countries, the operationalization of rurality is highly context-specific, with few universal measures or approaches to constructing a rurality index. The results will be helpful to develop a rurality index in Japan and other countries/areas.

Key words: geography, health services research, Japan, rurality index, scoping review
Background

Rural-urban health care disparities are an important challenge for health care providers. Numerous studies have reported that rural residents are more likely to have chronic diseases related to obesity and less likely to engage in healthy behaviours compared to urban residents.\textsuperscript{1-4} Since rural residents have a difficulty in access to health care providers, they visit family physicians/specialists less frequently than those in urban areas.\textsuperscript{5,6} Moreover, living in a rural area is associated with lower physical/social functioning, mental health, health perception\textsuperscript{7}, health of cancer survivors\textsuperscript{8} and overall quality of life.\textsuperscript{9} Also, recruitment and retention of the health care workforce are major challenges in rural areas.\textsuperscript{10}

Therefore, assessing rurality and evaluation of health outcomes based on rurality are indispensable. However, there is no universal measure of rurality\textsuperscript{11} and researchers and policy makers have employed different measures for their own purposes. For instance, Ontario, Canada uses the Rurality Index of Ontario (RIO)\textsuperscript{12} and Australia developed the Modified Monash Model (MMM).\textsuperscript{13} The RIO was originally developed in 2000 for policy development, especially for policies and incentives aimed at physician recruitment and retention in rural areas.\textsuperscript{12} The MMM was generated from Humphreys’s
(2012) paper and was also established for the recruitment and retention of health care providers.\textsuperscript{13}

A number of different measures have been included in rurality indices. These measures include population, population density, travel time to basic/advanced referral centres, geographical remoteness etc.\textsuperscript{12,13} Additionally, different methods have been used to calculate these indices. For example, the RIO used a sum of community population, travel time to nearest referral centre and travel time to nearest advanced referral centre.\textsuperscript{12} This resulted in a continuous variable ranging from 0 to 100. The lower the number, the more rural the setting.\textsuperscript{12} The MMM used a combination of population size and geographical remoteness which provides a 6-level classification with 1 representing a major city and 7 representing a high level of remoteness.\textsuperscript{13}

These indices have been widely utilized not only for recruitment/retention\textsuperscript{14,15} but also for health care research in rural areas, such as the prediction of high-cost health care users\textsuperscript{16} or estimation of prevalence of comorbidity among patients with HIV\textsuperscript{17} in these jurisdictions. The measurement of rurality in each country or jurisdiction is an important step for assessing accessibility, health outcomes and workforce shortage.

However, in Japan, researchers and policy makers do not have a rurality index. Japan
has 6,800 islands and 683,000 (0.5% of overall population) live on these islands.\textsuperscript{18} Also, 11 million people live in rural areas called “depopulated areas” (11% of overall and the area is 58% of all areas).\textsuperscript{18} Although the national government classified the “depopulated area” based on the municipality’s income, demand and population trends, it is determined rather qualitatively with no concrete definition or formula to consistently apply.\textsuperscript{19} Moreover, access to health care and medical resources varies greatly in these areas. Developing a rurality index which includes a measure of access to health care resources in Japan will promote clinical research in rural areas and be a more appropriate evaluation of Japanese rural medicine.

The overall goal of this project is to identify the important factors and methods of measuring rurality for the purposes of ultimately developing a rurality index in Japan. This scoping review is the first study of our project. The results of the scoping study will be used in a future study to develop a rurality index which will include a measure of access to health care resources for use in Japanese health care research. The findings also will be useful for other countries/areas to develop a new rurality index.

\textbf{Aims}
The aims of the scoping review are to 1) describe the publication characteristics of rurality indices, 2) identify commonly used factors in rurality indices, and 3) assess validity and reliability properties of published rurality indices.

**Methods**

**Study Design**

A systematic scoping review.

A systematic scoping review is a review of existing literature to clarify a complex concept and refine subsequent research.\(^{20}\) Usually, a systematic scoping review does not assess the quality of included studies, unlike a systematic review.\(^{20}\) Also, a systematic scoping review is different from a narrative review because the scoping process requires analytical reinterpretation of the included literature.\(^{20}\) This approach is suitable for a discipline in which the shortage of randomized control trials makes it difficult for investigators to conduct a systematic review.\(^{20}\) Arksey and O'Malley\(^ {21}\) presented a six-stage methodological framework to be used for scoping reviews that were further expanded by Levac et al.\(^ {20}\) This framework includes the following stages: identification of the research question; identification of relevant studies; selection of studies; charting of the data; collation, summarizing and reporting the results.
The research question of this study is to identify factors and methods to develop a rurality index, which will be used in a subsequent study to develop, implement and evaluate a Japanese rurality index to be used for the health care system and related research.

**Search Strategy (Identifying Relevant Studies)**

In the present study, we followed the systematic scoping review framework of Arksey and O’Malley (2005)²¹ and Levac et al (2010)²⁰ and the preferred reporting approach of PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation.²² This checklist includes 20 essential reporting items that reflect on the title, abstract, introduction, methods, results, discussion and funding.²² We developed a protocol for this study a priori. Although the protocol was not made publicly available, we can share the protocol a reader as necessary. We included articles and websites in English and Japanese. We searched the following bibliographic databases (MEDLINE, PubMed, CINAHIL, ERIC, Web of Science and the Grey Literature Report) to identify papers on rurality index. Also, we searched Government and Legislative Libraries Online Publications Portal (GALLOP), Registry of Canadian Government Information Digitization Projects, Canadian Research Index – Microlog, Municipal Information
Network, Canadian Public Policy Collection, United Nations digital library, the US Census website and Organization for Economic Co-operation and Development (OECD) library to look for rurality index information employed by national/local governments around the world based on feedback received from a Western University librarian. Moreover, we used Japanese databases, Ichushi-Web. Ichushi-Web is an online Japanese literature searching system provided by the non-profit Japan Medical Abstracts Society. Ichushi-Web covers about 10 million medical papers from 6000 journals in Japan and is often used for Japanese literature searches.23 We included studies that were published from 1 January 1989 to 31 December 2018 (the last 30 years) and websites. The search strategy was based on the following title/abstract keywords in English and Japanese: “rurality” OR “rurality index” OR “index of rurality” OR “rurality measurement” OR “remoteness index” OR “accessibility index” OR “population density index”. Moreover, we added “develop” OR “create” OR “construct” OR “generate” to above key words to search for information on development of a rurality index. In addition, we used MESH term: "Rural Health Services/classification" OR "peripherality index". We also reviewed the reference lists of relevant studies to identify research that might have been missed in the database search.
Inclusion/Exclusion Criteria (Study Selection)

Literature searches and data extraction were independently conducted by two investigators (MK and RO) and any discrepancies were resolved by discussion. In the present study, databases were searched for rurality index for health care research.

To develop a rurality index for Japanese health care providers and policy makers, this study included articles and websites related to developing a rurality index. This study also included literature reviews associated with developing a rurality index. This study excluded articles and websites only using a previously developed rurality index.

Data Extraction (Charting Data)

Extracted information based on a pilot search is shown in Table 1.
Table 1. Extracted information

| Data                                                                 |
|----------------------------------------------------------------------|
| Title of the article                                                 |
| Name of authors                                                      |
| Year of publication                                                  |
| Name of the journal/website                                          |
| Publication status: yes/no                                           |
| Peer review status: yes/no                                           |
| Citation index by Web of Science                                    |
| Country/province                                                    |
| Unit of analysis: geographical jurisdiction/health care institution/individual |
| Continuous or categorical variable: continuous/categorical            |
| Name of the index                                                    |
| Purpose of the index: for general purpose/for health care policy and research |
| Study design/how to decide the variables                             |
| Reliability measures                                                 |
| Validity measures                                                    |
We classified unit of analysis into three categories: geographical jurisdiction, health care institution and individual. Unit of analysis may depend on the purpose of the index. To assess rurality in specific areas, geographical jurisdiction is suitable for unit of analysis. Health care institution is employed for measurement of rurality from the viewpoint of each medical institution. Individual-level rurality is used for assessing each person’s accessibility to health care. We also categorize the purpose of the index into two categories: for general purpose and for health care policy and research. The index for general purpose can be used for various situations. The index for health care policy/research is developed to measure rurality in health-care areas.

**Results**

After searching through the titles and abstracts of 1,850 publications, 17 eligible publications\textsuperscript{12,13,24-38} were identified. Details about the reasons of exclusion are shown in Figure 1.

[Insert Figure 1 here]

Tittle: Flow diagram for the selection of studies in the systematic scoping review
Publication characteristics of the rurality indices

As shown in Table 1, 14 (82%) of the 17 articles have been published since 2000. Table 2 shows that the majority (13; 76%) have been published in Australia, Canada and the US. Three indices were developed in Europe (Germany, Italy, and Scotland) and only one index was generated from Asia (China). Of 17 indices, 12 (71%) were published in a peer-review journal and five were posted on the web.
Table 2. Publication characteristics of the rurality indices

| Author and publication year | Country      | Peer review (yes/no) | Citation index by Web of Science |
|-----------------------------|--------------|----------------------|---------------------------------|
| Department of Primary Industries and Energy, Department of Human Services and Health, 1994 | Australia | no | not included |
| Weinert et al., 1995 | USA | yes | 38 |
| Pitblado et al., 1997 | Canada | yes | not included |
| Department of Health and Aged Care, 2001 | Australia | no | not included |
| Australian Institute of Health and Welfare Canberra, 2004 | Australia | no | not included |
| Swan et al., 2008 | Scotland | yes | 9 |
| Boris Kralj, 2008 | Canada | no | not included |
| Matthew et al., 2009 | Australia | yes | 61 |
| Han et al., 2012 | China | yes | 9 |
| Humphreys et al., 2012 | Australia | yes | not included |
| Steinhaeuser et al., 2014 | Germany | yes | 8 |
| Mao et al., 2015 | USA | yes | 4 |
| Zhu et al., 2015 | USA | yes | not included |
| Inagami et al., 2016 | USA | yes | 3 |
| Alasia et al., 2017 | Canada | no | 6 |
| Calovi et al., 2018 | Italy | yes | 0 |
| Doogan et al., 2018 | USA | yes | 0 |
Description of rurality indices and their components

Table 3 describes that 13 indices (76%) were for health care policy/research and four (24%) were for general purpose. The indices for health care policy/research mainly aimed to measure access to health care resources or to determine incentives for health care providers based on rurality. For instance, “Rural, remote and metropolitan area” was developed for general research purpose and to allocate funding to areas by the Department of Primary Industries and Energy and the Department of Human Services and Health, Australia. Health care researchers and policy makers often use such a general index for health care research or policy-making. Alternatively, “Clinical peripherality indicator” in Scotland was an index to assess peripherality for rural health services. Regarding the types of variables, 14 indices (82%) employed a continuous variable to describe rurality.

[Insert Table 3 here]

The unit of analysis in each study was decided by the purpose of the index. Twelve indices (71%) employed geographical jurisdiction as a unit of analysis, such as statistical local area, county, state, or postal code. Three focused on a medical institution
(general practice) and two targeted individuals. All Australian indices used geographical jurisdiction. For example, “the Index of Rural Access” to assess the access to primary care focused on Collection Districts, which were the smallest census-defined units in Australia. On the other hand, “a General Practice Rurality Index” in Canada estimated rurality for every clinic based on remoteness from a basic referral centre, remoteness from an advanced referral centre, drawing population, number of general practitioners, number of specialists and presence of an acute care hospital. Also, two indices targeted individual-level rurality such as “MSU rurality index” to estimate more precise rurality in a specific local area in Montana, US. In terms of the components, the included indices consisted of two to six factors. The included factors are shown in Table 4. These factors were chosen mainly based on the previous literature search and availability of the factors. The most frequently used variable was population (size or density) (n=11: 65%). Travel distance and time to emergency care and/or referral centre were also often employed (n=7: 41% and 5: 29%, respectively). In four indices (24%), resource availability expressed either as the number of physicians (both primary care and specialists) or as physician/population ratio were also included as a variable. For example, “the Rurality Index for Ontario” in Canada was composed of community population, population density, travel time to nearest basic referral centre and advanced
referral centre. “Accessibility/Remoteness Index of Australia” calculated rurality by the road distance to service centres.

[Insert Table 4 here]

To construct a continuous rurality index score, 14 studies (82%) developed formulas by a mathematical operation: e.g. summing up the included variables, log transformation or a more complex operation. The formulas introduced rurality as a continuous variable, such as 0 to 1 or 0 to 100. Regarding the methods, Geographic Information System (GIS) was used in five studies (29%). Of them, two studies (12%) employed a two-step floating catchment area method to assess geographical accessibility. E.g. “Rural PHCWA index” in China was defined by “primary health care worker density per 1000 farming population index of the province” times “population density index of the province”. Moreover, “the IRR zip” in the US had three steps to calculate rurality: Step 1: Calculating maximum, minimum and range of population, population density and distance to metropolitan statistical area/micropolitan statistical area, Step 2: transforming each variable so that it is measured on a scale from 0 to 1, Step 3: calculating averages of the transformed variables. The IRR zip was a continuous
variable which could be 0 to 1. The details are shown in Table 3. A two-step floating catchment area method includes Step 1 (service catchment): For each service, find all populations that fall within a threshold distance (dmax) and calculate the population-to-provider ratio; and Step 2 (population catchment): For each population, find all services that fall within a threshold distance (dmax) and sum the population-to-provider ratios from step 1.30

Validity and reliability properties

Fifteen indices (88%) did not examine reliability and 12 indices (71%) did not examine validity. Most have no formal, psychometric testing of reliability or validity. In some studies, test/re-test and Cronbach’s alpha were used to assess reliability. Validity was confirmed by examining the correlation with other measures. “The modified RRS-Germany” employed Cronbach’s alpha to assess reliability and Spearman rank correlation to evaluate convergent construct validity. Also, “six-level geographical classification” in Australia utilized another Australian rurality index, ASGC-RA, to assess the validity. The details are shown in table 5.

[Insert Table 5 here]
Discussion

The scoping systematic review detected 17 rurality indices in seven countries. These indices mainly aimed to assess access to health care or to decide incentives for health care providers. This review found that while the concept of rurality and concerns about barriers to access to care for rural residents is shared by many countries, the operationalization of rurality is highly context specific, with few universal measures or approaches to constructing a rurality index. Frequently used variables for the indices were population size/density, travel distance/time to emergency care or referral centre. The findings will be useful to inform the development of a new rurality index in Japan and other countries/areas.

To define rurality, finding the optimal geographical unit and finding the specific set of rurality are key issues.\textsuperscript{11} However, both factors are highly context-dependent.\textsuperscript{11, 39} In terms of unit of analysis, the included studies mainly employed geographical jurisdiction. However, the “unit” was variously: statistical local area, county, state or postal code. From the results, population, travel distance and time are frequently used factors. The previous literature review also pointed out that a rurality index is generally
based on population size/population density and geographical indicators including travel
time.\textsuperscript{40}

Therefore, to develop a rurality index in Japan, the Japanese context needs to be
considered. In Japan, the largest unit is a prefecture and the second largest is a
municipality. The municipality in Japan includes city/town/village and it has a local
government. The following units are address and postal code. In Japan, available census
data are based on a municipality. For instance, it is difficult to grasp population density
in the area defined by postal code from official statistics. Thus, municipality may be
suitable as a unit of analysis of the rurality index in Japan. Also, since the majority of
the included indices employed continuous variables, a continuous variable may be
appropriate in comparison with a categorical variable from the viewpoint of research
use.

In Japan, generally, a secondary hospital has a role of referral centre and provides out of
hours care for a patient who potentially requires admission.\textsuperscript{41} Therefore, travel distance
or time to a secondary hospital needs to be taken into account. Also, Japan has many
remote islands\textsuperscript{18} and sometimes a patient can access a secondary hospital only by a ship
or an airplane. The rurality index in Japan has to consider frequency/number of a
round-trip flights or water transport.
In terms of reliability and validity, only 12% and 29% of all indices examined these measures, respectively. Reliability may need to be measured by consistent interpretation and application. Also, regarding validity, content validity such as face validity may be more important that other forms of validity due to the highly contextual nature of the index. Thus, to develop a Japanese rurality index, gathering advice from health care providers and policy makers may be an important next step.

**Study Strengths**

To the best of our knowledge, this is the first scoping systematic review about the methods and measures used in the development of a rurality index. Due to its high contextuality, a systematic review may never be an appropriate review method. However, summarizing the previous indices is helpful to inform the development of new rurality index.

**Study Limitations**

This study has several limitations. First, the present study may have excluded potential indices, such as, an index developed as part of a study on rural versus urban care. An index developed for a specific research question may not have the generalizability or
utility to inform the development of a standard rurality index for human resource planning, health care policy and research in a jurisdiction. We also excluded indicators only defined by population or census area because such a definition has not taken access to health care resources into account. Second, the information from this scoping systematic review may be insufficient to develop rurality index in Japan because, as we mentioned earlier, rurality indices are highly context dependent. Therefore, we need to create a provisional version of the index from the results of the study and official statistics and test the reliability and validity.

**Conclusion**

We identified 17 rurality indices by conducting the scoping systematic review. Although the operationalization of rurality is highly context specific, some variables were frequently employed in multiple countries/areas. The results will be helpful to develop a rurality index in Japan and other countries/areas.

**Abbreviations**

GALLOP: Government and Legislative Libraries Online Publications Portal

MMM: Modified Monash Model
OECD: Organization for Economic Co-operation and Development

RIO: Rurality Index of Ontario

Declarations

Ethics approval and consent to participate

The study did not require ethical approval because the study was a review of the published articles and websites.

Consent for publication

Not applicable

Availability of data and materials

All data relevant to the study are included in the article.

Competing interests

There are no potential competing interests to be declared relevant to this work.

Funding

This study was supported by the Grant-in-Aid for Young Scientists. The study sponsor had no role in the study design, data collection, analysis and interpretation, writing of the report, or the decision to submit the article for publication.

Authors' contributions
MK designed the study. MK and RO participated in the implementation, data collection and data analysis. MK took part in writing of the manuscript. MK also serves as the guarantor. EV, MM and TF contributed 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 accuracy of the analysis.

Acknowledgements

We thank David Le Sauvage, a retired member of Western Libraries Teaching and Learning Team and the Canadian Library of Family Medicine, for the great support in literature search and Machiko Inoue, Department of Family and Community Medicine, Hamamatsu University School of Medicine, for the warm support in the planning the study. We also thank the member of the committee of rural and remote medicine in the Japan Primary Care Association

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Table 3. Description of purpose if the index, types of variables and unit of analysis

| Author and publication year | Name of the index | Purpose of the index (for general purpose or health care policy and research) | Types of variables: continuous or categorical | Unit of analysis | How to decide the included factors |
|-----------------------------|-------------------|---------------------------------------------------------------------------------|-----------------------------------------------|----------------|----------------------------------|
| Department of Primary Industries and Energy, Department of Human Services and Health, 1994 | Rural, remote and metropolitan area (RRMA) | for general purpose | categorical | geographical jurisdiction: Statistical Local Area | consensus of a working group |
| Weinert et al., 1995 | MSU rurality index | for health care policy and research | continuous | individual | literature review and availability of the data |
| Pitblado et al., 1997 | General Practice Rurality Index (GPRI) | for health care policy and research | continuous | health care institution: general practice | literature review |
| Department of Health and Aged Care, 2001 | Accessibility/Remoteness Index of Australia (ARIA) | for general purpose | continuous | geographical jurisdiction: populated | GIS network analysis |
| Australian Institute of Health and Welfare, Canberra, 2004 | Australian Standard Geographical Classification (ASGC) | for general purpose | continuous | location | An enhanced geographical jurisdiction: Statistical Local Area
Swan et al., 2008 | Clinical peripherality indicator | for health care policy and research | continuous | health care institution: general practice | factor analysis
Boris Kralj, 2008 | Rurality Index for Ontario (RIO) | for health care policy and research | continuous | geographical jurisdiction: community | principal component analysis, maximum likelihood method
Matthew et al., 2009 | Index of Rural Access | for health care policy and research | continuous | geographical jurisdiction: collection district | modified two-step floating catchment area method
Han et al., 2012 | Rural PHCWA index | for health care policy and research | continuous | geographical jurisdiction: county | literature review
Humphreys et al., 2012 | six-level geographical | for health care | categorical | geographical | Geo-coded data |
| Author(s)            | Method                                      | Jurisdiction                  | Category          | Healthcare Policy and Research |
|----------------------|---------------------------------------------|------------------------------|------------------|-------------------------------|
| Steinhaeuser et al., 2014 | modified RRS-Germany (mRRS-G)               | continuous city             | primary care     | continuous                    |
| Mao et al., 2015     | Individual-based rurality and well-being measures | continuous individual | general practice | continuous individual          |
| Zhu et al., 2015     | Rural taxonomy                              | categorical? geographical    | primary care service area | categorical? geographical    |
| Inagami et al., 2016 | IRR zip                                     | continuous geographical     | primary care service area | continuous geographical     |
| Alasia et al., 2017  | index of remoteness                         | continuous geographical     | census subdivision | continuous geographical       |
| Calovi et al., 2018  | spatial accessibility index                 | continuous geographical     | two-step floating | continuous geographical       |
| Doogan et al., 2018 | Isolation scale | Policy and research for health care policy and research | Continuous | Jurisdiction: municipality | Catchment area method | Geographical | Literature review |

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GIS: Geographic Information System

PHCWA: Primary Health Care Worker Accessibility index

RRS: Rural Ranking Scale

IRR: Index of Relative Rurality
| Author and publication year                                          | Name of the index                                      | Population yes/no (population size) | Travel distance yes/no (distance to emergency care) | Travel time yes/no (distance to the nearest centre) | Travel cost yes/no |
|--------------------------------------------------------------------|-------------------------------------------------------|------------------------------------|-----------------------------------------------------|-----------------------------------------------------|-------------------|
| Department of Primary Industries and Energy, Department of Human Services and Health, 1994 | Rural, remote and metropolitan area (RRMA)            | yes                                | no                                                  | no                                                  | no                |
| Weinert et al., 1995                                               | MSU rurality index                                   | yes                                | yes (distance to basic/advanced referral center)    | no                                                  | no                |
| Pitblado et al., 1997                                              | General Practice Rurality Index (GPRI)                | yes                                | yes (distance to basic/advanced referral center)    | no                                                  | no                |
| Department of Health and Aged Care, 2001                           | Accessibility/Remoteness Index of Australia (ARIA)     | no                                 | yes (distance to the nearest centre)                | no                                                  | no                |
| Australian Institute of Health and Welfare Canberra, 2004          | Australian Standard Geographical Classification (ASGC) | no                                 | yes (distance to the nearest centre/the service town) | no                                                  | no                |
| Swan et al., 2008                                                  | Clinical peripherality indicator                      | yes (population size)              | no                                                  | yes (travel time to)                                | no                |
| Author(s)          | Index Name                        | Population Size | Population Density | Referral Centres | Travel Time |
|-------------------|-----------------------------------|-----------------|--------------------|------------------|-------------|
| Boris Kralj, 2008 | Rurality Index for Ontario (RIO)  | yes             | no                 | no               | yes         |
| Matthew et al., 2009 | Index of Rural Access             | yes: population size | no                 | no               | no          |
| Han et al., 2012  | Rural PHCWA index                 | yes             | no                 | no               | no          |
| Humphreys et al., 2012 | six-level geographical classification | yes             | yes                | no               | no          |
| Study                          | Methodology                      | Size          | Remoteness                  |
|-------------------------------|----------------------------------|---------------|-----------------------------|
| Steinhaeuser et al., 2014     | modified RRS-Germany (mRRS-G)    | no            | no                          |
|                               |                                  | yes (travel   | time from the practice to   |
|                               |                                  | next major    | hospital, to the nearest    |
|                               |                                  | general       | general practitioner       |
|                               |                                  | colleague at  | work, to the satellite clinic|
|                               |                                  | place of      | and to most distant         |
|                               |                                  | work, to the  | boundary covered by         |
|                               |                                  | satellite clinic| the practice)               |
| Mao et al., 2015              | Individual-based rurality and    | yes           | no                          |
|                               | well-being measures              | (population   | no                          |
|                               |                                  | density)      | no                          |
| Zhu et al., 2015              | Rural taxonomy                   | no            | no                          |
| Inagami et al., 2016          | IRR zip                          | yes           | yes (distance to no         |
|                               |                                  | yes (distance to| no                          |
|                               |                                  | no            | no                          |
| Study               | Measure                          | Population Size and Density | Metropolitan Statistical Area/Micropolitan Statistical Area | Travel Time | Distance to Outpatient Clinics |
|---------------------|----------------------------------|-----------------------------|-----------------------------------------------------------|-------------|--------------------------------|
| Alasia et al., 2017 | Index of remoteness             | yes                         | no                                                        | yes         | yes                            |
| Calovi et al., 2018 | Spatial accessibility index      | no                          | yes (distance to outpatient clinics)                      | no          | no                             |
| Doogan et al., 2018 | Isolation scale                 | no                          | yes                                                      | yes         | no                             |
Table 4. continued

| Health care resources yes/no | Health care needs yes/no | Others | Formula |
|------------------------------|--------------------------|--------|---------|
| no                           | no                       | level in urban hierarchy (small/large/metropolitan/capital city urban center) | not applicable |

Four mathematical operations are performed as below:

1. Distance and population measures are transformed to make the distribution of the resulting index as normal as possible

2. The transformed distance and population measures are standardized so that each has a standard deviation of one

3. The standardized transformed distance and population measures are weighted to produce an initial index of rurality that assigns high scores to rural families and low scores to urban families
4. The initial index constructed in operation #3 is restandardized to have a mean of zero and a standard deviation of one.

Sum the points for each of the following (maximum 100 points):

1. Remoteness from closest advanced referral centre (km) \( \div 50 \)

2. Remoteness from closest basic referral centre (km)\( \div 25 \)

3. \( 20 \times (\text{Drawing population} \div 2000) \)

4. \( (20 \div \text{number of full-time GPs with main place of business within 25 km of the centre of the community}) \)

5. Number of specialists

6. Presence of an acute care hospital

unweighted addition of the four (threshold-limited) ratio values for each of the four levels of service centre
| no | no |
|---|---|
| no | yes (number of patients on the practice list) |

Calculates distance to the nearest centre in each of five categories of service centre.

Practice list size, ward population density and travel time to hospital were log transformed to achieve near normality. The relationships among the variables were assessed by matrix plots and correlation coefficients. This was further multiplied by 100 for the index to range from 0 to 100 with a midpoint of 50. Higher values represent greater peripherality.

Sum the points for each of the following (maximum 100 points):

1. Measure of community population and population density
2. Measure of travel time to nearest basic referral centre
3. Measure of travel time to nearest advanced referral centre
yes (the number of full-time equivalent services at location and the population-to-provider ratio)

yes (health needs (Disability Adjusted Life Years: DALYs))

mobility (households without a car, individuals of low personal mobility and public transport availability)

\[ \sum_{j} \int_{0}^{100 \text{min}} f(dij) \cdot R_j \cdot \text{Mob}_j \]

\( f(dij) \): impedance function
\( R_j \): the population-to-provider ratio for service \( j \)
\( \text{Mob}_j \): equal to one within the initial catchment (10 minutes), and is less than one in the secondary catchment for areas of low mobility

Rural PHCWA index of X province
= primary health care worker density per 1000 farming population index of X province * population density index of X province.

not applicable

Sum the following six variables:
1. travelling time from the surgery to major hospital
2. on-call duty
3. receiving timely backup by a paramedic team within 15 minutes and numbers of GP which engaged in on-call duty

...
paramedic team
4. travelling time to nearest general practitioner colleague at place of work
5. travelling time to most distant practice boundary
6. satellite clinic

\[ \sum_{L=1}^{n} \text{Prob}_{L,i} \times \text{RuralDegree}_L \leq \sum_{L=1}^{n} \text{Prob}_{L,i} \]
1. \( n \) is the total number of places within individual \( i \)'s activity space
2. \( L \) represents any one of these places
3. \( \text{Prob}_{L,i} \) is the probability of visiting place \( L \) by individual \( i \)
4. the degree of rurality for all places (\( \text{RuralDegree}_L \)) were extracted with GIS database

yes (density of health facilities/social service facilities)
no

number of different ethnic groups/degree of land development/mean household income/density of loads

yes (provider resources: primary care physicians, medical specialists, non-physician practitioners, dentists)
no
economic resource, age distribution

not applicable
and facility resources:
staffed hospital beds,
provider resources,
average daily census,
medicare/medicaid
certified nursing home beds)

Step 1: Calculating maximum, minimum
and range of each variable.
Step 2: transforming each variable so that it
is measured on a scale from 0 to 1.
Step 3: calculating averages of the
transformed variables

The included variables are below:
1. population size,
2. population density
3. distance to closest metropolitan area

\[
\ln \sum_{k=1}^{n} \left( \frac{Pop_{cik}}{C_{ik}} \right)
\]

Pop: sizes of the population centres
C: travel cost
volumes of activity

\[ \sum_{j : d_{ij} < d_0} R_j \]

- \( d_{ij} \): the distance between \( i \) and \( j \)
- \( R_j \): supply-to-demand ratio at supply location \( j \)

\[ v(i,j) = a_j \delta^{d_{ij}} \]

\[ a = \max_j [v(i,j)] \]

- \( v \): function
- \( a_j \): neighbor’s resources
- \( d_{ij} \): distance
- \( \delta \): parameter which chosen based on research purpose

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Table 5. Validity and reliability properties

| Author and publication year | Name of the index | Reliability measures | Reliability score | Validity measures | Validity score |
|-----------------------------|-------------------|----------------------|-------------------|-------------------|---------------|
| Department of Primary       | Rural, remote and metropolitan area (RRMA) | not applicable | not applicable | not applicable | not applicable |
| Industries and Energy,      |                   |                      |                   |                   |               |
| Department of Human Services and Health, 1994 |                      |                      |                   |                   |               |
| Weinert et al., 1995        | MSU rurality index | test/re-test         | 0.94 or larger    | concurrent validity (comparison with other measure such as the participants' perception) | R²=0.41, r=0.85 and Z=4.09 |
| Pitblado et al., 1997       | General Practice Rurality | not                | not              | not applicable |               |
| Source                                                        | Index (GPRI) | Accessibility/Remoteness Index of Australia (ARIA) | Australian Standard Geographical Classification (ASGC) | Clinical peripherality indicator | The Rurality Index for Ontario (RIO) | the Index of Rural Access | Rural PHCWA index six-level geographical classification | modified RRS-Germany (mRRS-G) | Cronbach’s alpha | Concurrent validity | Convergent construct validity | Factor analysis: |
|--------------------------------------------------------------|--------------|---------------------------------------------------|--------------------------------------------------------|---------------------------------|-----------------------------------|-------------------------------|---------------------------------------------------------|---------------------------|------------------|----------------------|----------------------|------------------|
| Department of Health and Aged Care, 2001                     | applicable   | not applicable                                    | not applicable                                         | not applicable                  | not applicable                    | not applicable               | not applicable                                                          |                                            |                  |                      |                      |                  |
| Australian Institute of Health and Welfare Canberra, 2004    |              |                                                   |                                                        |                                 |                                    |                               |                           |                                           |                                            |                  |                      |                      |                  |
| Swan et al., 2008                                            |              |                                                   |                                                        |                                 |                                    |                               |                           |                                           |                                            |                  |                      |                      |                  |
| Boris Kralj, 2008                                            |              |                                                   |                                                        |                                 |                                    |                               |                           |                                           |                                            |                  |                      |                      |                  |
| Matthew et al., 2009                                         |              |                                                   |                                                        |                                 |                                    |                               |                           |                                           |                                            |                  |                      |                      |                  |
| Han et al., 2012                                              |              |                                                   |                                                        |                                 |                                    |                               |                           |                                           |                                            |                  |                      |                      |                  |
| Humphreys et al., 2012                                       |              |                                                   |                                                        |                                 |                                    |                               |                           |                                           |                                            |                  |                      |                      |                  |
| Steinhaeuser et al., 2014                                    |              |                                                   |                                                        |                                 |                                    |                               |                           |                                           |                                            |                  |                      |                      |                  |
| Author(s)          | Methodology                                      | Applicability 1 | Applicability 2 | Applicability 3 | Applicability 4 | R²  |
|--------------------|--------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----|
| Mao et al., 2015   | Individual-based rurality and well-being measures| not applicable  | not applicable  | not applicable  | not applicable  |     |
| Zhu et al., 2015   | Rural taxonomy                                   | not applicable  | not applicable  | not applicable  | not applicable  |     |
| Inagami et al., 2016 | IRR zip                                         | not applicable  | not applicable  | face validity   | not applicable  |     |
| Alasia et al., 2017 | the index of remoteness                        | not applicable  | not applicable  | not applicable  | not applicable  |     |
| Calovi et al., 2018 | The spatial accessibility index                 | not applicable  | not applicable  | not applicable  | not applicable  |     |
| Doogan et al., 2018 | Isolation scale                                 | not applicable  | not applicable  | Spearman correlation to test convergent validity and the Akaike information criterion for criterion validity | Spearman correlation for convergent validity r=0.99 |

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