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The health workforce demand: a systematic literature review

A procura por recursos humanos em saúde: revisão sistemática da literatura

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Abstract *Understanding imbalances between the supply and demand of the human resources for health (HRH) is essential for enhancing health outcomes. Addressing the HRH demand is particularly challenging, especially given the deficit of accurate data and surplus of unresolved methodological flaws. This study presents a systematic review of the literature surrounding HRH demand and answers the following key questions: How has HRH demand been addressed? What are the harms and barriers that accompany HRH demand modeling? This systematic review was performed following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) statement. Relevant keywords were used in a thorough search of the PubMed/MEDLINE, SCOPUS, and Web of Science databases. A total of 2,599 papers were retrieved and evaluated according to their title and abstract. Of these, the full-text of 400 papers was analyzed, 53 of which successfully met the inclusion criteria in our study. While the topic's relevance is widespread, it still lacks a validated approach to model HRH demand adequately. The main characteristics of the applied methods are presented, such as their application complexity by health policymakers. Opportunities and orientations for further research are also highlighted.*

Key words *Needs and Demand, Health Workforce, Systematic Review, Planning*

Resumo *A compreensão dos desequilíbrios entre a demanda e a oferta da mão de obra em saúde (MOS) é essencial para a melhoria dos resultados em saúde. A demanda por MOS, em particular, é bastante desafiante dada a falta de dados e aspetos metodológicos que ainda estão por abordar. Este estudo apresenta uma revisão sistemática da literatura procurando responder às seguintes questões: Como tem sido abordada a demanda por MOS? Quais são as barreiras e limitações neste processo? A metodologia adotada baseou-se no PRISMA statement (Preferred Reporting Items for Systematic Reviews and Meta-analyses). A pesquisa foi realizada nas bases de dados PubMed/MEDLINE, SCOPUS e Web of Science, usando palavras-chave relevantes. No total 2 599 artigos foram recolhidos e analisados de acordo com os respetivos títulos e resumos. O texto integral de 400 artigos foi alvo de análise, tendo sido selecionados 53 artigos com base em critérios pré-definidos. Apesar da relevância do tema, não existe, ainda, um método para modelar a procura por MOS validado pela literatura científica. Esta revisão, além de destacar oportunidades e apontar direções de investigação futura, apresenta as principais características da modelação da procura de MOS, como a sua aplicabilidade na ótica do utilizador (decisor político).*

Palavras-chave *Necessidades e Demandas, Mão de obra em saúde, Revisão sistemática, Planejamento*

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Introduction

Human resources for health (HRH) mark the cornerstone of any given health system and society since they provide vital health services to the population. Despite the emphasis of the health workforce planning on the international public health agenda, as has been highlighted by the World Health Organization (WHO)[1], the Organization for Economic Co-operation and Development (OECD)[2], the Joint Action on European Health Workforce Planning and Forecasting promoted by the European Union (EU) Public Health Programme 2008-2013[3] and by several renowned, international peer-reviewed scientific journals, it has become widely addressed as a significant worldwide concern, with several countries reporting a huge gap between HRH demand and supply, a critical issue which has led to a variety of troubling consequences.

Despite their worldwide relevance, demand analyses still have unresolved methodological weaknesses. A confluence of forces has contributed to this situation. First, there is a confusion between the terms *demand for* and *needs of* HRH[4,5]. For example, the term "demand" is very often used as a quantification of the utilization of health care services, also called "expressed needs"[4] (later converted to a certain amount of HRH needed). Likewise, it is also used to express the health care needs of a population by using incidence and prevalence rates. Unlike this example, the concept of HRH need is not purely quantitative but also *normative*. As such, it does not always align with the economic and financial considerations that might limit its definition[6]. Less popular definitions include "*felt need*" or "*want*", as expressed on behalf of the general population, but this definition is neither representative of real need nor useful for planning purposes[4]. Different definitions hinder the development of a clear understanding of the concept of HRH and, in discussions on the topic, often generate understanding impasses.

Besides the lack of consensus on defining HRH demand, there is also a deficit of valid and accurate data on the health workforce in general, particularly concerning demand-related indicators, which compromises the construction of robust models that could effectively address this topic[7]. However, noteworthy is that many efforts have been devoted to the design and development of methods to model the HRH demand, which are found in various studies in the literature, differing on their nature, scale and methodology.

Given the above difficulties in addressing the problem of HRH demand, this study aims to provide a systematic review of the literature surrounding the modeling of the HRH demand. A review is necessary not only given the global recognition and relevance of this topic but also because of the significant efforts that have been dedicated to this field, which, although they have produced inconclusive evidence on a valid approach to address the topic, may provide clues as to the better way forward in the effective and accurate modeling of HRH demand. Previous reviews found in the literature in this field are characterized by a broad scope, encompassing both supply and demand (needs) but focusing on specific HRH fields[5,8] or particular periods[9]. This study contributes to the literature by expanding its lenses beyond specific HRH fields or period and, instead, by addressing the demand for *all* workers providing health care to populations, and by identifying the advantages and disadvantages of existing approaches in the light of their practicability by policymakers. As such, to the best of our knowledge, this study is the first to comprehensively cover the issue of HRH demand for a wide variety of health professions, periods, and across different application scales.

This paper starts by describing the design of the systematic review (Methods), followed by the results of the review with an overview of selected papers (Results). Finally, we reflect on our review's primary outcomes and summarize significant potentials and concerns for research going forward (Discussion).

Methods

This study aims to provide a systematic review of the literature surrounding the modeling of HRH demand and intends to answer the following research questions:

How has HRH demand been previously addressed in real-world applications?

What are the advantages and barriers of modeling demand for HRH?

This systematic review methodology is based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) statement[10].

Literature Search

The literature search was conducted using two general databases - SCOPUS and Web of Science

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- and one specific database - PubMed/MEDLINE. A widespread search strategy was developed to assess the maximum number of appropriate studies in each database. All the possible formulations of the terms presented in Appendix A (combined with Boolean operators) were used in the search, performed on January 7, 2019.

Eligibility Criteria

The systematic review included papers in English published up to the end of 2018. Two screening rounds were performed following the removal of duplicates. At first, two authors independently reviewed all titles and abstracts of the retrieved papers. Search results that were outside the study's context were excluded. Next, the full-text of the results was evaluated according to the inclusion and exclusion criteria.

Data Extraction

The search results were incorporated into Microsoft Excel Professional Plus 2016, in which the following information was gathered and registered: (i) authors; (ii) title; (iii) abstract; (iv) publication year; and (v) source of publication. Next, studies were extensively analyzed to evaluate their relevance for inclusion in the present review, focusing the following aspects: (i) objectives; (ii) health profession; (iv) methods; (v) scale; and (vi) typology of health care services. Any hesitation or disagreement would require authors to discuss each case until they reached a consensus. The gathered data was then analyzed to provide initial answers to the research questions mentioned above.

Results

Selected Studies

A total of 2,946 titles were identified in the initial search, including 1,260 papers from the Web of Science, 1,211 from Scopus, and 475 papers from PubMed. Following the initial screening and removal of duplicates, 2,599 papers remained. After reviewing the titles and abstracts of these remaining papers, 2,199 were excluded from the study. After these screening procedures, 400 papers remained - the full text of which was assessed and evaluated per the eligibility criteria, which resulted in eliminating an additional 347 papers. Excluded studies from this review involved papers that:

- Were only available as abstracts;
- Reported reviews of demand-related methods;
- Only discussed HRH demand planning good practices or guidelines;
- Included epidemiological studies or other indirect issues, such as:
    - Papers discussing the link between the use of health care services (e.g., the number of visits) and demographic indicators;
    - Studies focusing on the accessibility of a population to health care facilities;
- Encompassed *ad hoc* techniques (e.g., in which demand estimations were exclusively based on current service utilization rates and disregarded experts' opinions on whether these health delivery patterns were adequate or optimal), non-specified methods, or theoretical papers (non-applicative) to avoid the inclusion of methods that might be impractical in real-world contexts.

In total fifty-three papers[11-63] were included in this systematic review (Figure 1) – this result did not consider manual search, i.e., bibliographies of the selected papers were not searched.

Overview of the Selected Studies

The selected studies' publication years ranged from 1976 to 2018, and most were published from 2009 onwards (Figure 2a). About 81% of the selected studies were published in the last decade, and of these, 67% were published in the last five years (2014-2018), which reveals this topic has gained momentum in the last years.

Appendix A. Search terms utilised in the review.

Model	Demand
"Method*" OR "technique*" OR "tool*" OR "Model?*" OR "estimat*"	"Health care" OR "healthcare" AND ("demand*" OR "requirement*")
Human resources for health	**Context**
"Workforce" OR "professionals" OR "worker*" OR "manpower" OR "human health resources" OR "human resources for health"	"Plan*" OR "policy*"

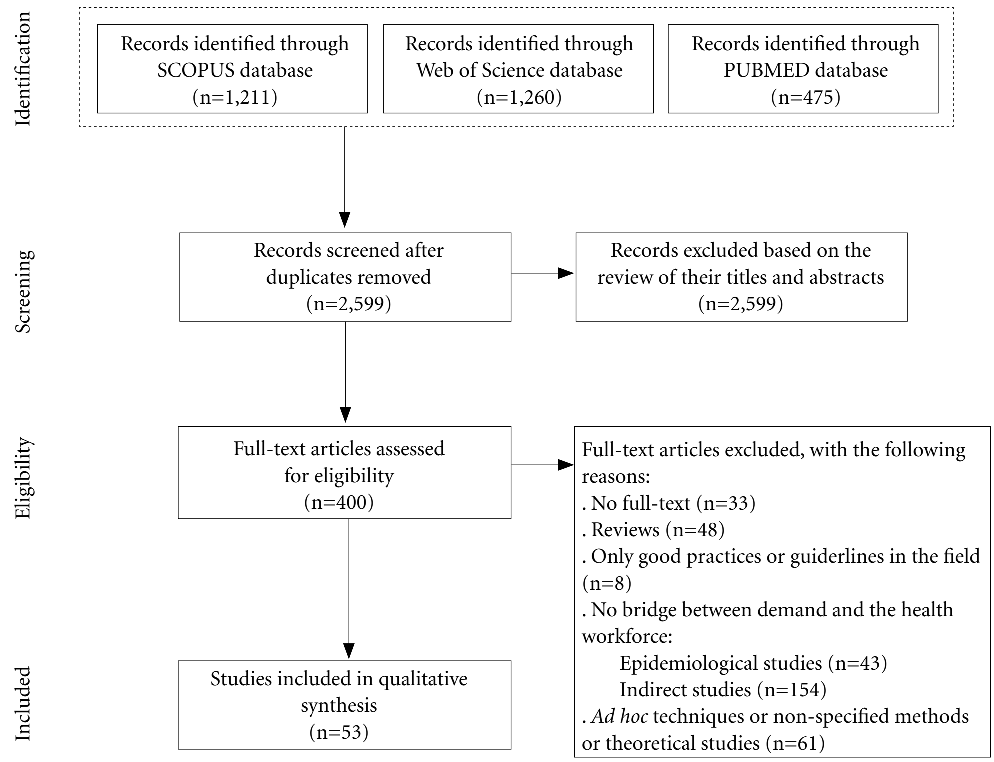

Figure 1. PRISMA flowchart of the study selection (cut-off date: 7th of January 2019).

Approximately 34% of the papers described U.S.-based applications, and 17% described European-based applications (Figure 2b). Five studies were conducted in Canada and Australia, respectively, and two studies were conducted in both Israel and Japan. Four studies were applied to more than one country: WHO countries (n=2), OECD countries (n=1), and Southeast Asian countries (n=1). Appendix B provides a map with the spatial distribution of the selected studies per country of affiliation. Regarding the scale of application (Figure 3a), most studies (n=36) were applied at a national level (country). Nine studies were implemented at a state level; these ranged from single-state studies (e.g., South Australia) to studies involving multiple states (e.g., any of the individual 50 U.S. states). The remaining eight studies were conducted in specific regions.

Forty-one of the 53 studies derived from different journals, which denotes a great variety of scope and research areas. Almost half of the papers were published in clinical journals (i.e., journals dedicated to one or more health professions), and most were included in medical journals. The remaining 27 studies were published in health policy and management journals (Figure 3b). The list of journal titles organized according to the journal's characteristics is provided in Appendix C.

Also, noteworthy is that the papers of Angus et al.[56] and Thomas et al.[15] were the most often cited, and both were published in journals devoted to the medical profession (Appendix D). Mainly, Angus et al.[56] aimed to estimate the requirements for adult care and pulmonologists in the U.S. In contrast, Thomas et al.[15] focused on mental health providers divided into two professional groups, namely, prescribers (psychiatrists) and non-prescribers (social workers, psychologists, nurses, among others).

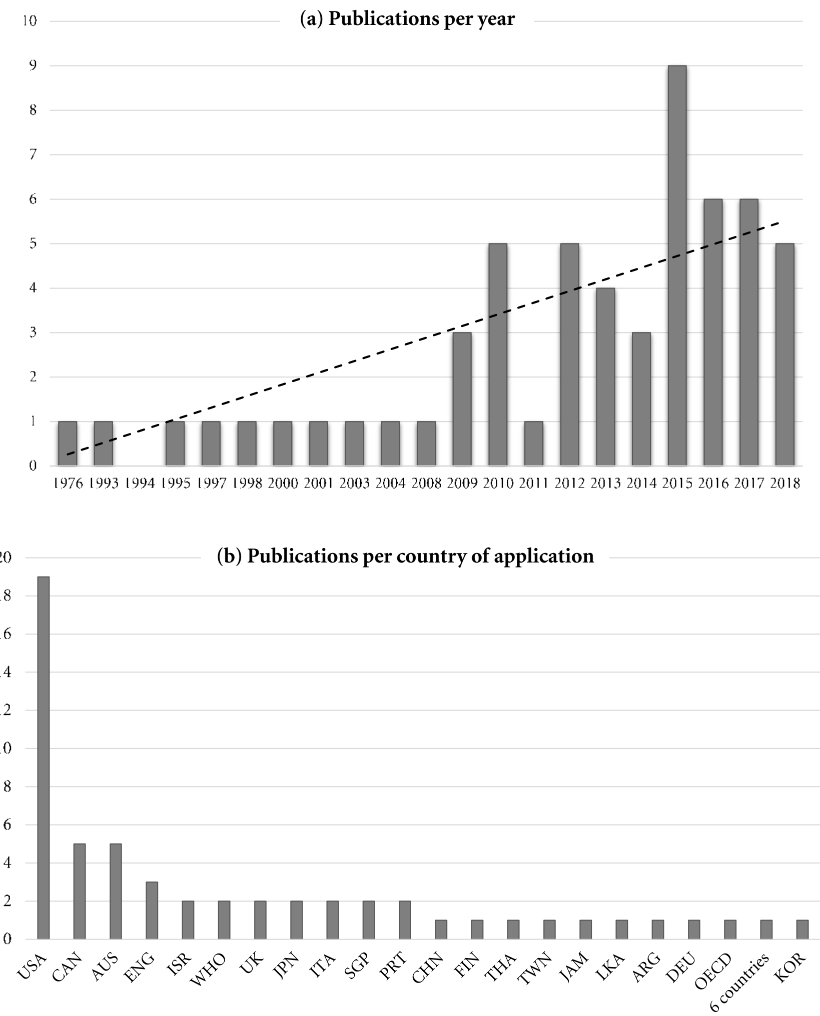

Figure 2. Overview of the general aspects of the selected publications.

Legend: 6 cowntries stand for AZE, MWI, MMR, PER, UZB and ZMB.

Appendix B. Spatial distribution of the selected studies per country of affiliation.

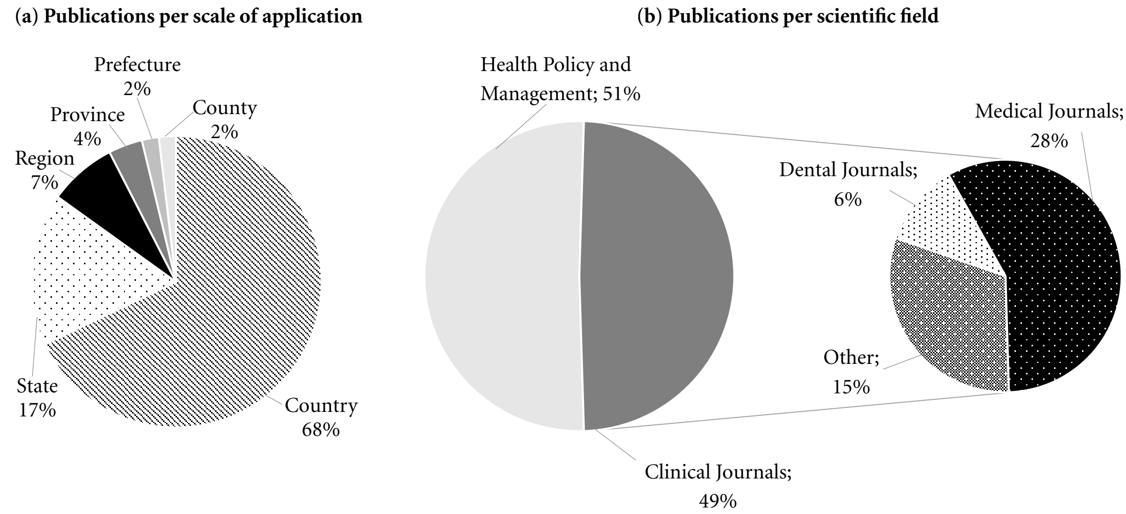

Figure 3. Characterization of the selected articles according to: (a) scale of application and (b) scientific field.

Appendix C. Journals according to their context.

Clinical Journals	
Medical journals	**Dental journals**
. Acta Ophthalmologica . Archives of Pathology & Laboratory Med. . Cardiologia . Cardiovascular Surgery	. British Dental Journal . Community Dentistry and Oral Epidemiology . International Dental Journal
. Investigative and Clinical Urology	**Others**
. Neurology . JAMA . Milbank Quarterly . Revista Argentina de Family Practice . Otolaryngology - head and neck surgery . Ophthalmology . Pediatrics . Pedriatics and Neonatology . The Annals of Thoracic Surgery . The Journal of Thoracic and Psychiatric Serv.	. Academic Emergency Medicine . Alimentary Pharmacology and Therapeutics . Diabetes Cares . Ethnicity and Disease . Journal of the Academy of Nutrition and Dietetics . Mayo Clinic proceedings . PM and R: The Journal of Injury, function, and rehabilitation
Journals Related to Health Policy and Management	
. Australian Health Review . BMC Public Health	. Human Resources for Health . IIE Transactions (Institute of Industrial Eng.)
. Bulletin of the WHO . Emerald Group Publishing Limited . Health Care Management Science . Health Policy . Health Policy and Planning . Health Systems	. Israel Journal of Health Policy Research . Long Range Planning . Management Science . PLoS One . Policy, Politics, and Nursing Practice . The Lancet Public Health

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Appendix D. Twenty most cited papers among the 53 selected studies.

Authors	Year of publication	Journal	Scopus citations
Angus et al.	2000	Journal of American Medical Association	712
Thomas et al.	2009	Psychiatric Services	194
Vijan et al.	2004	Alimentary Pharmacology & Therapeutics	121
Scheffler et al.	2008	Bulletin of the World Health Organization	105
Hofer et al.	2011	The Milbank Quarterly: A Multidisciplinary Journal of Population Health and Health Policy	104
Dall et al.	2013	Neurology	93
Schubert et al.	2001	Mayo Clinic Proceedings	37
Liu et al.	2017	Human Resources for Health	34
Murphy et al.	2012	Health Policy	27
Lipscomb et al.	1998	Management Science	25
Tuulonen et al.	2009	Acta Ophthalmologica	25
Gallagher et al.	2010	British Dental Journal	24
Zimbelman et al.	2010	PM & R: The Journal of Injury, Function and Rehabilitation	24
Kim et al.	2012	Otolaryngology-Head and Neck Surgery	23
Lee et al.	1995	Ophthalmology	20
Rizza et al.	2003	Diabetes Care	17
Murphy et al.	2009	Policy, Politics, & Nursing Practice	17
Hooker et al.	2012	Journal of the Academy of Nutrition and Dietetics	17
Vanderby et al.	2010	The Annals of Thoracic Surgery	16
Holliman et al.	1997	Academic Emergency Medicine	12

Health Professions and Typology of Services

More than half of the selected studies were focused on the medical profession (n=34). Ten papers approached the profession globally, and the remaining papers were related to one or more specialties. Regarding the latter, it is clear from our review that significant endeavors have been devoted to studying HRH demand in the medical specialties of family medicine, ophthalmology, and surgical specialties (see Appendix E).

Nursing and dental professions (e.g., dentists, hygienists, therapists, and technicians) are the second occupations with the highest number of studies (five studies each), with some being focused on specific nursing specialties, such as orthopedics, pediatrics, and neonatal fields. Four papers addressed other health professions (e.g., pharmacy, nutrition science, among others).

Despite 90% of the studies being focused on a single health career, since 2010, an increasing number of studies have been addressing multiple professions[24,47,50,54,55]. For instance, Stein et al.[24] covered both physicians and nurses, Murphy et al.[47] addressed physicians, nurses and midwives, and Hoope-Bender et al.[50] focused on sexual, reproductive, maternal, neonatal and adolescent HRH. Therapists and psychiatrists were also included in the remaining studies (Figure 4a).

Concerning the typology of the health care services addressed, more than half of the selected studies were dedicated to secondary health care services (Figure 4b). This finding was expected since central hospitals gather a wide variety of health care professionals. Four studies focused on the demand for HRH, focusing on primary health care services. All the typologies of health care services (including at the tertiary level) were covered in nine studies. The remaining studies (n=11) were geared to HRH demand in health care services not classified according to the primary, secondary, or tertiary health care typology or are a combination of two services in this typology.

Approaching HRH Demand

A large amount of research, from various perspectives, has been made in this field: From a demand-based approach to needs-based approaches and benchmarking.

The demand side approaches, also known as expressed needs or utilization-based approaches[4], are commonly used to quantify the use of health

Appendix E. Characteristics of the selected studies.

Nº	Ref.	Pub. year	Country Affiliation/ Application	Scale	Health professions	Components addressed
1	[18]	1976	ISR / ISR	Country	Physicians (GP; PD; SUR; D; OPH, GYN; OR; N; U) [1]	Demand and supply
2	[19]	1993	UK / CHN	Country	Physicians	Demand
3	[30]	1995	USA / USA	Country	Physicians (ophthalmologists and optometrists)	Demand, need and supply
4	[41]	1997	USA / USA	Country (states)	Emergency physicians (EP)	Demand and supply
5	[52]	1998	USA / USA	Country	Internal medicine	Demand
6	[63]	2000	USA / USA	Country	Physicians (intensivists and pulmonologists)	Demand, needs and supply
7	[67]	2001	USA / USA	Country	Physicians (anaesthesiologists)	Demand and supply
8	[68]	2003	USA / USA	Country	Physicians (endocrinologists)	Demand, needs and supply
9	[69]	2004	USA / USA	Country	Physicians (endoscopists)	Demand and supply
10	[70]	2008	USA / WHO region	Countries	Physicians	Demand, needs and supply
11	[20]	2009	CAN / CAN	Province (Nova Scotia)	Nurses	Demand, needs and supply
12	[21]	2009	FIN / FIN	Country	Physicians (ophthalmologists)	Needs, costs and supply
13	[22]	2009	USA / USA	County	Physicians (mental health professionals)	Demand, needs and supply
14	[23]	2010	USA / USA	State (Island of Hawaii)	Physicians	Demand and supply
15	[24]	2010	ENG / ENG	Country	Dentists	Demand and supply
16	[25]	2010	USA / USA	Country	Physical therapists (PT)	Demand and supply
17	[26]	2010	CAN / CAN	Country	Physicians (cardiac surgeons)	Demand and supply
18	[27]	2011	USA / USA	State (50)	Physicians (Primary healthcare)	Demand
19	[32]	2012	USA / USA	Country	Dietitians and dietetic technicians	Demand and supply
20	[28]	2012	USA / USA	Country	Physicians (otolaryngology workforce)	Demand and supply
21	[31]	2012	NLD / THA	Province	Mix of HRH (physicians and nurses)	Demand and needs
22	[33]	2012	CAN / CAN	Country	Nurses	Demand, needs and supply
23	[29]	2012	JPN / JPN	Country	Physicians	Demand and supply
24	[34]	2013	USA / USA	Country and 50 states	Physicians (neurology workforce)	Demand and supply
25	[35]	2013	UK / ENG	Subregional communities & region	Dental team	Demand, needs and supply
26	[36]	2013	TWN / TWN	Country	Physicians (paediatricians)	Demand and supply
27	[37]	2013	UK / ENG	Country	Dental team	Demand and supply
28	[38]	2014	CAN / JAM	Country	Pharmacists	Needs and supply
29	[39]	2014	CAN / CAN	Country	Cardiac surgeons	Demand and supply
30	[40]	2014	CAN / CAN	Country	Thoracic surgeons	Demand, needs and supply
31	[45]	2015	ITA / ITA	Region	Physicians	Demand and supply
32	[46]	2015	USA / USA	Country and 50 states	Occupational therapists	Demand and supply

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Appendix E. Characteristics of the selected studies.

Nº	Ref.	Pub. year	Country Affiliation/ Application	Scale	Health professions	Components addressed
33	[43]	2015	USA / USA	Country	Nurses (paediatric nurse practitioners (PNPs))	Demand and supply
34	[49]	2015	ISR / ISR	Country	Nurses	Demand and supply
35	[48]	2015	USA / USA	Country	Pathologists	Demand and needs
36	[47]	2015	SGP / SGP	Country	Ophthalmologists	Demand, needs and supply
37	[44]	2015	UK / LKA	Country	Odontology team	Demand, needs and supply
38	[42]	2015	AUS / AUS	Country	Physicians (radiology)	Demand and supply
39	[50]	2016	USA / USA	Country	Nurses	Demand
40	[51]	2016	ARG / ARG	Country	Physicians	Demand
41	[53]	2016	DEU / DEU	Region	Dentists	Demand and supply
42	[54]	2016	CAN / OECD countries	Country	Mix of HRH (midwives, nurses, physicians)	Needs and supply
43	[55]	2016	AUS / AUS	State (South Australia)	Physicians (GP)	Demand, needs and supply
44	[56]	2016	ITA / ITA	Region	Physicians	Demand, needs and supply
45	[57]	2017	CHE / 6 countries	Country (AZE, MWI, MMR, PER, UZB & ZMB)	Mix of HRH (SRMNAH[2] workers)	Needs
46	[58]	2017	KOR / KOR	Country	Physicians (urologists)	Demand and supply
47	[59]	2017	AUS / AUS	State (South Australia)	Physicians (general practitioners (GP))	Needs and supply
48	[60]	2017	JPN / JPN	Prefecture (Hokkaido)	Physicians	Demand and supply
49	[61]	2017	USA / WHO countries	Country (165)	Mix of HRH (nurses/midwives, physicians & other HRH)	Demand and supply
50	[62]	2018	AUS / AUS	State (South AUS)	Mix of HRH (Therapists, Psychiatrists, Psychosocialists)	Needs
51	[64]	2018	PRT / PRT	Country	Physicians	Demand
52	[65]	2018	AUS / AUS	State (South & Western AUS)	Physicians (General practitioners)	Demand, needs and supply
53	[66]	2018	PRT / PRT	Country	Physicians	Demand and supply

[1] GP: General practitioners; PD: Paediatrics; SUR: Surgery; D: Dermatology; OPH: Ophthalmology; GYN: Gynaecology; OR: Orthopaedics; N: Neurology; U: Urology. [2] SRMNAH: Sexual, reproductive, maternal, new-born and adolescent health workers.

care services by a population. HRH requirements are then calculated, adjusting the current amount of HRH delivered with the expected demographic changes in the target population. Hence, estimates translate neither the need nor the demand for HRH but solely preserve the *status quo* by assuming that satisfied demand is represented by (a) the current use of the health care services, (b) the current workforce-to-population ratio, and (c) the economic projections that relate social, political and economic factors to the consumption of health care services[63].

In the needs-based or epidemiological approaches, needs are expressed in terms of the required number of HRH that keep the population healthy. Typically, it involves epidemiological information (i.e., the observed health status of a population, through the use of incidence, prevalence, among other indicators) and evidence about adequate care delivery patterns (expressed

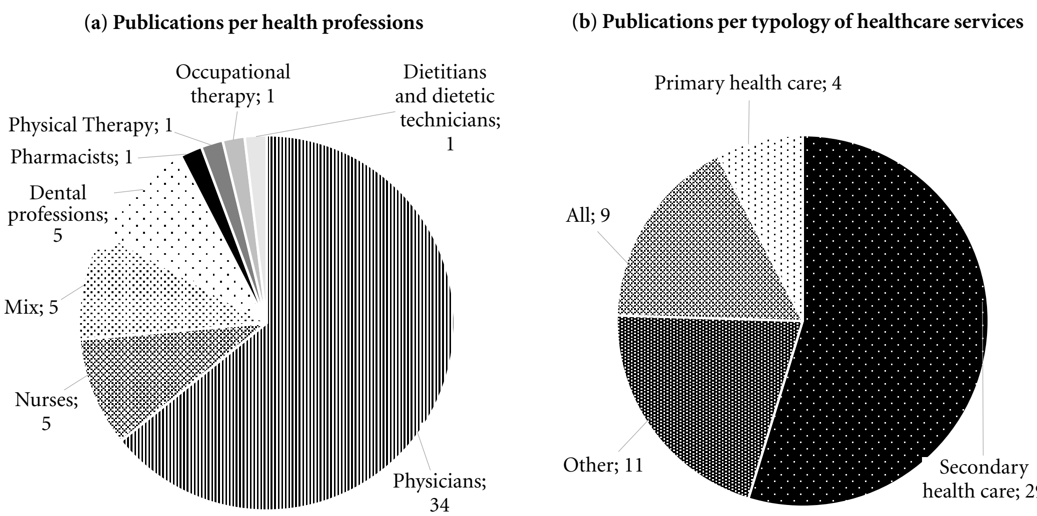

Figure 4. Characterization of the selected articles according to: (a) profession, and (b) typology of healthcare services.

in terms of HRH), which are commonly acquired through expert knowledge. HRH needs can be inferred from the gap between the observed and targeted health status. For instance, inspired by the work developed by the Graduate Medical Education National Advisory Committee in 1981[64], Lee et al.[23] estimated the public health need for ophthalmologists by considering (a) the incidence and prevalence rates for 97 eye-related diseases and conditions, (b) the clinical population for each disease or condition, and (c) the population at risk. The projected incidence and prevalence rates were then applied to population projections to infer the number of affected individuals. Next, some adjustments were made to distinguish patients with different characteristics (e.g., patients suffering from multiple conditions) by consulting an advisory panel. Worktime requirements were attained by a survey of more than 2,000 ophthalmologists and converted to the required HRH[12]. This study illustrated that a considerable amount of data is required to determine a specific medical specialty's needs, which makes this approach impractical for evaluating a wide range of HRH needs. This is even more critical with limited epidemiological data, making the demand-based approach the easiest, least time-consuming, and least expensive proxy for needs.

Benchmarking relies on identifying regions or countries comparable – both at the demographic and health level, but which are strikingly different in terms of the costs and deployment of the HRH. The primary approach is to apply these benchmarks (recognized as a reference of good practices) to the general population or build plausible scenarios. This approach's limitations include the definition of clear criteria for selecting the reference that can be best compared to the context under analysis.

This classification of approaches was proposed by Roberfroid et al.[8] and is widely disseminated, enabling the understanding of the process. Nonetheless, demand is typically modeled by more than a single approach. In particular, Rizza et al.[61] used three approaches to determine the demand for endocrinologists in the U.S. through 2020. Specifically, this study included scenarios in which demand was affected by (a) population growth; (b) utilization rates (e.g., patient visits), (c) changes in the incidence and prevalence of diabetes; and (d) benchmarks coupled with economic aspects[61].

Methods

HRH demand models have become progressively complicated and have adopted a system-wide perspective. The main dis tinctions are the premises underpinning the foundation of problem formu-

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lation and the available data (which is translated through the type of variables considered in the models); the number of methods used; how they are integrated; which type of software is used; and the inclusion of expert knowledge. Despite these efforts, there remains no established nor accepted approach to estimate the demand (or needs) for HRH adequately. This section presents the main characteristics of different methods and their advantages and disadvantages, which provides valuable insights for policymakers and the development of future research.

Most selected studies (n=28) used simulation-based methods to model HRH demand, while others used regression methods (n=17) and others relied on straightforward models (n=8) (see Table 1). A brief description of each methodological category is mentioned below.

Straightforward models

In this category, demand is given by simple mathematical formulations relating key demand parameters[36,50,55,59] or a combination of experts' opinions with alternative scenarios that assume different work hypotheses[16,41,42] (e.g., the steadiness of service utilization rates[23]). These models have a very narrow scope, whereas more general approaches, such as simulation-based methods or a combination of the latter with other tools, are more robust and can support more features of the demand for HRH. Although these straightforward methods might be the simplest and least costly technique to assess HRH demand, they might also be the least accurate. For these reasons, these methods' results should be thoroughly analyzed since they are typically representative of a particular context.

Regression methods

Regression methods are widely known and, through simple means, offer an overall picture of what happened in the past, what is happening in the present, and what will happen in the future. The main advantage of these tools consists of identifying the relationships between relevant variables (e.g., the utilization rates of services and economic, demographic, social, and epidemiological indicators), which serves as a mechanism for better understanding the realities of the health system.

The first steps in regression analyses of HRH demand can be traced back to 1976, in which Pizam et al.[11] estimated the demand for doctors by using a linear regression method that related total requirements to socioeconomic variables (e.g., population growth and GNP *per capita*). Other regression approaches have been applied for this purpose, relating demand variables through linear regression methods[18,39,63], generalized linear models[54], bivariate and linear analyses (through Ordinary Least-Squares)[15,46], multivariate regression models [20], extrapolation[21,25,28,34,60,61], autoregressive models (e.g., the Autoregressive Integrated Moving Average method)[51], and other statistical analyses[56,57]. Typically, these methods do not manage sensitivity and robustness analyses *per se*, but in this study, sensitivity analyses were performed considering stochastic error distribution of variables, literature reviews, survey data, and expert opinion. Finally, it is essential to note that some regression methods require specialized software and specific expertise, and their results are employed to feed simulation-based models[44].

Table 1. Distribution of the selected studies per methodology.

Methods	Reference
Straightforward models	[23,30,43,48,49,57,62,66]
Regression methods (linear regression, autoregressive models, multivariate reg. model)	[18,22,25,27,28,32,35,41,46,53,58,61,63,64,67,68,70]
Simulation-based methods	
System dynamics	[20,21,26,33,36,39,42,44,45,47,51,54,56,60]
Monte Carlo Simulation	[24,59]
Microsimulation	[34,40]
Other simulation models	[19,29,31,37,38,50,52,55,65,69]

Simulation-based methods

Simulation-based models provide a general overview of the problem, representing the relationships between variables in a transparent learning process. These generic approaches can either integrate assumptions from a scalar level or more sophisticated mathematical formulations. Following the terminology proposed by Banks et al.[65], simulation models can be either dynamic, static and deterministic, or stochastic. The term "dynamic" refers to systems that evolve over time instead of a static simulation that represents a system at a particular point in time. Deterministic simulations receive a well-known set of inputs and return a unique set of outputs; a stochastic simulation model receives random variables as inputs and returns random outputs.

System dynamics (SD) has been one of the most popular methods used in the selected studies (n=14) and has gained momentum in the past decade[14]. Created in the 1950s, SD attempts to manage the behavior of complex systems analyzed over time using stocks, flows, loops, specific functions, and time delays through differential equations solved numerically with specific software[14] (e.g., Vensim or STELLA).

These studies typically include two populations (HRH and inhabitants) and relate them to crucial parameters by assuming working hypotheses. For instance, some studies have determined the demanded number of HRH as a target provider's function *per capita*[26]. Other studies have estimated the number of HRH, considering variations in population needs and delivery patterns over time. Regarding the latter, these patterns revolve around operational indicators – like the number of patients served with a given number of full-time equivalents (FTEs) or headcounts; or service utilization through the number of outpatient visits[13,19,26,32,35,40]. Also, some studies complemented the estimates with international studies and experts' opinions[14,37,53]. A combination of SD with other tools was also found within the selected studies. For instance, Ishikawa et al.[53] made use of SD combined with GIS technologies to analyze the dynamic change and to measure regional disparities.

Microsimulation models have also been used to simulate micro-units' demand-related behavior (person-level) over time[27,33]. Edwards et al.[33] predicted the thoracic surgery workforce requirements by fixing the published rate of (in)operable lung cancers as indicative for the overall demand. Some key parameters were not included, such as economic variables or disease complexity. Dall et al.[27] estimated the demand for neurologists by patients' willingness and ability to pay for services, given patient needs and the cost of services.

Predictive equations included (a) the Poisson regression, which was used to quantify the relationship between patient characteristics and the number of consultations; and (b) the logistic regression used to determine the probability of emergency visits and hospitalizations for specific conditions, considering patient demographics and health characteristics as explanatory variables. Despite the methodological innovation in some of these methodological approaches, some authors argued that a lack of documentation limits its knowledge transfer, which might lead to new modelers merely reinventing the wheel[66].

Table 1 displays the distribution of the selected studies per methodology. Chart 1 summarizes the advantages and disadvantages of the typologies of methods considered in this review and highlights the benefits, challenges, and issues regarding HRH planning.

Social component

Experts' consultation is key for estimating HRH demand[67], especially when it comes to accessing the staff standards that meet the population's needs and defining plausible scenarios. Fifteen studies carried out this component through either focus groups, Delphi panels, or interviews[14,16,19,23,24,32,41,42,45,49,53,55,56]. Typically, experts were individuals with different backgrounds, such as HRH, academic researchers, or management personnel. Other studies do not specify and describe the underlying participatory technique[30,35,37,38,40,48,50,52]. An impressive amount of studies selected in this review did not include this component, thus revealing different understandings about the potential of experts' knowledge or the limitations of time restrictions that undergirded the development of their participatory techniques.

Discussion

Barriers to the modeling of HRH demand

Estimating the demand for HRH is a crucial component in HRH planning, which affects population well-being. How many HRH does the population need? How should we model the de-

Chart 1. Pros and cons of selected methods.

Pros and cons	How it benefits the HRH planning	Challenges and issues
Straightforward models +Simple to use -Narrow scope -Easy to misuse the results by not recognizing the boundaries of their credibility -Limited validity, since the past and current data represent what was provided rather than a target -Subject to criticism, given the lack of scientific evidence	The development and implementation of these models are simple and have a low time consumption A typical user can use them (e.g., a policymaker) Reduced implementation costs Do not require specialized software	Results should be carefully analyzed, as they are based on strong assumptions and typically on few demand-related parameters Uncertainty and sensitivity analyses are typically unaddressed
Regression methods +Simple, widely known +Creates an overall understanding of what happened in the past and provides valuable insights regarding what may happen in the future -Limited validity, since the historical data represent what was provided rather than what is needed -Subject to criticism when this tool is not coupled with other instruments	Can help in the identification of critical relationships between relevant variables Can serve as a scenario to explore and an input (complement) for simulation models	Dependent on data availability Do not deal with uncertain data Do not display a component of sensitivity analysis Specialized software and specific expertise may be required
Simulation-based models +Building process can clarify the understanding of the real system +Allow optimization of the real system +Can maintain better control over experimental conditions +Time compression/expansion: can evaluate the system on a slower or faster time scale than the real system -Expensive and time-consuming -Easy to misuse simulation -Deterministic simulations are unable to deal with data uncertainty -Stochastic simulation usually requires several runs at given input values	They provide an overall picture of the problem and represent the links between variables A generic approach that can incorporate assumptions and restrictions from a scalar level to sophisticated mathematical formulations Stochastic simulations can perform robustness analysis by handling data uncertainty or scenario building Allow sensitivity analysis	Development can be demanding and laborious Complex for typical users Require specialized software and specific expertise Higher costs of implementation

Captions: "+" stands for positive aspects and "-" for negative aspects.

mand for HRH? These are pertinent questions, but answering them is challenging due to the following elements:

1. Lack of reliable and accurate data regarding the key drivers (from epidemiological information and costs to an exhaustive list of indicators for measuring utilization rates such as office visits), which is shared among all the selected studies. The existence of valid and updated data is paramount for us to understand where we are coming from, appraise the current situation, and develop an informed understanding of the future.

2. Arbitrariness in the definition of the drivers representing current and future demand, especially given the lack of an accurate description of what demand is and how it should be measured. The previous section revealed studies following different perspectives, which lead to considering distinct data sets. We highly recommend the previous consultation of the work developed by O'Brien-Pallas et al.[9] to avoid this non-uniformed pattern of research development and application, which provides a full list of data requirements for approaching demand within certain health professions. We believe this proposal is paramount for all HRH.

3. Hard-to-predict changes in HRH demand, as these changes are affected by uncertain factors

– namely deriving from changes in demography, patient complexity (e.g., the demand-related behavior of micro-units (person-level)[27,33]), technology, policy, and economy. There is currently no consensus among researchers on how to handle and predict the consequences of such changes. For instance:

a. On the one hand, some authors have argued that new technology increases the number of treatable medical conditions and could reduce HRH demand; on the other hand, other studies advocate the opposite stance[42]. Moreover, while these debates in the literature show an association between new technological devices and management, quality, and cost of care, only one of the selected studies have spent time discussing this topic[42].

b. Regarding the epidemiological profile of different populations, it was challenging to quantify adequate health services (and HRH) for a wide range of conditions, highlighted by the lack of consensus among researchers and experts on this topic. Some studies assume that older age groups consume more health care services and, consequently, invoke higher health expenditures as discussed by Lopes et al.[59]. In contrast, other authors disagree with this assumption and focus instead on the positive influence of preventive medicine, better care, and healthier lifestyles that promise to delay the onset of chronic diseases and disability within a given lifetime, while considering residual changes in life expectancy. Also, from this perspective, morbidity would remain during a shorter time in a life cycle[42].

c. Political changes with impact at the level of HRH required in each facility, either through reforms in the organization of service delivery or through modifications in HRH's role, which are subject to change. For instance, the nurse-to-physician ratio in European countries is already changing, and, as such, political measures and international evidence points to an expansion of nurses' role in these contexts[68-70].

4. HRH demand models require monitoring and updating data throughout the years, which unavoidably involves specific expertise and costs that might not be feasible for policymakers.

Research needs

The relevance of modeling the demand for HRH is acknowledged in the literature, and this review intends to provide some guidance to policymakers, researchers, and those involved in improving HRH modeling. Several challenges emerged from this review and pointed to challenges that may need to be confronted to improve future research in this area:

1. Enhance the databases' quality and quantity regarding key drivers, as a requirement for any sound HRH demand modeling.

2. Extend research to other HRH, namely to diagnosis and therapy technicians, and to psychologists, as most (90%) focused on a single health career.

3. Adequately address HRH demand at a territorial level. Few studies covered this topic[24,46,53], possibly due to the methods required to do so (which involve including geographic information systems that are not widely established in the health sector) and due to the lack of a generally accepted definition of adequate access[46]. Hence, there is room for expanding methods to:

- Characterize the future population's needs regarding the various typologies of health services. Such tools depend on epidemiological data, which should be available at the territorial level;
- Evaluate the territorial level equity of health care access and other public services (e.g., in schools). According to Ono et al.[2], it remains a policy issue in most OECD countries because it directly affects the ability to attract and retain HRH in underserved areas.

4. Develop a compromise between simplicity and accuracy of the demand modeling, as simple methodsmay not provide reliable results but, at the same time, overly complicated methods requiring extensive implementation time or exaggerated expertise requirements run the risk of triggering rejection by policymakers, as stressed in Chart 1.

Limitations

Sound search procedures (i.e., PRISMA) were used to select papers for this systematic review. Nevertheless, some papers may have been overlooked in this process. The multiple designations and diverse terminology that abound within the field might have caused the authors to miss papers featuring keywords that are not typically used in existing terminologies. Moreover, the search was restricted to English-language studies and peer-reviewed published papers, which might have limited the search results". However, we believe that inherent risks of our selection process are overshadowed by the large number of studies included in this review, which covers a broad range of HRH and provide a host of different perspectives and methods.

Finally, it is worth noting that the scientific

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quality of the studies was not appraised. However, we consider that this step was also overshadowed by another consideration – the definition and implementation of a rigorous list of exclusion criteria and a careful analysis of the methods applied in each paper.

Collaborations

DF Lopes and AL Ramos designed the study. DF Lopes collected the data, performed the analyses, and wrote the initial draft. AL Ramos and EA Castro (supervision) were involved in the correction of the manuscript's final drafts. The authors all read, contributed to, and agreed to submit the manuscript for publication.

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