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ORIGINAL ARTICLE

Workforce requirements in rheumatology: a systematic literature review informing the development of a workforce prediction risk of bias tool and the EULAR points to consider

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ABSTRACT

Objective To summarise the available information on physician workforce modelling, to develop a rheumatology workforce prediction risk of bias tool and to apply it to existing studies in rheumatology.

Methods A systematic literature review (SLR) was performed in key electronic databases (1946–2017) comprising an update of an SLR in rheumatology and a hierarchical SLR in other medical fields. Data on the type of workforce prediction models and the factors considered in the models were extracted. Key general as well as specific need/demand and supply factors for workforce calculation in rheumatology were identified. The workforce prediction risk of bias tool was developed and applied to existing workforce studies in rheumatology.

Results In total, 14 studies in rheumatology and 10 studies in other medical fields were included. Studies used a variety of prediction models based on a heterogeneous set of need/demand and/or supply factors. Only two studies attempted empirical validation of the prediction quality of the model. Based on evidence and consensus, the newly developed risk of bias tool includes 21 factors (general, need/demand and supply). The majority of studies revealed high or moderate risk of bias for most of the factors.

Conclusions The existing evidence on workforce prediction in rheumatology is scarce, heterogeneous and at moderate or high risk of bias. The new risk of bias tool should enable future evaluation of workforce prediction studies. This review informs the European League Against Rheumatism points to consider for the conduction of workforce requirement studies in rheumatology.

Key messages

What is already known about this subject?

- The projections from existing workforce studies in rheumatology vary by a factor of five, largely due to methodological heterogeneity.

What does this study add?

- This study provides a synthesis of information of the workforce prediction literature in rheumatology and other medical fields about general aspects, supply, need and demand factors considered in workforce models.
- We hereby use a self-developed workforce prediction risk of bias tool to guide and assess the quality of workforce studies in rheumatology.

How might this impact clinical practice?

- The developed tool is meant to improve the methodological quality of future workforce studies and ultimately to lead to better workforce planning in rheumatology.
- This review informs the European League Against Rheumatism points to consider for the conduction of workforce requirement studies in rheumatology.

INTRODUCTION

Rheumatic and musculoskeletal diseases (RMDs) are highly prevalent and, according to the burden of disease report, present a major cause of disability-adjusted life years worldwide.[1] Due to population growth, ageing and improved diagnosis, the prevalence of RMDs in developed countries increased by 60% from 1990 to 2010.[2] While expert consensus exists with respect to how best manage RMDs in order to prevent adverse long-term consequences,[3–5] inadequate manpower documented in many countries hinders implementation of these recommendations.[6 7] Workforce planning in

healthcare is further challenging due to time and costs involved in training of new physicians. Methodologically sound workforce planning should guide policy decisions on the number of students entering into education and medical training programmes.[8]

A recent systematic literature review (SLR) on workforce projection models in rheumatology from Western countries identified a large heterogeneity in methods for projecting the rheumatology workforce needs.[9] Notably, published studies covered only a handful of Western countries, and the resulting projections from available studies varied by a factor of five[9] and are thus not a reliable basis for political decisions. Therefore, the development and implementation of a sound approach to health workforce planning is needed to ensure access of the population to best practice disease management.

The need for an agreed-on methodology for workforce predictions is discussed not only in the field of rheumatology. A number of workforce prediction studies have also been conducted in other medical fields.[10–12] It is likely that major principles of workforce modelling are common to other specialties in medicine. To date, however, insufficient attention has been given to synthesise the existing evidence on methodologies used for workforce predictions. To our knowledge, there has been no attempt so far to agree on a standard methodology for the conduction of workforce studies, nor has there been any attempt to appraise such studies for methodological quality and risk of bias.

The overarching aim of this SLR was to inform the European League Against Rheumatism (EULAR) task force working on 'points to consider' for the conduction of workforce requirement studies in rheumatology.[13] The specific objectives of the present work were (1) to perform an update of the published SLR on workforce prediction in rheumatology,[9] (2) to conduct a hierarchical SLR (overview of reviews) of workforce prediction models in other medical fields, and (3) using available data to develop a workforce prediction risk of bias tool and to apply it to existing workforce studies in rheumatology.

METHODS

Design of the systematic literature search

We conducted two SLRs, including an update of an SLR of workforce requirement studies in rheumatology[9] and a hierarchical SLR (which is an overview of systematic reviews) of workforce prediction studies in other medical fields (including all medical specialties, but also related areas like nursing, physiotherapy and pharmacy) in Western countries.

Search strategy and eligibility criteria

The EULAR task force to develop 'points to consider' for the conduction of workforce requirement studies in rheumatology outlined the scope of the literature search according to the PICO (Population, Intervention, Comparator, Outcomes) format. The *population* was defined as (1) adult rheumatologists (for the update of the recent SLR in rheumatology) and (2) other medical fields, namely medical specialists and other health professionals (for the hierarchical search). The scope of the update did not include paediatric rheumatologists. The *intervention* was defined as (1) the type of workforce model, (2) the factors used to build up the model or (3) the empirical data used for the calculation of workforce requirements. The *comparator* could not be defined for this review question. The *outcome* was defined as the number of rheumatologists/other specialists needed to serve the (general) population. Studies with any *time frame* for predictions, including those making calculations for baseline only (ie, calculations referring to the year when prediction has been made), were included.

For the update search in rheumatology, we used the same search strategy and eligibility criteria as in Dejaco *et al*.[9] MEDLINE, Embase, PubMed, CINAHL and the Cochrane Library were searched (Search Strategy in the Online Supplementary Text S1) between 1 November 2015 (date of the original search) and 6 October 2017. The search strategy for the hierarchical SLR was designed by an experienced librarian (LF). First, using known studies on workforce prediction in other fields, a number of searches were run in PubMed applying special features to find similar articles and/or SLRs where these studies were included, followed by a cited reference search on Web of Science. Further, using a set of search terms (online supplementary text S2), we conducted a search in MEDLINE and Cochrane library (1946 to 29 September 2017), PubMed Clinical Queries and PubMed Health (both limited to SLRs and to 2017).

In order to get a full scope of practices in workforce prediction in rheumatology and other medical fields, we also searched for grey literature including screening homepages of 37 societies of rheumatology and other medical associations between May and September 2017 (online supplementary table S1). The following search terms were used: 'workforce models', 'workforce', 'forecasting', 'workforce forecasting', 'calculating workforce', 'workforce planning', 'workforce supply' and 'workforce demand'. Additionally, we emailed national societies of rheumatology to enquire about how the rheumatology workforce calculation was done at a national level (online supplementary table S2). Furthermore, authors of the studies retrieved by the original SLR were inquired whether any post-evaluations of the published model quality and accuracy had been performed.

Study selection and data extraction

For both searches, references and abstracts were imported into the reference management software Endnote V.X7.0.2. Duplicates were removed. Two researchers (JU and PP) independently screened all abstracts and titles. Next, full texts were reviewed to determine eligibility. Disagreements were resolved by discussion, and if necessary, a third author (SR) was involved to make a final decision.

For both searches, study details and results of eligible studies were retrieved using a standardised data extraction sheet. For the SLR in rheumatology, we extracted data on the same parameters as in the original SLR,[9] mainly on factors related to demand/need and supply of rheumatologists, as well as country, year, total number of rheumatologists required to serve the population and type of model. Additionally, information about regional heterogeneity, uncertainty analyses, application of any weighting of included factors, stakeholder involvement, role of other health professionals as well as employment trends were extracted from the 11 studies in the original SLR[9] and the newly identified papers.

For the SLR in other medical fields, the following data were extracted: (1) study characteristics, including information about authors, year, medical field, design, objective, numbers of studies reviewed and sponsor/grants; and (2) content of the study, including information about type of workforce models, country, number of studies using the specific model, advantages and disadvantages of models, factors related to supply, need and demand, regional heterogeneity, uncertainty analyses, stakeholder involvement, prediction quality and others.

The quality of the SLRs was not assessed as we were mostly interested in reviewing which models and underlying factors have been used in other fields and not in the prediction results of these studies.

Development of a rheumatology workforce prediction risk of bias tool

Based on the results of both literature reviews, key factors for workforce prediction models were identified. These included general factors (eg, type of the model, stakeholder involvement) as well as factors specifically related to the prediction of the workforce need/demand (eg, percentage of referrals to rheumatologist, epidemiology of diseases) and supply (eg, time spent on rheumatological care, entry and exit from the profession). Three risk of bias levels (low, moderate or high) were distinguished for each factor, with a clear description of which evidence would correspond to each of the levels. High risk of bias indicates that the factor was not or was only insufficiently considered in the workforce prediction model (without reasonable justification); low risk of bias corresponds to a well-considered factor in sufficient level of detail and based on reliable evidence. A moderate risk of bias reflects that the factor was partially described but without full level of detail. The decisions were driven by available evidence in rheumatology and other medical fields as well as task force expertise, with a few informal rounds to define the number of factors, shape and optimise the wording. We developed this workforce prediction risk of bias tool in order to use it for evaluating the risk of bias of the existing workforce modelling studies in rheumatology.

RESULTS

For the SLR in rheumatology, the literature search yielded 3221 hits. Screening of homepages (online supplementary table S1), contacting national rheumatology societies (37/49 answered; online supplementary table S2) and hand searches yielded seven additional records. After removing duplicates, a total of 2453 articles remained. After a formal assessment, three studies were included and added to the existing 11, so in total there were 14 studies in rheumatology chosen for analysis (flowchart in online supplementary figure S1). The SLR in other medical fields yielded 4649 articles, of which 10 articles met the inclusion criteria (flowchart in online supplementary figure S2).

General characteristics of workforce prediction studies in rheumatology

General characteristics of the 14 workforce prediction studies in rheumatology are presented in table 1. Studies were performed for the USA (n=4),[14–17] Canada (n=3),[18–20] Germany (n=3),[7 21 22] UK (n=2),[23 24] Spain (n=1)[25] and one study covered USA and Canada (n=1).[26] Most studies (n=8)[7 14 15 17 19 21 22 25] used some form of an integrated model, which included demand, need and supply factors, and four studies considered the existing imbalance between demand and supply at baseline.[14 17 19 24] Half of the studies (n=9) provided predictions for the future (as opposed to limiting predictions to study time),[7 14–17 19 20 25 26] with a time horizon varying between 10 and 20 years. An assessment of the model performance was attempted by a total of four studies,[7 15–17] with two studies having done an update of an earlier prediction.[7 17] Both studies reported inaccuracies in the previous prediction, due to underestimating the retirement tendencies and employment patterns (part-time work) of female rheumatologists[17] or changes in the life expectancy and demographic characteristics of the population.[7] While more than half of the studies did not perform uncertainty analyses, a few reported some form of uncertainty analyses by considering variation in one or several parameters (eg, population growth, insurance coverage, income growth).[14 15 17 25] Three studies took regional heterogeneity into account.[7 16 17] Involving stakeholders from multiple disciplines was not common practice as it was only done in a few studies performed by large study groups.[7 15 17] Detailed information about the three newly included studies is depicted in online supplementary table S3–S5.

Factors related to need/demand for rheumatology care

Table 2 provides an overview of factors that influence the need/demand for rheumatology care. Large heterogeneity was observed with regard to the scope of the diseases covered by rheumatologists, even within the same countries.[7 14–17 19 21–25] Most of these studies have also estimated the percentage of patients referred to rheumatologists.[7 14 15 17 19 21 23 24] Rheumatologist workload in terms of numbers of visits per year was included

Table 1 General factors used in rheumatology workforce studies

Author, year	Country	Model[1]	Time horizon[2]	Update of the model[3]	Assessment of model performance[4]	Uncertainty analyses[5]	Regional heterogeneity[6]	Stakeholder involvement[7]
Ogryzlo, 1975[26]	USA Canada	Needs based	5 years	No update	No assessment	Not performed	Outlying communities and many urban centres (with population exceeding 100 000) do not have enough rheumatologists	Not stated
Marder *et al*, 1991[14]	USA	Need, demand and supply based, assumed demand≠supply at baseline	10 and 20 years	No update	No assessment	Most conservative estimate calculated based on (1) simultaneity adjustment (1.25); (2) productivity factor (5000 visits/year); (3) decrease in need of other medical visits. Result: twice as high need of rheumatologists	Not stated	Not stated
Deal *et al*, 2007[15]	USA	Need, demand and supply based, assumed demand=supply at baseline	20 years with predictions for 5-year interval	Update performed in 2015[4]	Assessment performed in the update of 2015	Tested decline in people without insurance and a higher increase in income	Not stated	Involved an advisory panel including physicians and health professionals
Zummer and Henderson, 2000[18]	Canada	Need and supply based	Baseline only	No update	No assessment	Not performed	Not stated	Not stated
Edworthy, 2000[19]	Canada	Need, demand and supply based, assumed demand≠supply at baseline	10 years	No update	No assessment	Not performed	Not stated	Not stated
Hanly, 2001[20]	Canada	Need and supply based	25 years with predictions for 5-year interval	No update	No assessment	Not performed	Not stated	Not stated
Raspe, 1995[22]	Germany	Need, demand and supply based, assumed demand=supply at baseline	Baseline only	No update	No assessment	Not performed	Not stated	Not stated
German Society for Rheumatology, Committee for Care, 2008[21]	Germany	Need, demand and supply based, assumed demand=supply at baseline	Baseline only	Update performed in 2017	No assessment	Not performed	Not stated	Not stated

Continued

Table 1 Continued

Author, year	Country	Model[1]	Time horizon[2]	Update of the model[3]	Assessment of model performance[4]	Uncertainty analyses[5]	Regional heterogeneity[6]	Stakeholder involvement[7]
Làzaro y De Mercado *et al*, 2013[25]	Spain	Need, demand and supply based, assumed demand=supply at baseline	11 years	No update	No assessment	Base scenario: Increased demand (15%) due to population growth and increased demand in care Best scenario: increase in demand only due to population growth Worse scenario: increase in demand (30%) due to population growth and increased demand for healthcare	Not stated	Not stated
Committee of Rheumatology, 1988[23]	UK	Need and supply based	Baseline only	No update	No assessment	Not performed	Many counties of the UK are lacking rheumatological service	Not stated
Rowe *et al*, 2013[24]	UK	Need, demand and supply based, assumed demand≠supply at baseline	Baseline only	No update	No assessment	Not performed	Input data will change based on regional variations in patient demographics and models of care	Not stated
American College of Rheumatology, 2015[38]	USA	Need, demand and supply based, assumed demand≠supply at baseline	15 years with predictions for 5-year interval	NA, too recent	Assessed against study of 2005[15]	Best-worse scenario: Male-female ratio in workforce Retirement projections Full- and part-time projections Academic vs non-academic setting Number of new graduates Number of non-physician providers (NP and PA) Number of patients with OA seen by rheumatologists	Is assessed at baseline (2015) for 10 regions of USA, and separately for the 10 largest metropolitan areas No change in geographic services in the next 10 years is assumed Physicians practicing in metropolitan statistical area work on average 15% less hours than those not working in these areas	Multidisciplinary expert group: eight core members and additional expert liaisons made up of various affiliations and disciplines to ensure a wide-range of ideas and experiences in the field of rheumatology; focus groups with select stakeholders (not stated which)
HRSA Health Workforce, 2015[16]	USA	Need, demand and supply based, assumed demand=supply at baseline	12 years	NA, too recent	Face validity by experts, internal validation (verification, including 'stress test' for extreme values), external and predictive validation against other (not used in modelling) data sources, between model validation (with results of other models)	Not performed	Separate estimates for four regions, baseline supply≠to baseline demand in regions	Not stated

Continued

Table 1 Continued

Author, year	Country	Model[1]	Time horizon[2]	Update of the model[3]	Assessment of model performance[4]	Uncertainty analyses[5]	Regional heterogeneity[6]	Stakeholder involvement[7]
German Society for Rheumatology, 2017[7]	Germany	Need, demand and supply based, assumed demand=supply at baseline 🟡	Time horizon not provided for all aspects 🟡	NA, too recent	Assessed against study of 2008[9] 🟡	Not performed 🔴	General regional deficit of 0–1, 2 rheumatologists/100 000 inhabitants 🟢	The study group consisted of rheumatologists (ambulant/inpatient, rehabilitative setting), epidemiologists and members of the German Rheumatology Society 🟢

The risk of bias scores: red dot (🔴)=high risk of bias, indicating that the factor has not been considered or considered in an inadequate way, in workforce prediction model; orange dot (🟡)=moderate risk of bias, when a factor has been considered with limitations; green dot (🟢)=low risk of bias and corresponds to a well-considered factor in sufficient level of detail and based on a reliable evidence. Detailed description of grading system is presented in online supplementary table S7.
(1) For the most accurate prediction, a model should consider supply, need and demand factors and not assume that demand is equal supply at the baseline.
(2) Predictions between 5 and 15 years seem to be the most adequate time horizon for workforce calculation in rheumatology.
(3) Frequent updates of the model (1-year to 4-year interval) should be done in order to take into account the variability of assumptions.
(4) At least two kinds of quality assessment for baseline calculations and/or for future predictions are recommended.
(5) Uncertainty analyses with more than two parameters are recommended in order to detect assumptions that may vary due changes.
(6) Predictions should consider the relevant regional profile of the country.
(7) The involvement of more than one group of stakeholders is highly relevant for all stages of the prediction.
HRSA, Health Resources and Services Administration; NA, not applicable; NP, nurse practitioner; OA, osteoarthritis; PA, physician assistant.

in six studies.[7 14 19 21 22 24] Projections of population ageing were considered by most of the studies[7 14–18 20 25]; however, epidemiological developments[17] or economic factors[7 15–17] such as insurance or household income were rarely included in the predictions. The potential of medical development to modify the demand and need for care has been acknowledged in a number of studies; however, it not actually modelled into the predictions because of difficulty in making robust assumptions.

Factors related to supply of rheumatologists

Table 3 shows supply-based factors considered by the studies. Most of the studies (n=11)[7 14 16 17 19–25] described the clinical setting, with few studies making their predictions for multiple settings, for example, private and public. Time spent on rheumatological care (as opposed to teaching or administrative tasks) was considered in 10 out of 14 models[7 14 15 17 19–22 24 25]; however, it should be noted that the data used for calculations were frequently based on authors' assumptions. Effects of task shifting between professionals (eg, increasing role of nurse professionals in care) was another difficult to estimate factor, with only few studies making an attempt to put this into numbers.[14 15 17 23 24] Predictions of the entry to (eg, training) and exit (eg, emigration, illness) from the profession were considered.[14–19 25 26] Workforce demographic trends comprised an important part of the future workforce prediction. Estimation of the number of physicians projected to retire and/or gender structure of future workforce was incorporated in 8 of 14 models.[7 14–18 20 25] An important trend of more women entering the profession has been observed in a few studies,[15–17 20 25] and, given that women are more likely to work part-time, this had important implications for the number of physicians to be trained. Studies typically presented the results of prediction in headcounts (ie, number of rheumatologists). Four studies (three of which were found in update search) also presented full-time equivalents (FTEs).[7 16 17 20]

Manpower requirements in other medical fields

The 10 SLRs from the second search (overview of systematic reviews) covered a heterogeneous scope of areas, including nurses (n=2),[27 28] pharmacists (n=1),[29] paediatric specialties (n=1),[30] public health (n=1)[31] and studies that were not limited to any specialty (n=3)[32–34] or considered a mix of specialties (n=2)[35 36] (online supplementary table S6).

Of the 10, only two reviews[35 36] actually provided a summary of the workforce projections, and none has provided an assessment of the model performance. The remaining reviews synthesised models from a methodological and theoretical point of view, describing which models were used and which need, demand and supply factors should be considered.

While most of the SLRs acknowledged the relevance of regional heterogeneity, only one considered it by making different predictions according to the region or

Table 2 Need/demand factors used in rheumatology workforce studies

Author, year	Scope of diseases covered by rheumatology specialty[8]	Disease definition[9]	Source of prevalence data*	Visits/year per patient[10]	% patients referred to rheumatologist[11]	Projection of population development[12]	Source used for projection of population development*	Projection of epidemiology of diseases[13]	Source used for projection of epidemiology of diseases*	Effects of medical development[14]	National economic indicators[15]
Ogryzlo, 1975[26]	Not stated	Not stated	Author's estimate[16]	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Marder *et al*, 1991[14]	20 conditions and fibromyalgia and osteoporosis Modified Graduate Medical Education National Advisory Committee (GMENAC) list[17]	ICD9-CM	National Arthritis Data work group (NADW)	2–4 visits/year per patient[18]	Estimated for each disease separately	Age	United States Bureau of the Census population (US Census projections)	Not stated	Not stated	Regular referral patterns and average number of visits may change due to medical developments, but too little info was available to estimate	Not stated
Deal *et al*, 2007[15]	8 diseases[19]	Partially cited[20]	NADW 5 and updates	Not stated	Estimated for each disease separately[21]	Age	US Census projections	Not stated	Not stated	Discusses effect of medical development and change in practice organisation, difficult to quantify	Per capita income and insurance status
Zummer and Henderson, 2000[18]	Not stated	Not stated	Author's estimate[22]	Not stated	Not stated	Age	Not stated	Not stated	Not stated	Not stated	Not stated
Edworthy, 2000[19]	7 disease(s) groups[23]	Not stated	Author's estimate[24]	Time consumed by patient/year with range 0.7–3 hours	Estimated for some disease groups	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
Hanly, 2001[20]	Not stated	Not stated	Not stated	Not stated	Not stated	Age	Statistics Canada	Not stated	Not stated	Not stated	Not stated
Raspe, 1995[22]	6 disease groups[25]	Partially cited[6]	Author's estimate[26]	Four visits/year per patient	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated	Not stated
German Society for Rheumatology, Committee for Care, 2008[21]	5 inflammatory disease groups[27] and 5 other disease groups[28]	Not stated	Author's estimate[29]	Number of visits differ from type of disease: average of 4 visits/year per patient[30]	Estimated 100% inflammatory, 12% of other diseases	Not stated	Not stated	Assumed not to change	Not stated	Not stated	Not stated
Làzaro y De Mercado, 2013[25]	12 disease groups[31]	Not stated	Not stated	Not stated	Not stated	Age	National Institute of Statistics	Not stated	Not stated	Improvement of medical technologies increases manpower need	Not stated
Committee of Rheumatology, 1988[23]	5 disease groups[32]	Not stated	Author's estimate[33]	Not stated	Inflammatory 100%, 12% of other diseases	Not stated	Not stated	Assumed not to change	Not stated	Not stated	Not stated
Rowe *et al*, 2013[24]	12 disease(s) groups[34]	Partially cited[6]	Several UK and international studies	As per NICE guidelines, distinguishes between first visit (30 min) and follow-up visit (10–15 min)	Considered but no details provided	Not stated	Not stated	Not stated	Not stated	Discusses workload increase due to more frequent use of toxic drugs	Not stated

Continued

Table 2 Continued

Author, year	Scope of diseases covered by rheumatology specialty[8]	Disease definition[9]	Source of prevalence data*	Visits/year per patient[10]	% patients referred to rheumatologist[11]	Projection of population development[12]	Source used for projection of population development*	Projection of epidemiology of diseases[13]	Source used for projection of epidemiology of diseases*	Effects of medical development[14]	National economic indicators[15]
American College of Rheumatology, 2015[38]	10 diseases[35]	Self-reported: physician-diagnosed and self-diagnosed	National Health Information Systems Surveillance statistics, Centers for Disease Control and Prevention[36]	Not stated	Assessed number of visits in the patient population (proxy to % of patients referred), specific assumptions for OA are given[37]	Age and sex	US Census projections	Discussed increased numbers due to obesity trends	Data (of RA) based on the Rochester Epidemiology Project in Minnesota and different studies	Discussed changes in cost of drugs	Household annual income and socioeconomic conditions
HRSA Health Workforce, 2015[16]	Diseases of the musculoskeletal system and connective tissue[38]	ICD9 (codes 725–729)	U.S. Centers for Medicare and Medicaid Services	Not stated	Not stated	Age and sex	ACS, BRFSS, NNHS, Census Bureau	Health status for prediction of the use of healthcare	Not stated	Assumed healthcare delivery will not change substantially from the base year	Household anual income and socioeconomic status
German Society for Rheumatology, 2017[7]	Inflammatory diseases[39] and autoinflammatory diseases	Not stated	Based on Zink *et al*, 2016[7]	Estimated amount and time for prevalent (4×20 min) and incident cases (1.5×40 min)	Assumptions for co-consultation for osteoarthritis, osteoporosis and pain syndromes are given[41]	Age	Not stated	Not stated	Not stated	Discusses that digital developments and other health personnel may have an influence on workload	Amount of insurance services is discussed

Continued

Table 2 Continued

Author, year	Scope of diseases covered by rheumatology specialty[8]	Disease definition[9]	Source of prevalence data*	Visits/year per patient[10]	% patients referred to rheumatologist[11]	Projection of population development[12]	Source used for projection of population development*	Projection of epidemiology of diseases[13]	Source used for projection of epidemiology of diseases*	Effects of medical development[14]	National economic indicators[15]

The risk of bias scores: red dot (🔴)=high risk of bias, indicating that the factor has not been considered or considered in an inadequate way, in workforce prediction model; orange dot (🟠)=moderate risk of bias, when a factor has been considered with limitations; green dot (🟢)=low risk of bias and corresponds to a well-considered factor in sufficient level of detail and based on a reliable evidence. Detailed description of grading system is presented in online supplementary table S7.
(1) The scope of diseases covered by rheumatology specialty is defined and the probability that it is representative is high.
(2) A criteria-stated disease definition that relies on physician-reported diagnoses and using more than one source is recommended.
(3) Separate estimations for the type of diseases, the disease phase or the type of visits should be done.
(4) It is recommended to consider separate estimations of the percentage of referrals per disease group.
(5) For the consideration of the development of the population, workforce calculations should incorporate age and/or sex structure and/or other factors, relying on more than one data source.
(6) The involvement of more than two factors that influence the epidemiology of diseases, using more than one data source, should be considered in the predictions.
(7) Workforce calculations should consider the effects of medical development, either based on formal data or expert consensus.
(8) For a good forecasting model, the consideration of more than one economic factors for the national economic development of a country is recommended.
(9) No published data referenced; author assumes total prevalence of rheumatic diseases=prevalence of rheumatoid arthritis×5.
(10) The following conditions were summarised in the Modified Graduate Medical Education National Advisory Committee (GMENAC) list: gonococcal infection of joint, crystalline arthritis, psoriatic arthropathy, pyogenic arthritis, acute non-pyogenicarthritis, rheumatoid arthritis, ankylosing spondylitis, osteoarthritis, residual arthritides, fibromyalgia, osteomyelitis, Paget's disease, osteoporosis, disc displacement, neck and back pain, internal joint derangement, bursitis and tendinitis, connective tissue disease, other musculoskeletal disorders.
(11) Assumed a higher number of needed visits for psoriatic arthritis, pyogenic arthritis, RA, fibromyalgia and connective tissue disease; considered severity of disease.
(12) Rheumatoid arthritis, osteoarthritis, spondyloarthritis, polymyalgia rheumatica, lupus, low back pain, gout, osteoporosis.
(13) Partially cited means that sometimes published criteria were cited and sometimes not.
(14) Estimated according to the National Ambulatory Medical Care Survey (NAMCS): RA 52.0%, OA 7.0%, spondyloarthritis 77.3%, polymyalgia rheumatica 48.3%, lupus 29.9%, low back pain 2.9%, gout 11.7%, osteoporosis 5.1%.
(15) No published data referenced; author assumes a total prevalence of arthritis to be 19% in women and 11% in men.
(16) Polyarthritis, crystal arthropathies, connective tissue diseases, vasculitis, soft-tissue diseases, degenerative musculoskeletal diseases, osteoporosis.
(17) No published data referenced; author assumes a total prevalence of polyarthritis of 1%, crystal arthopathies 0.1%, connective tissue diseases 0.1%, vasculitis 0.05%, soft-tissue diseases 5% and degenerative musculoskeletal diseases 10%.
(18) Rheumatoid arthritis, spondyloarthritis, connective tissue disease, vasculitis, polyarticular secondary osteoarthritis, generalised pain syndromes.
(19) Author assumes total prevalence of rheumatic diseases to be 4%—estimate supported by several references ranging from local German studies to large studies from the USA.
(20) Undifferentiated arthritis, rheumatoid arthritis, spondyloarthritis, connective tissue diseases, vasculitis.
(21) Osteoarthritis, crystal arthropathies, suspected inflammatory back pain, fibromyalgia, bone diseases.
(22) No published data referenced; author assumes total prevalence of 2% for inflammatory rheumatic diseases and 10% for the other conditions described.
(23) Estimated amount and time for prevalent (4 visits×20min) and incident cases (1.5 visits×40 min) and also for co-consultation for other diseases. For the co-consultation, they assumed 10% of 26 000 severe cases per 100 000 inhabitants for co-consultation (2600 cases×15min).
(24) Rheumatoid arthritis, spondyloarthritis, osteoarthritis, other metabolic bone diseases, systemic autoimmune diseases, soft-tissue diseases, neck and back pain, fibromyalgia, crystal arthropathies, paediatric rheumatology, tumour and infectious pathologies, other pathologies.
(25) Rheumatoid arthritis, osteoarthritis, backache, connective tissue diseases, other rheumatic disorders.
(26) No published data referenced; author assumes total prevalence of ~2.7% for diseases.
(27) Musculoskeletal conditions, osteoarthritis-related joint pain, osteoporosis, back pain, rheumatoid arthritis, ankylosing spondylitis, systemic lupus erythematosus, scleroderma, gout, regional pain syndromes, chronic widespread pain, juvenile idiopathic arthritis.
(28) Rheumatoid arthritis, spondyloarthritis, systemic lupus erythematosus, systemic sclerosis, Sjogren's syndrome, osteoarthritis, polymyalgia rheumatica, giant cell arteritis, gout, fibromyalgia.
(29) Report based on surveys and another two survey-based publications.
(30) Assumed that 25% of patients wents with OA are seen by a rheumatologist.
(31) No further specification.
(32) Rheumatoid arthritis, spondyloarthritis, crystal arthropathies, collagenosis, vasculitis.
(33) Zink A, Albrecht K (2016). Wie häufig sind muskuloskeletale Erkrankungen in Deutschland? Z Rheumatol 75:346–353.
(34) Assumed 10% of 18 million people (2600×15 min).
*Risk of bias related to the data source is taken into account in scoring of the respective factor
ACS, American Community Service; BRFSS, Behavioral Risk Factor Surveillance System; HRSA, Health Resources and Services Administration; ICD9-CM, International Classification of Diseases, Ninth Revision—Clinical Modification; NA, not applicable; NICE, National Institute for Health and Care Excellence; NNHS, National Nursing Home Survey; OA, osteoarthritis; RA, rheumatoid arthritis.

Table 3 Supply factors used in rheumatology workforce studies

Author, year	Clinical setting[42]	Time spent on clinical (rheumatological) care[43]	Source of data for estimating of % of patient care in rheumatology*	Tasks delegated to other health professionals in rheumatology (HP)[44]	Demographic trends in workforce[45]	Entry and exit from the profession[46]	Source of information for in- and outflow of medical graduates*	Result presented in number of rheumatologists and/or clinical FTEs[47]
Ogryzlo, 1975[26]	Not stated	Not stated[48]	Not stated	Not stated	Not stated	Attrition rate of training programme	Not stated	Number of rheumatologists
Marder *et al*, 1991[14]	Ambulatory and hospital (outpatient only)	~80%–85% of working time[49]	Not stated	Per morbidity indicated the expected number of visits delegated to a non-physician member of the office staff: PsA, RA, SpA, OA, OP 5%–15% of visits	Retirement and death due to age	Projected number of new entrants	Historical trends	Number of rheumatologists
Deal *et al*, 2007[15]	Not stated	~90% of rheumatologists see patients	Not stated	About 25% of rheumatologists are working with a NP or PA	Female and older rheumatologists have less visits, younger doctors tend to work less hours	Number and fill rate of rheumatology positions, including foreign students	Council of Graduate Medical Education	Number of rheumatologists
Zummer and Henderson, 2000[18]	Not stated	Not stated	Not stated	Not stated	Over 50% of rheumatologists are >50, and 15% will retire in next 10 years	Number of trainees in relation to current vacancies, number of graduated specialists that will practice out of Canada	Survey by the Economics and Manpower Committee of the Canadian Rheumatology Association	Number of rheumatologists
Edworthy, 2000[19]	Community, academic, administrator	5%–80% of working time[50]	Not stated	Not stated	Not stated	Attrition rate including illness, emigration (estimated at 10%), number of new graduates entering the market	Not stated	Number of rheumatologists
Hanly, 2001[20]	Academic	~50%–60% of working time	Not stated	Not stated	The 'greying' of the physicians, changing lifestyles and expectations of young physicians, increasing proportion of women	Not stated	Not stated	Number of rheumatologists and clinical FTE
Raspe, 1995[22]	Hospital, private practice, centres of excellence (outpatient only)	45 hours/week	Not stated	Primary care specialist[51]	Not stated	Not stated	Not stated	Number of rheumatologists
German Society for Rheumatology, Committee for Care, 2008[21]	Outpatient clinic	75% of working time[52]	Not stated	Not stated	Not stated	Not stated	Not stated	Number of rheumatologists

Continued

Table 3 Continued

Author, year	Clinical setting[42]	Time spent on clinical (rheumatological) care[43]	Source of data for estimating of % of patient care in rheumatology*	Tasks delegated to other health professionals in rheumatology (HP)[44]	Demographic trends in workforce[45]	Entry and exit from the profession[46]	Source of information for in- and outflow of medical graduates*	Result presented in number of rheumatologists and/or clinical FTEs[47]
Làzaro y De Mercado, 2013[25]	Academic, non-academic, private practice	78.4% of working time[53]	Survey among rheumatologists	Not stated	Age and gender of current and future workforce taken into account	Number of residents that graduates each year	Not stated	Number of rheumatologists
Committee of Rheumatology, 1988[23]	General hospital	Not stated[54]	Not stated	Junior medical staff House officer: 0.5 FTE per consultant, secretarial and administrative support 1 FTE per consultant	Not stated	Not stated	Not stated	Number of rheumatologists
Rowe *et al*, 2013[24]	Community (rheumatologist, rheumatologist with GIM), academic	25%–65%[55]	Programmed activities based on British Society of Rheumatology recommendations	Shared care between primary and secondary care necessary but dependent on the existence of intermediate care[56]	Not stated	Not stated	Not stated	Number of rheumatologists
American College of Rheumatology, 2015[38]	Academic (80%) and non-academic (20%)	Academic setting 1 doctor=0.5 clinical FTE Non-academic setting 1 doctor=1 FTE	Expert consensus	Include number of NP and PA in the modelling	Workforce is ageing; women work 7 hours less per week and see 30% less patients. Share of women increasing	Number and fill rate of rheumatology positions, drop-out, number of those who will practise outside USA	Survey and data from American Medical Association (AMA)	Number of rheumatologists and clinical FTE
HRSA Health Workforce, 2015[16]	7 settings: Emergency rooms, hospitals, provider offices, outpatient departments, home health, nursing homes, residential facilities	Not stated	Not stated	Not stated	Age and gender distribution of the workforce taken into account[57]	Number of newly trained doctors entering the market	AMA Masterfile for physicians, the Association of American Medical Colleges (AAMC) 2012–2013 Graduate Medical Education Census, Physician Assistant Education Association survey	Number of rheumatologists and clinical FTE
German Society for Rheumatology, 2017[7]	Hospital, private practice, rehabilitation centres	Of a total of 54 hours/per week, 38 hours patient work[58]	Source are given for the definition of the number of working hours/week and the time dedicated to rheumatology care	Not stated	Rheumatologists are ageing and many will retire soon	Not stated	Not stated	Number of rheumatologists and clinical FTE

Continued

Table 3 Continued

Author, year	Clinical setting[42]	Time spent on clinical (rheumatological) care[43]	Source of data for estimating of % of patient care in rheumatology*	Tasks delegated to other health professionals in rheumatology (HP)[44]	Demographic trends in workforce[45]	Entry and exit from the profession[46]	Source of information for in- and outflow of medical graduates*	Result presented in number of rheumatologists and/or clinical FTEs[47]

The risk of bias scores: red dot (🔴)=high risk of bias, indicating that the factor has not been considered or considered in an inadequate way, in workforce prediction model; orange dot (🟠)=moderate risk of bias, when a factor has been considered with limitations; green dot (🟢)=low risk of bias and corresponds to a well-considered factor in sufficient level of detail and based on a reliable evidence. Detailed description of grading system is presented in online supplementary table S7.
(1) Considering more than one level of setting for the calculation of workforce supply improves the accuracy of the projections.
(2) Accurate projections require the percentage of time spent on clinical care by making estimations for the number, durations and types of visits, using more than one data source.
(3) Possible task shifting with HP is relevant for workforce calculation and can rely on data or formal expert consensus.
(4) More than one demographic trends like ageing and millennial trend should be considered for forecasting.
(5) The accuracy of the model can be increased by considering more than one entry and exit factor, using more than one data source.
(6) Projected number of rheumatologists and clinical FTEs should be explicit from the calculations.
(7) According to author's statement calculation adjusted for clinical care, research and teaching; 2000 rheumatologists in USA from which 1700 are practising, 300 are teaching/researchers; same proportions are assumed for Canada.
(8) Authors estimate a ~15%–20% extra number of rheumatologist to compensate for 'other activities' including research and education.
(9) Authors assume that community based rheumatologists use 80% of a 55-hour week (=44 hours) for clinical visits, 20% for administrative work and education; academic rheumatologists use 25% of a 60-hour week (=15 hours) for clinical visits and 75% for administration, research and training; administrators use 5% of a 60-hour week (=3 hours) for clinical visits and 95% for administrative work and work with complex medical systems and provincial organisations. A total of 46 working weeks/year is assumed (5-week vacation, 1 week conference).
(10) Authors provide a diagram on patients' flow from primary to specialist care and vice versa; however, the effect of this diagram on the number of visits/rheumatologists required was not provided.
(11) Authors estimate that out of a 10-hour working day, 7.5 hours will be available for clinical visits.
(12) According to the survey performed the following activities reduce the time for clinical visits: research, teaching, scientific sessions, training, congresses, institutional participation and other activities.
(13) All rheumatologists spend time on development and maintenance of educational programmes for continuing education of general practitioners and colleagues in other specialties and for other health professionals.
(14) Community-based rheumatologist: 55% of working time for clinics, 10% ward work, inpatient referrals, day unit and multidisciplinary team meeting (MDT) support, 10% administrative work, 25% supporting professional activities (teaching, training, appraisal, audit, clinical governance, CPD (continuing professional development), revalidation, research, departmental management and service, development); community-based rheumatologist with general internal medicine: 45% of working time for clinics, 18% for GIM and specialty ward round, inpatient referrals, day unit and MDT support, 9% for patient-related administration, relatives and contact, 9% for peri-take and post-take ward rounds weekdays and weekends, 19% for teaching, training, appraisal, audit, clinical governance, revalidation, research, departmental management and service development; academic rheumatologist: 15% special clinics, 10% inpatient referral and ward work, 50% full academic sessions, 25% supporting professional activities; a 20%–25% reduction of patients per clinic is suggested in case a consultant is involved in teaching junior staff, students or supervising nurse clinics.
(15) Local CATS (intermediate services between primary and secondary care known as Clinical Assessment and Treatment services) and the possibility to involve general practitioners, the introduction of nurse-led clinics, telephone follow-up clinics or electronic advice to general practitioners.
(16) Assumed that current rates of workforce participation will remain stable into the future (2025).
(17) Considered the number of working hours/week and the percentage of rheumatologists who are working in the hospital or as freelancer.
*Risk of bias related to the data source is taken into account in scoring of the respective factor.
CPD, continuing professional development; FTE, full-time equivalent; GIM, general internal medicine; NP, nurse practitioner; OA, osteoarthritis; OP, Osteoporosis; PA, physician assistant; PsA, psoriatic arthritis; RA, Rheumatoid arthritis; SpA, Spondyloarthritis.

Table 4 Need/demand and supply factors identified from systematic literature reviews of workforce studies in other medical fields than rheumatology

Factors of need/demand and supply that were discussed in relation to workforce modelling process	Studies discussing the factor
Demand/need factors	
Use patterns, market factors (eg, access to services and preferences of health consumers), insurance coverage	6 studies[27 29 31 32 34 35]
Morbidity, mortality, incidence and severity, degree of need (dependency-acuity method)	6 studies[27 28 32–35]
Population growth, ageing	7 studies[27 30–35]
Desirable service volume (estimated demand for care), in relation to population health referral volume	2 studies[27 30]
Changes in guidelines that can help to anticipate increase or decrease in need/demand	1 study[27]
Income and education level, deprivation	2 studies[28 34]
Geographical distribution, travel distances	2 studies[28 30]
Adjustments for market inefficiencies[1]	1 study[32]
Technology development, increased complexity of care	4 studies[29 32 34 35]
Supply factors	
Age structure, mortality, retirement, millennial and feminisation trends, full-time and part-time unemployment, manpower work pattern	9 studies[27–35]
Substitution rates, entry into practice and attrition, foreign medical graduates	6 studies[27 29–33]
Clinical FTE or % of non-clinical activities (research, teaching, travelling time, time out, time invested in education)	6 studies[28–30 32 34 35]
Mobility patterns and practice style, migration	3 studies[27 29 35]
Increasing no of support staff, task shifting, skill mix, expansion in roles	3 studies[27 29 35]
General labour market regulations (eg, Working Time Directive), economic and political factors, unemployment	6 studies[27 30–34]
Productivity rates, caseload, referrals	4 studies[27 28 30 31]
Practice organisation, staffing norms, skill mix	2 studies[27 35]
Payment methods, incentives	2 studies[27 35]
Job satisfaction factors	2 studies[29 31]
Spouse's employment status	1 study[31]

(1) Authors of the included studies have adjusted for known US health market inefficiencies, eg, that FFS (fee-for-service) practices require 56% more physicians compared with HMO (health maintenance organisations).

metropolitan area.[30 36] Three reviews reported uncertainty analyses by summarising different scenarios or results of simulation models.[27 35 36] The quality of prediction was discussed by more than half of the reviews (n=6),[27 28 32–35] without doing a formal quality appraisal, stating that quality improves when more parameters are considered in the model. On the other hand, poor quality of data has been acknowledged to have a profound impact on prediction results. Only two SLRs[27 35] recognised the importance of involving stakeholders as they form the background for decisions.

Factors related to need/demand and supply in other medical fields

Table 4 shows need/demand and supply-based factors considered in workforce prediction studies in other medical fields. Care use patterns and market factors (eg, access to services, preferences of health consumers, insurance coverage) were described but not always included in the workforce calculations.[27 29 31 32 34 35] Population growth and ageing, morbidity and mortality statistics was another group of commonly mentioned factors.[27 30–35] Factors like income and educational level (n=2),[28 34] geographical distributions (n=2)[28 30] or service and referral volume (n=1)[30] were less frequently discussed, and real examples of how these could be modelled in the workforce prediction were absent.

Workforce supply–related variables like workforce age, mortality, retirement, millennial (persons who entered workforce in the new millennia) and gender trends, full-time and part-time employment were considered (at least in part) by most of the reviews (n=9).[27–35] Six reviews[27 29–33] also took substitution rates (eg, replacement of retiring physicians) and entry into practice into account. Factors related to time spent on clinical work or the percentage of non-clinical activities, time out (eg, career breaks) or time invested in education were covered by 6 of 10ten SLRs.[29 30 32 34 35 37] Fewer reviews considered mobility patterns and practice styles as well as migration (n=3)[27 29 35] and task shifting to other health professionals (n=3)[27 29 35] in their models.

Most of the types of models and factors used were in line with the workforce prediction literature in rheumatology.

Development of the workforce prediction risk of bias tool

Based on the results of the literature review, 21 key factors for a workforce prediction model (see online supplementary figure S3) were identified. These factors were divided into three groups, namely, general factors, need/demand factors and supply-based factors.[13] A short overview of the factors and the proposed grading system is depicted in table 5. A full description of the grading tool with the underlying rationale is given in online supplementary figure S7. Figure 1 summarises the envisaged structure of the potential comprehensive workforce prediction model that includes the factors outlined in the risk of bias tool.

Application of the workforce prediction risk of bias tool

We applied our workforce prediction risk of bias tool to 14 workforce studies in rheumatology. An overview of this assessment is provided in tables 1 and 2 and in online supplementary table S8–S10. No single study scored with a low risk of bias on all 21 factors, rather the majority of studies had high or moderate bias in several items. Quality of data sources, incorporated in some of the gradings, was one of the most important reasons for increasing the risk of bias. For example, if a workforce prediction study included task-shifting between professionals but calculations were based only on author's assumptions, it was graded as moderate, as opposed to when authors have obtained empirical data or a more formal expert consensus. In assessment of performance of general factors, several studies performed well in the choice of the model,[14 17 19 24] time horizon[14–17 19 20 25] and stakeholder involvement.[7 15 17] Highest risk of bias was found concerning the regular update of models and the assessment of model accuracy, both of which have rarely been done. Most studies failed to adequately consider regional heterogeneity and uncertainty analyses. Among demand/need factors, reporting the scope of the diseases covered by rheumatologists was the only item in which most of the studies performed well. No single study achieved the lowest risk of bias score on disease definition, population projections and effects of medical developments. Among supply factors, the definition of clinical setting and demographic trends in workforce were adequately addressed in most studies, whereas task shifting, time dedicated to clinical care, or measuring the entry to and exit from the profession were frequently of low quality.

DISCUSSION

This study had three closely linked objectives, namely summarising the review of workforce prediction studies in rheumatology and other medical fields, as well as the development of a tool for the assessment of risk of bias of workforce studies and its subsequent application in rheumatology studies.

The review of workforce studies in rheumatology was an update of an earlier SLR.[9] We have identified three new studies, two of them[7 17] representing an update of the previously conducted workforce predictions in the USA and Germany. The updates of workforce calculations provide an important source of information for the assessment and validation of the models. Major conclusions of these updates referred to underestimations in the supply side of the models due to retirement patterns or gender trends (more women) in the rheumatology workforce resulting in a greater need for rheumatologists than previously predicted in order to cover the existing and expected future demand for care.[17 38] Other sources of inaccuracy were forecasts around life expectancy and demographic developments,[7] also resulting in a higher predicted need for care.

While methods and models used in the newly included studies were as heterogeneous as in older studies, in the most recent literature there was a tendency towards the use of integrated models with a wide range of relevant supply, need and demand factors. Two of the three new studies involved a multidisciplinary group and multiple stakeholders,[7 17] which seems appropriate given the complexity of the topic and the different users of the results. Another trend more commonly seen in recent studies was the expression of results in headcounts and FTEs acknowledging the increment in part-time work. Increasing efforts in workforce predictions from different countries and a growing body of evidence underline the need and timeliness of synthesising the literature into a more solid methodological basis for future studies in the area.

The overview of SLRs in other medical fields has led to several important insights. First, the need for accurate workforce prediction has also been voiced across different medical specialities. Second, no standardised approaches for workforce prediction exist in other medical fields, leading to a similar heterogeneity of methods and predictions as in rheumatology. Third, studies in other fields have taken into consideration workforce supply, demand and need factors similar to studies in rheumatology. Finally, workforce prediction in other fields faces challenges similar to those in rheumatology. These include accuracy and validation of the models, data quality, uncertainty around assumptions and to some extent stakeholder involvement and consideration of regional imbalances in larger countries. It is important to note that none of the systematic reviews in other medical fields reported an empirical evaluation of the workforce prediction model; hence, it remains unknown whether one can rely on the theoretical and conceptual assumptions provided and to what extent the suggested parameters improve model performance.

We have identified 21 key factors relevant for rheumatology workforce prediction, categorised into general factors and workforce need/demand and supply factors. Making use of these key factors, we developed a tool that can be applied for the assessment of the risk of bias of

Table 5 Workforce prediction risk of bias tool *

Factor	Risk of bias
General factors	
Type of model	High: model was only based on demand or need or supply factors Moderate: integrated model that considered demand, need and supply with supply=demand at baseline Low: integrated model that considered demand, need and supply with supply≠demand at baseline
Time horizon	High: predictions >30 years Moderate: predictions <5 or between 16 and 30 years Low: predictions between 5 and 15 years
Update of the model	High: no update was performed Moderate: any kind of update was performed, but not within 1–4 years' interval Low: frequent updates were performed (1–4 years' interval)
Assessment of model performance	High: no assessment was done Moderate: one kind of quality assessment was done to ensure the rigour and accuracy of the model Low: more than one assessment was done
Uncertainty analyses	High: no uncertainty analysis was performed Moderate: one or two uncertainty analyses were performed, without clear justification of the choice Low: more than two uncertainty analyses were performed, choices and analyses well justified
Regional heterogeneity	High: regional heterogeneity was not considered Moderate: calculations were performed on national level but anticipated regional discrepancies are discussed Low: calculations took into account relevant regional profile of the country
Stakeholder involvement	High: stakeholders were not involved in the workforce prediction Moderate: one group of stakeholders was involved in the workforce prediction Low: more than one group of stakeholders was involved in the workforce prediction
Demand/need factors	
Scope of diseases covered by rheumatology specialty	High: either not listed or not deemed representative (eg, insufficient number of disease groups, unjustified author's estimate etc) Moderate: stated but the probability that they are representative is limited Low: stated and the probability that they are representative is high
Disease definition	High: not stated Moderate: unclear criteria, self-reported diagnoses or ICD codes from the registry (single or multiple data sources) *or* criteria stated, relying on physician-reported diagnoses using single source of data Low: criteria stated, relying on physician-reported diagnoses and using more than one source, including at least data from population based database
No and length of visits/year per patient	High: not considered Moderate: considered, but separate estimations done for at least one aspect Low: considered, including separate estimation for more than two aspects (type of disease, disease phase, type of visit)
% patients referred to rheumatologist	High: not considered Moderate: considered without distinguishing between diseases Low: considered, including separate estimation per disease group

Continued

Table 5 Continued

Factor	Risk of bias
Projection of population development	High: not considered or only size of population is included Moderate: age or/and sex structure and/or other factors included but using single data source Low: age or/and sex structure and/or other factors included using more than one source and relying on statistics or national population projections
Projection of epidemiology of diseases	High: not considered Moderate: one or multiple factors influencing epidemiology (incidence/prevalence) considered but using single source of data Low: more than two factors considered, using more than one data source
Effect of medical development	High: effects of medical development not considered Moderate: effects of medical development considered based on author's estimates Low: effects of medical development considered based on formal data or expert consensus
National economic development	High: not considered Moderate: one economic factor influencing economic development (eg, per capita income) considered Low: more than one economic factor considered
Supply-based factors	
Clinical setting	High: not considered in calculation Moderate: one type of settings considered in the calculation Low: more than one type of settings considered in the calculation
Time spent on clinical (rheumatologic) care	High: not considered in calculation of supply Moderate: % of time dedicated to clinical duties defined without detailed estimation of number, duration, and type of visit (single or multiple data sources) *or* % of time dedicated to clinical duties calculated through estimating the number, duration and type of visits, but using single data source Low: % of time dedicated to clinical duties calculated through estimating the number, duration and type of visits, using more than one data source
Tasks delegated to other health professionals in rheumatology (HP)	High: involvement of other HP in care for rheumatological patients not considered Moderate: involvement of other HP considered based on author's estimates Low: involvement of other HP considered in the workforce calculation based on data or formal expert consensus
Demographic trends in workforce	High: not considered Moderate: one demographic trend (eg, ageing, feminisation, millennial trend) considered Low: more than one demographic trends considered
Entry and exit to profession (not related to demographic changes of workflow)	High: not considered Moderate: one or multiple entry and exit factors considered but using single data source Low: more than one entry and exit factors considered, using more than one source
Result presented in number of rheumatologists and/or clinical full-time equivalents (FTEs)	High: projections only presented in necessary clinical FTEs without possibility to recalculate in number of persons Moderate: projections only presented in number of rheumatologists without possibility to recalculate in FTEs Low: both projected number of rheumatologists and FTE per population

*Complete version of the tool together with further details and rationale can be found in online supplementary table S7.

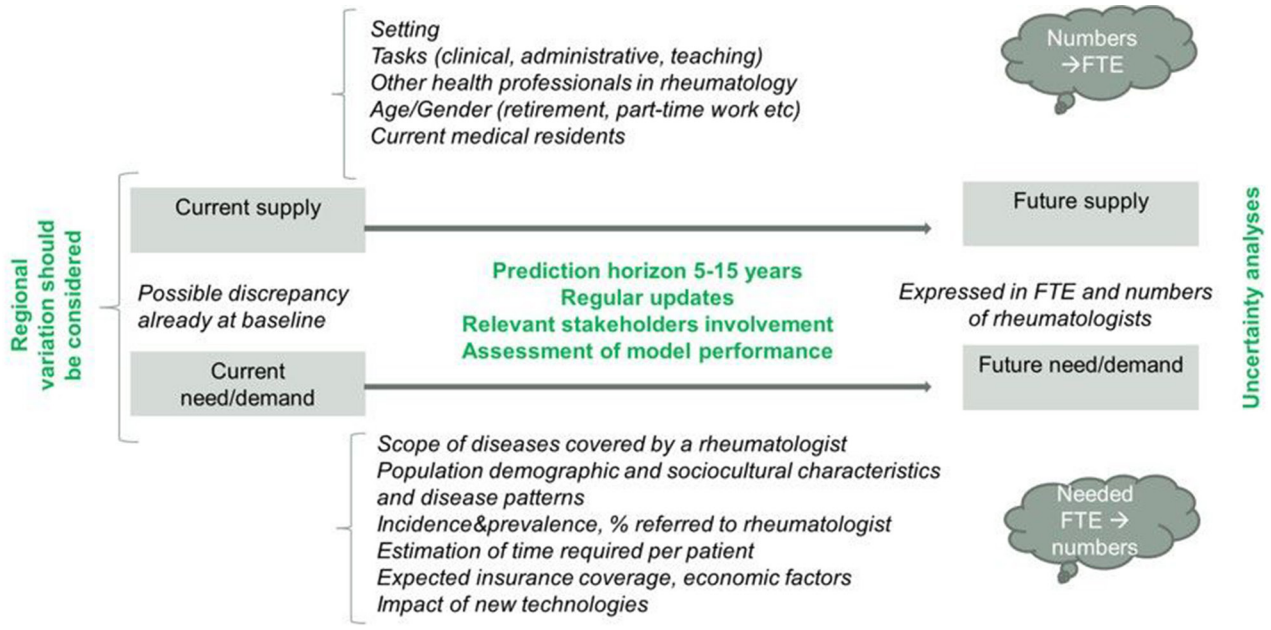

Figure 1 Structure of comprehensive workforce prediction studies. The figure illustrates the logic of workforce prediction planning and the factors that should be considered in a low risk of bias model. Planning should adopt an integrated model that includes a number demand/need and supply factors. Prediction should be optimally made for 5–15 years' horizon, with regular updates and performance assessment. Baseline imbalance between need/demand and supply should be taken into account. Uncertainty analyses should be done to test the critical assumptions. Relevant stakeholders should be consulted throughout the process. Results of the prediction should be convertible to headcounts and full-time equivalents (FTEs) to facilitate decision-making process at different levels.

other workforce prediction studies. The appraisal of existing models in rheumatology revealed that none of the studies had low risk of bias scores for all items; rather, the majority of studies had moderate to high bias in several categories. For several parameters, such as the effects of medical developments on future workforce need, none of the studies scored with a low risk of bias; nonetheless, we feel that meeting requirements for a low risk of bias for these factors is realistic and should be the target of future studies.

Our study has several limitations. First, the studies included in the two literature searches were limited to published literature and over several decades. Although we used a sensitive approach to identify workforce studies in rheumatology as well as SLRs in other medical fields, we cannot exclude that some relevant papers were missed. In countries with highly centralised healthcare planning, prediction models may not have been published and medical societies (which were contacted to retrieve unpublished literature) may not have been involved in these exercises and thus not aware of existing studies. Nonetheless, the grey literature search identified reports about supranational efforts (ie, EU and OECD) which summarised workforce prediction practices in healthcare planning in different countries.[8 12] These reports from respected agencies, while having different focuses and thus not meeting the inclusion criteria of any of our searches, were reviewed, reassuring the task force that it is unlikely that any substantial parameters have been missed. However, most of the research has been done in the USA and Canada, which present only one part of the health systems of the Western world. Next, this review had a limited focus on prediction of the requirement of rheumatologists and left beyond the scope detailed review of workforce planning for other health professionals involved in care for patients with RMDs. Other limitations refer to the subjective character of the risk of bias tool and the absence of reliable methods for external validation of the quality of workforce studies. Future workforce prediction should thus pay more attention to the validation and assessment of the model performance in order to identify the key threats to model validity and the parameters with the highest priority. It should be recognised that certain factors affecting workforce requirement cannot be foreseen at time of model conduction (eg, social media were unknown in the last millennium but may affect demand today and in future), hence a regular update of the model is essential in order to increase the validity of predictions.

While workforce planning is not an exact science, it has an important role in the dialogue between different stakeholders to guide the decisions around workforce training and more general organisation of healthcare in order to cover the expected future demand of the population.[12] The current study provides an important and novel synthesis of contemporary workforce prediction practices. The existing evidence on workforce prediction in rheumatology and other fields is scarce, heterogeneous

and of low to moderate quality. The workforce prediction risk of bias tool should facilitate future evaluation of workforce prediction studies.

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