SYSTEMATIC / NARRATIVE REVIEW ARTICLE

Exploring measurement tools to optimise hospital physician distribution

Mohd Azri Mohd Suan, MSc[1], Shahrul Aiman Soelar, MSc[1], Rosilawati Abd Rani, MPH[2], Nur Anisah Anuar, BSc[2], Khairul Azlan Abdul Aziz, MIntMed[3], Huan-Keat Chan, PhD[4], Wee Kooi Cheah, MRCP[2,5], Saiful Safuan Md Sani, MRCP[3,6], Rosaida Md Said, MRCP[7], Muhammad Radzi Abu Hassan, MRCP[4]

[1]Clinical Research Center, Hospital Sultanah Bahiyah, Alor Setar, Kedah, Malaysia, [2]Clinical Research Center, Hospital Taiping, Taiping, Perak, Malaysia, [3]Department of Internal Medicine, Hospital Kuala Lumpur, Kuala Lumpur, Malaysia, [4]Office of Director General, Ministry of Health Malaysia, Putrajaya, Malaysia, [5]Department of Internal Medicine, Hospital Taiping, Taiping, Perak, Malaysia, [6]Clinical Research Center, Hospital Kuala Lumpur, Kuala Lumpur, Malaysia, [7]Department of Internal Medicine, Hospital Serdang, Serdang, Selangor, Malaysia

ABSTRACT

Introduction: Equitable healthcare delivery is essential and requires resources to be distributed, which include assets and healthcare workers. To date, there is no gold standard for measuring the correct number of physicians to meet healthcare needs. This rapid review aims to explore measurement tools employed to optimise the distribution of hospital physicians, with a focus on ensuring fair resource allocation for equitable healthcare delivery.

Materials and Methods: A literature search was performed across PubMed, EMBASE, Emerald Insight and grey literature sources. The key terms used in the search include 'distribution', 'method', and 'physician', focusing on research articles published in English from 2002 to 2022 that described methods or tools to measure hospital-based physicians' distribution. Relevant articles were selected through a two-level screening process and critically appraised. The primary outcome is the measurement tools used to assess the distribution of hospital-based physicians. Study characteristics, tool advantages and limitations were also extracted. The extracted data were synthesised narratively.

Results: Out of 7,199 identified articles, 13 met the inclusion criteria. Among the selected articles, 12 were from Asia and one from Africa. The review identified eight measurement tools: Gini coefficients and Lorenz curve, Robin Hood index, Theil index, concentration index, Workload Indicator of Staffing Need method, spatial autocorrelation analysis, mixed integer linear programming model and cohort-component model. These tools rely on fundamental data concerning population and physician numbers to generate outputs. Additionally, five studies employed a combination of these tools to gain a comprehensive understanding of physician distribution dynamics.

Conclusion: Measurement tools can be used to assess physician distribution according to population needs. Nevertheless, each tool has its own merits and limitations, underscoring the importance of employing a combination of tools. The choice of measuring tool should be tailored to the specific context and research objectives.

KEYWORDS:
Review, physicians, resource allocation, delivery of healthcare

INTRODUCTION

Equitable allocation of health resources is crucial for ensuring optimal healthcare delivery, characterised by providing equal opportunities for individuals to access healthcare services.[1] This principle is particularly important during the ongoing COVID-19 pandemic,[2,3] which has further intensified the challenge of allocating limited resources in healthcare systems already under strain. The impact of the pandemic has been particularly severe in lower-income countries, leading to disruption in essential services, including maternal and childcare, vaccination programs and cancer care.[4-6]

Healthcare delivery systems encompass public health, community care and hospital care, each with distinct resource needs. In hospital settings, a multidisciplinary approach has been widely adopted to provide comprehensive and patient-centred care, with physicians often assuming clinical leadership roles. Hence, it is important to ensure an equitable distribution of physicians across hospitals.[7] However, achieving this equity remains a global challenge influenced by various factors. Typically, urban regions with higher living standards tend to have a higher physician density.[8]

Several measurement tools have been employed to assess the distribution of physicians across hospitals. However, a universally accepted standard measure is currently absent. Policymakers face the task of carefully selecting appropriate measuring tools to facilitate human resource planning. The selected tool should be straightforward and provide timely information to effectively guide the allocation of physicians to suitable geographical areas. Therefore, this rapid review aimed to explore the various measurement tools specifically designed or adapted to guide the allocation of hospital physicians and evaluate their respective advantages and disadvantages.

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Corresponding Author: Mohd Azri Mohd Suan
Email: irzah96@yahoo.com

MATERIALS AND METHODS

Ethics Approval

This review was prospectively registered with National Medical Research Register (NMRR-22-02136-2S5) and obtained exemption from the Medical Research and Ethics Committee, Ministry of Health Malaysia as all data used in this review is publicly available.

Stakeholder Engagement

This review was conducted to provide guidance for policymaking in response to a request from the Committee of Internal Medicine, Ministry of Health Malaysia, with a strict timeline for completion. Multiple meetings were held with the head of service for internal medicine, senior consultants, physicians and health system researcher to develop literature search strategies, assessment methods and a data extraction plan. Stakeholders were regularly updated on the progress of the review, and all decisions were made in close consultation with them.

Search Strategy

The research question was formulated using the problem-concept-context format. Primary research articles published in English between January 2002 and June 2022, which described the use of at least one measurement tool to assess the distribution of hospital physicians, were considered eligible for inclusion in the review. Literature search was performed in three databases (PubMed, EMBASE and Emerald Insight) using search strings as follows: (placement OR distribution OR allocation OR planning OR equity OR fairness) AND (tool OR method OR index OR measure) AND (physician OR hospital-based internal medicine OR specialist). Additionally, a search of grey literature was conducted using Google Search.

Study Selection

The article selection process involved a two-level screening approach. In the level 1 screening, a pilot screening was independently conducted by three authors (RAR, SAS, NAA) on 5% of the records using titles and abstracts. Any inconsistencies in decision-making were resolved through discussions to reach a consensus. Subsequently, the same researchers screened the titles and abstracts for the remaining 95% of records. In the level 2 screening, the full texts of the records selected in the level 1 screening were retrieved and independently assessed for eligibility by two other authors (MAMS and KAAA). Any disagreements during the article selection were resolved through discussions and consensus.

Data Extraction and Synthesis

A data extraction form was created and pre-piloted on two selected articles. Two authors (RAR and MAMS) independently extracted the following information into the form: author and publication date, country of origin, measurement tools used to assess hospital physician distribution and the specific variables used. Any uncertainties during the data extraction process were discussed until consensus was reached. Subsequently, data extraction was conducted on all included articles in the review using the form for narrative synthesis.

Quality Appraisal

Study appraisal employed an assessment tool by Hawker et al., which evaluates each study's reporting quality for elements such as the abstract, title, introduction, objectives, methods, sampling, data analysis, ethics approval, researcher reflexivity, population generalisability and findings' implications.[9] Scores for each element range from 1 (very poor) to 4 (good). One author (MAMS) appraised all studies, while another author (RAR) evaluated 10% of the studies. Both authors' assessments demonstrated 95% agreement, with the remaining 5% of discrepancies resolved through discussion.

RESULTS

Included Studies

The initial literature search identified a total of 7,199 records, with an additional record retrieved from grey literature sources. After the removal of 1,460 duplicate records, the remaining 5,739 titles and abstracts underwent thorough screening. Subsequently, 46 articles were considered for full-text review. During this phase, 33 articles were excluded based on the predefined criteria, leaving with a final selection of 13 articles for the review.[10-22] The reasons for excluding articles during the full-text review primarily revolved around ensuring relevance to the specific focus of this study on hospital-based physician distribution and the evaluation of measurement tools. In details, a subset of the excluded articles (seven in total) did not pertain to hospital-based physicians, three articles were excluded due to a lack of explicit mention or discussion regarding the specific formula or method employed in the distribution of physicians, and a significant portion of the excluded articles (23 in total) did not delve into the subject of physician distribution. A detailed breakdown of the article search, selection process, and reasons for exclusion is presented in Figure 1. It's noteworthy that literature search also identified one relevant record from grey literature, which offers valuable insights into the intricate dynamics of physician supply and demand.

Study Characteristics

The selected articles are predominantly from Asian countries, particularly Thailand, Japan, China, Iran and Taiwan, reflecting a geographical emphasis in the literature on hospital physician distribution. It is worth noting that there is representation from Africa, albeit with only one article included in the review. A notable aspect is that five out of the 13 articles took a comprehensive approach by employing a combination of measurement tools. This methodological choice enhances the depth of understanding, offering a more nuanced evaluation of the dynamics involved in hospital physician distribution within populations. The characteristics of the selected articles are summarised in Table I.

Measurement Tools Used to Assess the Distribution of Hospital Physicians

A total of eight distinct measurement tools used to assess the hospital physician distribution: the Lorenz curve and Gini coefficient, the Robin Hood index, the Theil index, the concentration index, the Workload Indicator of Staffing Need method, the mixed integer linear programming model, the cohort-component model and the spatial autocorrelation

Table I: Summary of included articles for data synthesis

No.	Title	Year Published	Country	Tool/measure(s) used
1.	Equity of health workforce distribution in Thailand: an implication of concentration index.[13]	2019	Thailand	Concentration index
2.	Examining changes in the equity of physician distribution in Japan: a specialty-specific longitudinal study.[14]	2017	Japan	Gini coefficients and Lorenz curve
3.	Equity analysis of Chinese physician allocation based on Gini coefficient and Theil index.[11]	2021	China	1. Gini coefficients and Lorenz curve 2. Theil index
4.	Physician distribution across China's cities: regional variations.[20]	2021	China	Gini coefficients and Lorenz curve
5.	The cost of health workforce gaps and inequitable distribution in the Ghana Health Service: an analysis towards evidence-based health workforce planning and management.[21]	2021	Ghana	Workload Indicator of Staffing Need method
6.	Model for allocation of medical specialists in a hospital network.[19]	2018	Thailand	Mixed integer linear programming model
7.	Future projection of the physician workforce and its geographical equity in Japan: a cohort-component model.[16]	2018	Japan	Cohort-component model
8.	What about the health workforce distribution in rural China? An assessment based on eight-year data.[22]	2019	China	1. Gini coefficient and Lorenz curve 2. Theil index
9.	Equity in distribution of health care resources; assessment of need and access, using three practical indicators.[12]	2013	Iran	1. Gini coefficient and Lorenz curve 2. Concentration index 3. Robin Hood index
10.	Comparing regional distribution equity among doctors in China before and after the 2009 medical reform policy: a data analysis from 2002 to 2017.[10]	2020	China	1. Gini coefficient 2. Theil index
11.	Incorporating spatial statistics into examining equity in health workforce distribution: an empirical analysis in the Chinese context.[17]	2018	China	1. Spatial autocorrelation analysis 2. Theil index
12.	Examining sufficiency and equity in the geographic distribution of physicians in Japan: a longitudinal study.[15]	2017	Japan	Gini coefficient and Lorenz curve
13.	Measuring inequality in physician distributions using spatially adjusted Gini coefficients.[18]	2016	Taiwan	Gini coefficient and Lorenz curve

analysis. Table II summarised all the measurement tools found including data requirements, standard formulations, advantages and limitations for each tool.

1. Lorenz curve and Gini coefficient

The Lorenz curve (LC) is often regarded as equivalent to the Gini coefficient. The LC serves as a graphical representation illustrating the distribution of health resources, specifically physicians. It is constructed by plotting the cumulative percentage of physicians, categorised into different levels based on the populations or regions, on the vertical axis against the cumulative percentage of the population on the horizontal axis. The LC appears as a diagonal line when physicians are equally distributed. Deviations from the diagonal line indicates the degrees of disparities in physician distribution.

The Gini coefficient, derived from the LC, is a numerical measure to quantify health resource inequality in a population with a single value. It is a commonly used measurement tool by studies included in this review. A population with total inequality has a Gini coefficient of 1, while a population with a perfect distribution has a value of 0. The Gini coefficient is calculated by comparing the area between the LC and the line of perfect equality (a diagonal line) to the total area under the line of perfect equality. A higher Gini coefficient indicates a more unequal distribution of physicians.

Gini coefficients and LC are applied to assess inequality in physician distribution, revealing if specific regions or specialties dominate concentration. They are effective in visually representing distribution disparities and identifying areas or specialties with disproportionate physician concentration. In this review, their application can be seen in eight studies conducted in various countries, including Japan and China.[10-12,14-15,18,20,22] Common variables for analysis include the number of physicians per population and population data. The application of Gini coefficient and LC allows the visualisation of a decreasing trend in physician numbers per population over time, with some specialties experiencing increases.[12,14,15] In other studies, results from Gini coefficient and LC analyses can highlight disparities between urban and rural areas, emphasising the importance of balancing medical resources.[10,11,20,22] An additional study conducted in Taiwan proposed spatially adjusted Gini coefficients, integrating the use of Geographic Information Systems (GISs) to analyse the impact of geographic accessibility (travel distance and travel time) in relation to the utilisation of health services.[18] This study concludes that by increasing physician numbers in medium-sized cities and improving transportation infrastructure, one can address geographical maldistribution effectively.

In terms of advantages, both the Gini coefficient and LC are sensitive to changes in the distribution of physicians. They can capture even small shifts in the distribution and detect

Table II: Summary of measurement tools for hospital physician distribution

No	Method	Brief Description	Data Requirements	Standard Formulation*	Advantages	Limitation
1	Lorenz curve, Gini coefficient	Measure and compare cumulative percentage of physicians that ranked according to different populations or regions and the cumulative percentage of the population. Gini coefficient took values between 0 and 1, with higher values indicating higher levels of inequality. The standard of Gini-coefficient in health resource allocation is as follow; Gini coefficient <0.2 indicates in highly fair distribution; 0.2-0.3, relatively fair; 0.3-0.4 indicates reasonable distribution; 0.4-0.5 indicates a large gap; and >0.5 indicates a high degree of unfairness[11].	1. Number of physicians in different populations or regions. 2. Total number of physicians. 3. Population of units or region.	The Lorenz curve is a graphical representation and doesn't have a single mathematical formula. It is created by plotting the cumulative percentage of the population (x-axis) against the cumulative percentage of physician in the population (y-axis). Gini coefficient = A / (A + B), where A is the area between the Lorenz curve and the line of equality, and B is the area under the line of equality.	1. Generally regarded as gold standard in economic work. 2. The Lorenz curve provides a visual assessment of how physician availability is distributed across different regions or population groups. 3. Both the Gini coefficient and Lorenz curve are sensitive to changes in the distribution of physicians, meaning it can capture even small shifts in the distribution and detect improvements or deteriorations in fairness over time. 4. Enable comparisons of physician distribution across different regions or time periods.	1. May not fully capture the complexities of healthcare access and disparities that go beyond income considerations as they primarily designed to measure income or wealth inequality. 2. Able to provide an overall summary of inequality in a population but does not capture disparities within specific subgroups or regions (within or between group comparison). 3. Do not consider non-health factors that influence healthcare resource allocation, such as disease prevalence, healthcare needs, and efficiency of healthcare systems.
2	Robin Hood index	Measures proportion of physicians to be redistributed from areas with above-average provision to areas with below-average provision to achieve equal distribution. Based on the Lorenz Curve, it is equivalent to the maximum vertical distance from the Lorenz curve to 45° equality line and is denoted as a vertical line. The index value ranges from 0 (complete equality) to 100 (complete inequality).	1. Physician distribution data across different geographical areas or population groups. 2. Population data for the same geographic areas or population groups.	Robin Hood index = (Vertical Distance / Total Area Under Lorenz Curve) * 100	1. Result is easier to understand compare with Loren curve and Gini coefficient outcome. 2. It highlights the potential for redistribution to achieve a more equal distribution.	1. Although the index primarily addresses the redistribution of resources based on health needs or socioeconomic status, other dimensions of equity (geographic disparities, cultural factors, or specific health requirements of different population groups) may not fully capture.
3	Theil index	Measure the equity of physician distribution within and between different populations or regions. Theil index took values between 0 and 1, with higher values indicating higher levels of inequality.	1. Number of physicians allocated in different populations or regions. 2. Total number of physicians. 3. Population of units or region. 4. Total population.	Theil index = Σ (Xi) * log (Xi/Yi) where Xi is the proportion of population in the ith city / state accounting for the total population. Yi is proportion of physician in the ith city / state accounting for the total physician.	1. Well reflect the contributions to inequality by within group and between group and is complementary to the Gini coefficient.	1. Not intuitively interpretable as some other inequality measures. Thus, the result interpretation could be challenging. 2. Cannot directly compare populations with different sizes as calculation depends on the number of physicians in the population or region.

No	Method	Brief Description	Data Requirements	Standard Formulation*	Advantages	Limitation
4	Concentration index	Measures whether the number of physicians is distributed fairly across different socioeconomic groups. The CI value ranges from -1 to +1. CI=0 indicates equal physicians' distribution among socioeconomic groups; CI>0 indicates physicians' distribution is disproportionately concentrated on higher socioeconomic groups; CI<0 indicates physicians are more concentrated among lower socioeconomic groups.	1. Ranked data of socioeconomic status such as income of individuals or households. 2. Physician to population ratio.	Concentration index = 2 *Cov (Y, R)/μ, where Y is the health variable of interest (e.g., physicians per population), R is the rank of individuals by socioeconomic status, Cov is the covariance, and μ is the mean of Y (the variable).	1. Helps assess the concentration of physicians in specific areas and reveals the extent to which the distribution is skewed towards certain regions or socioeconomic groups. 2. Allows for comparisons across different regions, demographic groups, or time periods.	1. Can only be applied if a strict ranking socioeconomic variable, like income, is available. 2. Unable to make comparison within and between income/socioeconomic group.
5	Spatial autocorrelation analysis	Measure the distribution of physicians across different geographic areas and examine any spatial patterns or clustering in their allocation. Global Moran's I and the local Moran's I were used to evaluate the degree of spatial autocorrelation and estimate the local autocorrelation between a single area and its neighbours, respectively.	1. Data that represents the geographic boundaries and spatial units of the study areas such Geographic Information System (GIS) data. 2. Number or density of physicians in each geographic area. 3. Population data for each geographic area.	Spatial autocorrelation analysis involves various statistical tests, and the specific formulae may depend on the method used.	1. Can gain insights into the spatial relationships between different locations. It helps determine whether nearby locations tend to have similar or dissimilar values, indicating potential patterns or trends. 2. Can highlight areas where there might be disparities or uneven access to healthcare services, enabling policymakers to identify areas that require attention and intervention. 3. Helps in targeting areas that require additional healthcare infrastructure, recruiting more physicians, or implementing policy interventions to improve access to healthcare services.	1. Require data on spatial units or boundaries which may not readily available or inaccurate. 2. Choice of spatial units or boundaries used in the analysis can significantly impact the results. Different levels of aggregation may reveal different patterns of physician distribution. 3. Only provides a snapshot of physician distribution at a specific point in time. Many factors can influence the distribution patterns over time. 4. Require special software for spatial analysis and clustering map generation.

No	Method	Brief Description	Data Requirements	Standard Formulation*	Advantages	Limitation
6	Workload Indicator of Staffing Need (WISN) method	Assess physician distribution and determine the optimal number of physicians required in a particular setting or facility. Does not have specific values range applicable, but calculation typically result in ratio or percentage. This ratio represents the estimated physician requirement based on the workload demand. A ratio greater than 1 indicates that additional physician is needed to meet the workload, while a ratio less than 1 suggests an excess of physician relative to the workload.	1. Service profiles: types of services provided by physician including specific tasks and procedures, frequency to perform the tasks. 2. Work measurement: the time required to deliver different tasks. 3. Workforce data: number of physician available, working hours of physicians.	WISN ratio = Workload demand/available workforce	1. The approach to staffing decisions is more objective and evidence based. By matching workforce distribution with workload requirements, it helps prevent understaffing or overstaffing situations. 2. It is a flexible technique for labour planning since it take into consideration of variations in service profiles and working conditions.	1. Physician's task varies between facilities or study area and may not be reflective if categories under larger job scopes. 2. May not fully consider other elements such as population demographics, healthcare demands, or infrastructure availability because it focuses solely on workload and physician capability. 3. Data required are retrospective in nature, which may not accurately reflect current workload variations. 4. Require regular reviews and updates on various parameters to maintain results relevance and accuracy.
7	Mixed integer linear programming (MILP)	A mathematical optimisation model to measure and optimize physician distribution in a systematic and quantitative manner.	1. Healthcare system data, (e.g., number of healthcare facilities, capacity, and geographical coverage area). 2. Population data on the population served by the healthcare system, (e.g., demographics, geographical distribution, and healthcare needs). 3. Physician data on the available pool of physicians, their specialties, skills, and constraints (e.g., working hours, preferences). 4. Data on constraints (e.g., minimum staffing requirements, workload capacities and travel distances, or equity considerations).	Formulations depend on specific objectives, constraints, and decision variables chosen by the modeler. Involves equations representing population changes due to births, deaths, and migration, specific to demographic and workforce dynamics.	1. Offer a systematic approach to physician distribution. Due to the optimisation of resource allocation choices based on predetermined goals and constraints, better distribution outcomes are produced. 2. These models are flexible and can accommodate various constraints, objectives, and scenarios.	1. As a mathematical model, it requires computational resources and expertise in mathematical programming. 2. Large-scale problems cannot always be solved.
8	Cohort-component model	Measure physician distribution by projecting the future supply of physicians based on population characteristics and workforce dynamics.	1. Population data 2. Current physician workforce. 3. Population's birth and death rates. 4. Information on internal and external migration.	Involves equations representing population changes due to births, deaths, and migration, specific to demographic and workforce dynamics	1. The model able to estimate the future physician's distribution enables long-term planning. 2. Considers various demographic elements to help policymakers to match physician distribution to the population's changing demographics.	1. It is highly dependent on reliable birth, death, and migration data. Thus, it may be difficult to collect the information to apply this method. 2. Assumes that survival and birth rate and estimates of net migration will remain the same throughout the projection period.

*General formulations, and variations may exist in different studies or applications.

Table III: Quality of studies assessing hospital physician distribution

Study title	Abstract and title	Introduction and objectives	Method and data	Sampling	Data analysis	Ethics and bias	Finding and results	Transferability and/or generalisability	Implications and usefulness
Equity of health workforce distribution in Thailand: an implication of concentration index.[13]	4	4	4	3	4	1	4	4	4
Examining changes in the equity of physician distribution in Japan: a specialty-specific longitudinal study.[14]	4	4	4	3	4	4	4	4	4
Equity analysis of Chinese physician allocation based on Gini coefficient and Theil index.[11]	3	4	4	4	4	3	4	4	4
Physician distribution across China's cities: regional variations.[20]	4	4	4	4	4	4	3	3	3
The cost of health workforce gaps and inequitable distribution in the Ghana Health Service: an analysis towards evidence-based health workforce planning and management.[21]	4	4	4	4	4	4	4	4	4
Model for allocation of medical specialists in a hospital network.[19]	3	4	3	3	3	1	3	3	3
Future projection of the physician workforce and its geographical equity in Japan: a cohort-component model.[16]	4	4	4	4	4	4	4	4	4
What about the health workforce distribution in rural China? An assessment based on eight-year data.[22]	3	3	3	4	3	4	3	3	4
Equity in distribution of health care resources; assessment of need and access, using three practical indicators.[12]	2	3	4	3	3	4	3	3	3
Comparing regional distribution equity among doctors in China before and after the 2009 medical reform policy: a data analysis from 2002 to 2017.[10]	4	4	4	4	4	3	4	4	4
Incorporating spatial statistics into examining equity in health workforce distribution: an empirical analysis in the Chinese context.[17]	4	4	4	4	4	3	4	4	4
Examining sufficiency and equity in the geographic distribution of physicians in Japan: a longitudinal study.[15]	4	4	4	4	4	4	4	4	4
Measuring inequality in physician distributions using spatially adjusted Gini coefficients.[18]	4	4	3	4	4	4	4	4	4

Note: 1 = Very poor, 2 = Poor, 3 = Fair, 4 = Good

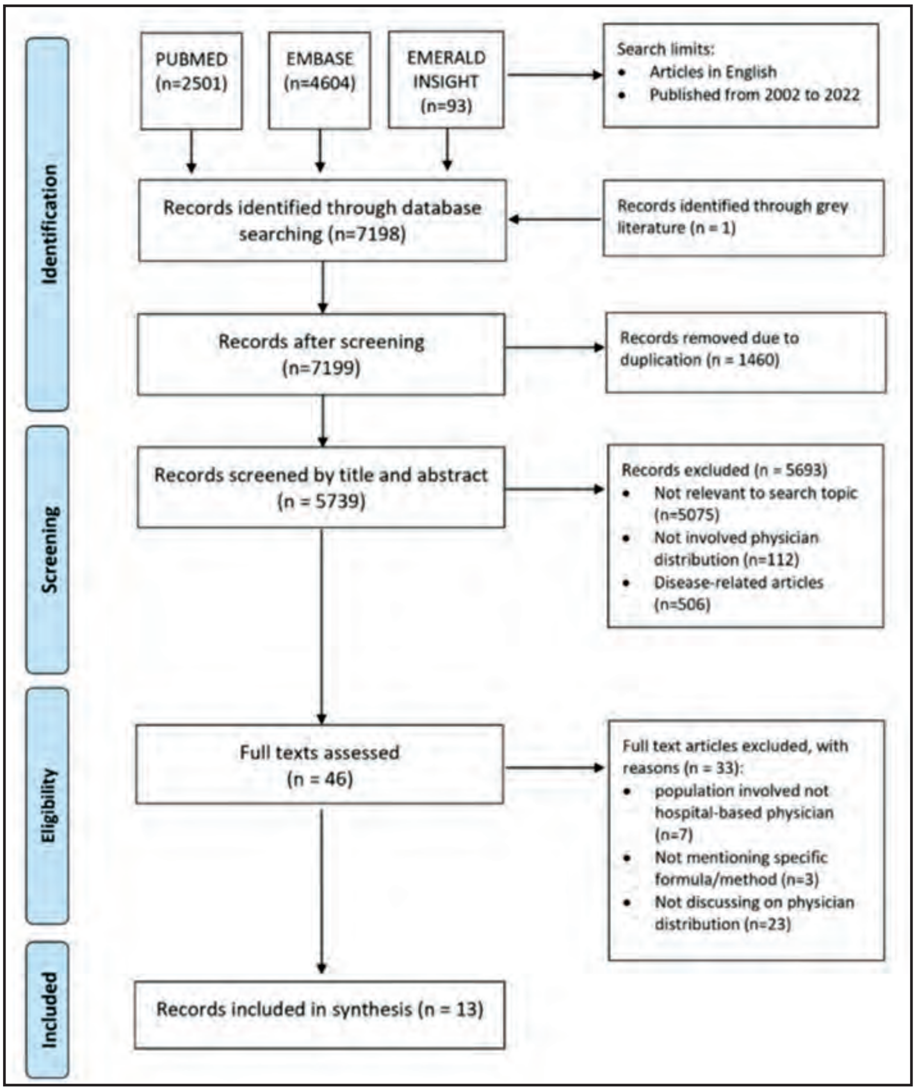

Fig. 1: PRISMA flow diagram of included studies.

improvements or deteriorations in fairness over time.[14] Additionally, both tools enable comparisons of physician distribution across different regions or time periods. However, these measurements may be sensitive to extreme values, potentially leading to misinterpretations if outliers significantly impact the distribution. Furthermore, they do not fully capture the complexities of healthcare access and disparities that go beyond income considerations.[12,20] Primarily designed to measure income or wealth inequality, they treat all the regions or areas equally and do not account for geographic disparities in healthcare access. Furthermore, the Gini coefficient is limited to assessing overall inequality without providing insights into its sources, whether originating between different regions or within each region.[22] Therefore, the incorporation of the Theil index (more information on Theil index can be found later) can complement the Gini coefficient by offering a means to measure and understand the specific sources of inequality.

2. Robin Hood index

The Robin Hood index, a measure derived from the LC and known as the Hoover index, the Pietra index and the Ricci-Schutz index, quantifies the proportion of resources to be relocated to achieve an equal distribution. It evaluates the impact of redistributive policies, indicating if certain areas or groups disproportionately benefit from physician resources. This index measures the vertical distance between the LC and the equality line. Only study by Omrani-Khoo et al used this index in this review.[12] In the context of physician distribution, it signifies the proportion of physicians to be redistributed from populations or regions above the mean to those below the mean, ranging from 0 (complete equality) to 100 (complete inequality).

In essence, elevated Robin Hood values signify greater societal inequality, suggesting that a larger proportion of physicians must be redistributed to attain equality. This tool offers a more intuitive interpretation than the Gini coefficient, emphasising the potential for redistribution based on health needs and socioeconomic status.[23] However, it is important to note a limitation of the Robin Hood index. Although the index primarily addresses the redistribution of resources based on health needs or socioeconomic status, it may not fully capture other dimensions of equity such as geographic disparities, cultural factors, or specific health requirements of different population groups.

3. Theil index

The Theil index, another valuable measure for assessing physician distribution disparities, was referenced in four articles.[10,11,17,22] It considers variations in physician allocation within populations or regions and between them. Moreover, it helps identify areas or groups experiencing more significant disparities in physician supply, contributing to a comprehensive understanding of distribution equality. For a given variable, it is calculated as the sum of the ratio of each subgroup's value to the overall average, multiplied by the natural logarithm of this ratio. When applied to physician allocation, the Theil index can pinpoint specific subgroups with significant gaps in access to physicians, aiding policymakers in comprehending the extent of these disparities for resource allocation decisions. One key advantage of the Theil index is its capacity to offer a detailed analysis, capturing disparities both within and between subgroups, well reflecting the contributions to inequality by within-group and between-group factors.[22] It serves as a complementary measure to the Gini coefficient. Like the Gini coefficient, the Theil index falls between 0 and 1, with higher values indicating greater inequality. However, the result from Theil index is less intuitive to interpret compared to some other inequality measures, making the interpretation of results potentially challenging.[24] Additionally, this index cannot directly compare populations with different sizes, as its calculation depends on the number of physicians in the population or region.

4. Concentration index

The concentration index (CI) is another tool to assess the fairness of physician distribution across different socioeconomic groups. The CI usually defined in relation to the concentration curve, which plots the cumulative percentage of the population, ranked according to living standards, starting with the low standard, on the x-axis, and the cumulative percentage of the health human resources or physicians, corresponding to each cumulative percentage of the living standard variable, on the y-axis.

The CI is calculated as twice the area between the concentration curve and the line of equality (the 45-degree line), with values ranges from -1 to +1. A value of 0 indicates an equal distribution of physicians among socioeconomic groups, reflecting equality. A positive index suggests that physicians are more concentrated among higher socioeconomic groups, reflecting an inequitable distribution. Conversely, a negative index indicates a concentration of physicians among lower socioeconomic groups, which signifies an inequitable distribution in the opposite direction. This tool is effective in understanding how specific factors influence the concentration of physicians in different regions. For example, Witthayapipopsakul et al. applied the CI to assess the equity of health workforce distribution in public hospitals in Thailand, and the CI values demonstrated equity in health workforce distribution, with doctors being relatively concentrated in wealthier provinces.[13] However, the applicability of the CI relies on the availability of strictly ranked socioeconomic variables, such as income.[25] Missing or unreliable income data can result in misleading interpretations of the CI.[26]

5. Spatial autocorrelation analysis

Many traditional methods used to measure the equity in health workforce distribution have ignored spatial location information.[27] Overcoming this limitation, Zhu et al. adopted spatial statistics into traditional methods through spatial autocorrelation analysis.[17] Spatial autocorrelation analysis identifies spatial patterns in physician distribution, showing if similar values cluster or disperse geographically. It is useful for understanding geographic clustering of physicians, particularly in scenarios where spatial patterns are crucial for equitable distribution. Zhu et al. applied this method for studying physician distribution patterns and detecting spatial clustering or dispersion of similar values across geographic regions in China.[17] It explores whether nearby locations exhibit similar physician allocation or non-random differences. This analysis yields two key indices: global Moran's I and local Moran's I.

Global Moran's I evaluates the overall spatial pattern of physician distribution across all study areas or geographical units, with values ranging from -1 to +1. A positive Moran's I indicates positive spatial autocorrelation, signifying the clustering of areas with similar physician densities. This suggests the presence of regions with concentrated physicians alongside those with fewer physicians. Conversely, a negative Moran's I suggests negative spatial autocorrelation, indicating that areas with contrasting physician densities cluster.[17,28] A value close to zero denotes no spatial autocorrelation, indicating a random pattern of physician distribution.

Local Moran's I, an extension of the global measure, examines local spatial patterns by calculating spatial autocorrelation for each area separately. It helps identify local clusters or outliers in physician distribution and categorises areas as having high-high (areas with high physician density surrounded by areas with high physician density), low-low (areas with low physician density surrounded by areas with low physician density), high-low, or low-high spatial autocorrelation. This analysis not only highlights areas with potential healthcare disparities but also aids in targeting regions that need additional healthcare infrastructure, more physicians, or policy interventions to enhance access to healthcare services. However, the accuracy and availability of spatial units or boundary data, as well as the need for advanced software for spatial analysis and clustering map generation, may limit the use of this analysis.[29]

6. Workload Indicator of Staffing Need

The Workload Indicator of Staffing Need (WISN) is a workforce planning tool used to determine the required number of physicians in a given area. It helps assess physician adequacy or shortages based on workload and population health needs in a specific region. Only study by Asama et al. conducted in Ghana applied WISN method to quantify the inequitable distribution of health workforce.[21] The WISN method require data on physician services (including specific tasks and their frequency), task durations and workforce details (physician numbers and working hours). Using these variables, the WISN method calculates physicians' needs by comparing workload demand to the available workforce, typically resulting in a ratio or percentage.

The resulting ratio reflects the estimated physician requirement based on workload demand. A ratio exceeding 1 indicates the need for additional physicians to meet the workload, while a ratio below 1 suggests an excess of physicians. The WISN method's core purpose is to align workforce distribution with workload requirements, preventing situations of understaffing or overstaffing. However, the complexity and diversity of physician tasks can introduce challenges and variability, potentially affecting staffing estimates' accuracy. Moreover, all data required for WISN are retrospective in nature, which may not accurately reflect current workload variations.[30] The number of physicians needed in a facility may evolve over time due to factors like population growth, changing healthcare needs, policy shifts, increasing healthcare demands, and new service requirements. Therefore, regular reviews and updates of these calculations are essential to maintain their ongoing relevance and accuracy.

7. Mixed integer linear programming models
Mixed integer linear programming (MILP) models offer a systematic approach to physician distribution, simultaneously considering multiple criteria and constraints. These models guide resource allocation decisions based on predefined goals and constraints, leading to improved distribution outcomes. They are effective in scenarios with diverse objectives and constraints. For example, Suppapitnarm and Pongpirol conducted a study on the model for the allocation of medical specialists in Thailand's hospital network.[19] They aim to enhance the systematic approach to physician distribution by leveraging the capabilities of MILP models.

Five MILP models were formulated, aiming to find an optimal solution for resource allocation, minimising transportation costs, while maximising physician engagement and meeting patients' needs. These models differed based on the inclusion of part-time medical specialists and the consideration of the case mix index. Based on data analysis, the Medical Services' executives favoured Model 5 due to its reported feasibility and practicality.[19]

While MILP models offer valuable insights into allocation strategies and policy changes, it is essential to recognise that, being mathematical in nature, they can pose computational challenges.[31] Implementing this method requires computational resources and mathematical programming expertise, particularly in large-scale healthcare systems or when dealing with numerous constraints. Policymakers should carefully explore different allocation strategies and conduct sensitivity analyses to assess the robustness of distribution outcomes.[32]

8. Cohort-component model
The cohort-component model is a commonly used technique for population projection.[33,34] In the context of physician distribution, this model employs demographic techniques to estimate physician distribution based on population dynamics and workforce characteristics. This model is useful for long-term planning, projecting future physician needs based on changes in population demographics. It examines the interplay between aging, population growth and physician supply, tracking distinct age and gender-based cohorts over time. This model considers migration, births, deaths and physician workforce changes, enabling predictions of physician distribution in various regions or healthcare settings.

This review identified one study conducted by Hara et al. that applied a cohort-component model to project the future geographical distribution of physicians and their demographics in Japan.16 The study projected that from 2005 to 2035, the absolute number of physicians aged 25 to 64 will decline by 6.1% in rural areas with an initially lower physician supply, while it will increase by 37.0% in urban areas with an initially lower supply. Despite an increase in the overall number of physicians in rural areas, the geographical disparity in physician distribution is expected to worsen, with physicians aged 25 to 64 becoming more concentrated in urban areas. By employing this model, policymakers can visualise regional disparities in physician supply and address them through effective measures to ensure equitable distribution.

However, to effectively use a cohort-component model for physician distribution, accurate data on population, current physician workforce, birth and death rates and migration, both internal and external, are crucial. Challenges in collecting comprehensive and reliable data for these variables may limit the model's accuracy.[16,35]

Quality Appraisal
All studies, except one,[12] featured informative abstracts with clear titles, as detailed in Table III. Each study received good or fair ratings for the introduction, aims, and well-described methods, including sampling and data collection. These aspects included specifics on targeted samples, recruitment processes and sample size justifications. Clear data analysis descriptions also earned good or fair ratings across all studies. Ethical and bias considerations were addressed adequately in all studies, except for two,[13,19] that did not mention these issues. The presentation of results was explicit and logically structured in all studies, with the exception of four[12,19,20,22] that require additional explanations for better comprehension. All studies, except for six,[12-14,19,20,22] offered sufficient context and setting descriptions, supporting generalisability. Furthermore, all studies contributed to generating new knowledge, offering ideas for future research and suggesting policy or practice implications, except for three.[12,19,20]

DISCUSSION

Statement of Principal Findings
The current review identified 13 published articles that utilised eight different tools to assess distribution of hospital physicians across populations or regions. Each tool, namely the Lorenz curve and Gini coefficient, the Robin Hood index, the Theil index, the concentration index, the Workload Indicator of Staffing Need method, the mixed integer linear programming model, the cohort-component model and the spatial autocorrelation analysis, possess its own strengths and limitations.

Interpretation within the Context of the Wider Literature
Interestingly, all but one of these 13 articles focused on work conducted in Asia, suggesting that imbalanced physician

distribution is a common issue in this region. Most Asian countries are characterised by their large size and challenging terrain, facing significant obstacles in providing equitable healthcare services and achieving balanced physician distribution. Within these countries, larger cities often offer more attractive opportunities for physicians, including career advancement, better employment prospects, active lifestyles, and enhanced educational opportunities for their children.[36-38] Geographical maldistribution of physicians also concerns European countries, as their physician density grew at a slower rate between 1990 and 2005 compared to the period from 1975 to 1990.[39] However, unlike low- and middle-income countries, most high-income countries have the capacity to mitigate the effects of maldistribution through strategies such as air medical services or the adoption of telemedicine technology.[40-42]

Among the eight measures identified, the LC, Gini coefficient, Theil index, CI and Robin Hood index are economic methodologies conventionally used to assess socioeconomic disparities within a population. While originally developed for income inequality analysis, these measures can be adapted for assessing fairness or inequality in various contexts,[43] including physician and healthcare resource distribution.[44] The Gini coefficient and LC are widely considered as gold standards in economic analysis due to their simplicity and interpretability.[17] This may explain their prevalent use in analysing geographical physician distribution disparities in eight articles from this study. Nevertheless, the traditional Gini coefficient fails to account for the fact that people living in adjacent regions may share medical services. Therefore, Hsu et al. recommended the use of spatially adjusted Gini coefficients, which incorporate factors like neighbourhood population density, travel distance and travel time, to effectively evaluate inequality in physician distributions.[18]

Selecting the appropriate tool for physician allocation relies on the availability of essential data. This review revealed that all methods require regional data on the population and the number of physicians. Researchers with this data can readily employ simple measurement tools, such as the Gini coefficient and LC, the Robin Hood index and the Theil index to measure physician distribution. However, other methods necessitate more complex information. For example, the CI method relies primarily on the selection of socioeconomic indicators, commonly utilising population or individual income data.[25] Income data is typically obtained from household surveys and must be used cautiously.[26] Challenges in accurately measuring income, such as recall bias or capturing all sources of income, can affect the reliability of CI interpretations. Difficulty in obtaining essential data, such as geographical boundaries (for spatial autocorrelation analysis), service profiles and work measurement (for WISN method), workload capacities and travel distance (for MILP) and information on population migration (for cohort-component model), also limit the use of these measurement tools.

Implications for Policy, Practice and Research

It is also important to note that no single measurement tool can fully capture the complex factors influencing physician distribution and equitable healthcare delivery. For policy makers and researchers, the choice of tool should be tailored to the specific context and research objectives. Furthermore, assessing physician distribution is just the initial step. The findings should ultimately inform evidence-based policy decisions and interventions aimed at addressing disparities and improving healthcare equity. Regular monitoring and evaluation of the distribution of hospital physicians are also crucial to assess the effectiveness of implemented strategies and identify the need for further adjustments.

STRENGTHS AND LIMITATIONS

Some limitations encountered in this review should be acknowledged. The review was conducted to provide stakeholders with timely evidence. Due to time constraints, the literature search was limited to a few databases and included only English-language articles, potentially leading to the omission of relevant data and selection bias. Additionally, the abbreviated timeframe restricted extensive data extraction and synthesis, potentially impacting the depth and accuracy of the findings.

CONCLUSIONS

In summary, this rapid review identified eight different measurement tools to assess the distribution of hospital physicians. Each tool has its own merits and limitations, underscoring the importance of employing a combination of tools. Adopting a comprehensive and evidence-based approach are crucial for policymaking to promote equitable healthcare. Additionally, advocating for ongoing evaluation and refinement of measurement tools is essential. Rigorous validation studies, comparative analyses and the incorporation of novel data sources can also further enhance the precision and reliability of these measurement tools.

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