






Global research publications on cardiovascular and pulmonary rehabilitation and their alignment with population rehabilitation needs: An ecological study

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Abstract

Purpose: Towards informing health research policy and planning, this article evaluates the relationship of the research publications in cardiac rehabilitation (CR) and pulmonary rehabilitation (PR) with the rehabilitation needs arising from cardiovascular diseases (except stroke) and chronic respiratory diseases, over time (1990–2017).

Methods: Ecological study using a secondary analysis and linear regressions of public domain data to associate two datasets of population-level data: (1) research publications for CR and PR (data from the PubMed database); and (2) global need for CR and PR (data from the Global Burden of Disease study).

Results: The percentage of both CR and PR publications (among total rehabilitation research) significantly decreased from 1990 to 2017 (both: $p < 0.01$). PR needs and research publications were aligned: around 5% of total rehabilitation needs and rehabilitation research. For CR needs (around 2%, but significantly increasing since 1990), we found a greater portion of CR research publications (6.5% or over). Finally, we found an inverse association among the percentage of CR research publications and CR needs ($b = -6.08$; $r^2 = 0.37$, $p = 0.001$).

Conclusion: The portion of CR and PR research (among total rehabilitation research) is declining over time. Yearly

percentage of CR publications were greater than those of PR but for lower level of rehabilitation need, but the disparate trend was significantly decreasing over time. Population rehabilitation needs and their alignment with research volume must be one factor in the design of population-centred, equitable health research priorities.

KEYWORDS

cardiovascular diseases, health policy and planning, health services needs and demand, lung diseases, rehabilitation

Highlights

- Cardiac rehabilitation (CR) and pulmonary rehabilitation (PR) publications and population CR and PR needs were compared.
- Percentage of CR and PR publications among total rehabilitation research is declining.
- PR needs and research publications were aligned but not for CR needs and publications.
- Health research policy and planning must account for CR and PR needs and their alignment with research volume.

1 | INTRODUCTION

Prevalent cases of cardiovascular diseases (CVD) and chronic respiratory diseases (CRD) are increasing worldwide over the last decades: 92.9% and 39.8% from 1990 to 2017, respectively.^{1,2} Deaths also increased, reaching 18.6 million in 2019 and 3.9 million in 2017, respectively, which make them the world's leading and third leading causes of death.^{1,2} In addition, CVDs remain the leading cause of disease burden in the world, and years lived with disability (YLD) attributed to these diseases doubled from 1990 to 2019.¹ CRD, in turn, accounted for 32.4 million YLDs in 2019, whereas chronic obstructive pulmonary disease and asthma were the main contributors to the global burden of respiratory disease.³ Furthermore, a broad range of cardiothoracic conditions (i.e., CRD, chest injuries, CVD—except stroke, and heart failure sequelae from any health conditions) was one of the three major contributors to the world's physical rehabilitation needs.⁴

Given the global disease burden arising from CVDs and CRDs, it is important to understand whether scientific production worldwide is aligned with the healthcare needs and the burden of specific diseases in the population. A previous study evaluated publication trends in rehabilitation (2001–2013) and showed that the number of clinical trials and systematic reviews, as a broad indicator on the scientific production volume, were the greatest and improving at a greater rate for the rehabilitation of neurological conditions than for any other condition type, including cardiothoracic.⁵ Despite the rehabilitation research focus on neurological conditions, data from the Global Burden of Disease (GBD) shows that either musculoskeletal or all cardiothoracic conditions account for a greater portion of the world's physical rehabilitation needs.⁴

Overall, imbalances in the distribution of health research publications relative to population health or health systems research needs worldwide have been commonly found in recent research, pointing for inequities in the distribution of the research volume per conditions addressed and their respective burden of disease.^{5–8} Moreover, a recent study showed that high-income countries still accounted for more than three-quarters of human resources for health research publication compared to low- and middle-income countries.⁷ Nonetheless, to the best of our

knowledge, there are no studies that evaluated the research publication trends in cardiac rehabilitation (CR) and pulmonary rehabilitation (PR) in relation to physical rehabilitation needs arising from CVD and CRD, respectively.

At this backdrop, towards informing health research policies and planning worldwide, the aim of this study is to evaluate the relationship (i.e., alignment and association) of research publication trends in CR and PR with the physical rehabilitation needs arising from CVD and CRD over a long time-span (1990–2017).

2 | METHODS

2.1 | Study design

Ecological study, using a secondary analysis of public domain data to associate two key datasets of population-level data. These datasets were on (1) research publications for CR and PR (using indexed publication data from the PubMed database), and (2) global rehabilitation needs arising from CVD and CRD (using data from the GBD Study).⁹

2.2 | Analyses of research publication trends

The PubMed database and the indexing system for its largest sub-component (MEDLINE) was the one used for the analysis of research publication trends in CR and PR. Albeit not exhaustive, PubMed is a comprehensive database of health research. For instance, research has shown that searching for other scientific databases in addition to PubMed had a limited impact on the number of papers included in a systematic review of therapeutic interventions.¹⁰ For detecting CR and PR research publications in PubMed, we were based in search strategies used previously in analyses of rehabilitation research trends,^{5,6,8,11,12} including in a stratified analyses per condition type that includes cardiovascular and pulmonary conditions.^{5,6} The method is based on the use of indexed terms, notably Medical Subject Headings (MeSH) for CVD and CRD selected from the MeSH tree, and exclusively searched as a major field. These terms were coupled with previously developed comprehensive search filters for detecting rehabilitation research content in PubMed.^{5,6,8,11,12} This search allowed the inclusion of studies indexed as pertaining to the rehabilitation of CVD and CRD respectively. The details of the search strategy are available in Supporting Information S1.

The search was performed in April 2020, but only articles published until the end of 2017 were retrieved in order to account for the often 2 years of delay in PubMed indexation, as commonly performed in the studies using PubMed data.^{5,6,8,11,12}

2.3 | Rehabilitation needs worldwide arising from cardiovascular and pulmonary health conditions

Physical rehabilitation needs of the population worldwide were here based on the GBD estimates, specifically the YLDs which is the measure in the GBD—a global standard in health loss determination—that focuses exclusively on non-fatal health losses.³ YLDs can be a relevant population-based indicator of physical rehabilitation needs as it consists of aggregative measure on the prevalence of a health condition, the years lived with any short-term or long-term health loss from that conditions, and further weighted for severity by disability weights.¹³ YLDs do not account for fatal health losses, arguably relevant as indicator of physical rehabilitation needs as those who die from an health condition (e.g., stroke, heath attack) do need rehabilitation service, unlike those who survive with varying levels of sequalee accounted for in the YLDs. Other studies have relied on YLDs for estimating rehabilitation needs worldwide.^{14–19} In this study, we used YLDs per 100,000 people (i.e., YLDs Rates), which adjusts YLD values to the size of the population. As in previous studies,^{4,14–18} the YLD Rates were extracted from the GBD Results Tool for the GBD

2017, here with a focus on CRD and CVD—excluding stroke which rather provides neurological sequelae, subject to neurological rehabilitation. Data from every year from 1990 to 2017, matching the dates of the publications, were extracted and then used for determining yearly changes in rehabilitation needs.

2.4 | Statistical analyses

All the data (i.e., yearly research publications in CR and PR from PubMed and yearly YLD Rates attributed to CVD and CRD: 1990–2017) were exported into Excel spreadsheets, and displayed into time-series plots. Additionally, we computed relative percentages for each of those values. For the rehabilitation needs, we used the YLD Rates from CVD and from CRD—used as numerators, along with YLD Rates for the total physical rehabilitation need (i.e., all conditions relevant to physical rehabilitation combined)¹⁸—used as common denominator. For the rehabilitation publications, we used the number of PubMed-indexed PR and CR research publication as numerator, along with the total number of rehabilitation publications as the common denominator. This data transformation turned the resultant percentages comparable. Then, linear regressions models were used to evaluate the growths in research publications and YLD Rates, using their relative percentages over time.

Finally, linear regressions evaluated the association of the percentage of CR and PR research publications (among total rehabilitation publications) with the percentage of YLD Rates amenable to rehabilitation attributed to CVD and CRD, respectively.

Statistical analyses were performed using STATA version 15.1. A *p*-value <0.05 was considered statistically significant.

3 | RESULTS

Of the 135,255 research publications in rehabilitation from 1990 to 2017, 9806 (7.25%) and 6807 (5.03%) were focused on CR and PR, respectively. Both the PR and CR research publications increased from 1990 to 2017 (see Figure S1). Despite these absolute values, the percentage of either CR or PR publications among total rehabilitation research publications significantly decreased from 1990 to 2017 (Figure 1). In turn, in contrast to this reduced preponderance of CR or PR publications, the percentage rehabilitation needs attributed to CVD significantly increased (1990–2017: *p* < 0.0001; $r^2 = 0.907$) even though not significantly changed over time for CRD (Figure 2).

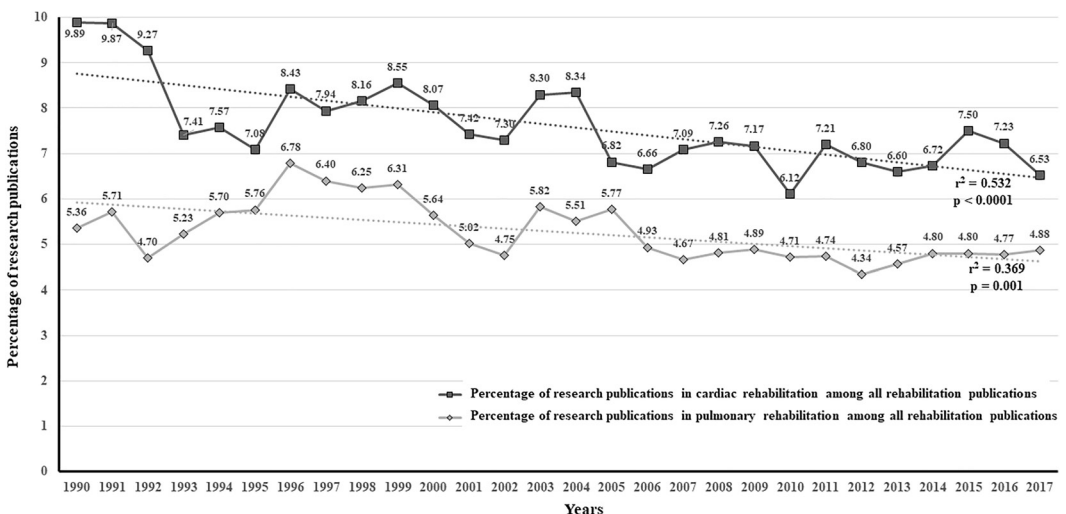


FIGURE 1 Percentage of research publications in cardiac and pulmonary rehabilitation among all rehabilitation publications from 1990 to 2017.

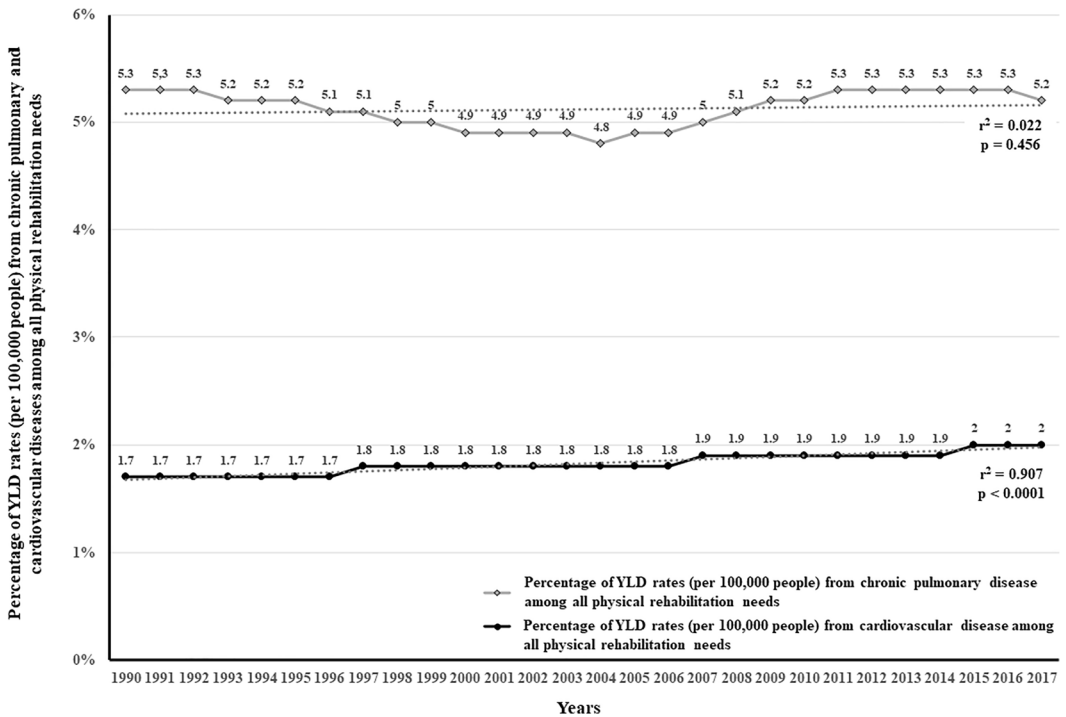


FIGURE 2 Percentage of years lived with disability (YLD) Rates from chronic pulmonary and cardiovascular diseases among all physical rehabilitation needs from 1990 to 2017.

For a visual display and comparison, Figure 3 combines the yearly alignment of the percentage of research publications and population need for CR and PR. From the data, we observe a relative yearly match between the percentage of PR research publications and PR needs, both around 5%. However, the percentage of PR needs among overall rehabilitation needs has been relatively stable, while the percentage of research publications significantly declined over time ($p = 0.001$; $r^2 = 0.369$, Figure 3).

For CR, the picture is different. For a lower level of rehabilitation needs attributed to CVD—around 2%, but significantly increasing over time ($p < 0.0001$; $r^2 = 0.907$, Figure 3), we found a greater percentage of CR research publications (yearly range from 6.5% to 9.9%) even though declining significantly from 1990 to 2017 ($p < 0.0001$; $r^2 = 0.532$, Figure 3). Finally, a linear regression model shows an inverse association among the percentage of CR publications and CR needs, meaning that as one variable grows the other significantly declines ($b = -6.08$; $r^2 = 0.37$, $p = 0.001$; Table 1). However, in this case (i.e., greater yearly percentages of CR research for lower CR need levels from 1990 to 2017), this inversed association is working towards a convergence among the percentage of CR research publications and the respective portion of CR needs.

4 | DISCUSSION

This study analysed the relationship of research publication trends in CR and PR with the respective rehabilitation needs arising from CVD and CRD over time. We found a significant decrease of the preponderance of both CR and PR among total rehabilitation publications. Also, we found a relative alignment among the rehabilitation needs from CRD and the respective PR research publications; yet, we did not find the same alignment among the portion of rehabilitation needs attributed to CVD and the portion CR research publications. All these findings are worth discussing.

The decline over time of the portion of CR and PR publications among total rehabilitation research does not reflect an absolute decline in CR and PR publications. The trend rather reflects a lower growing pace than that of all

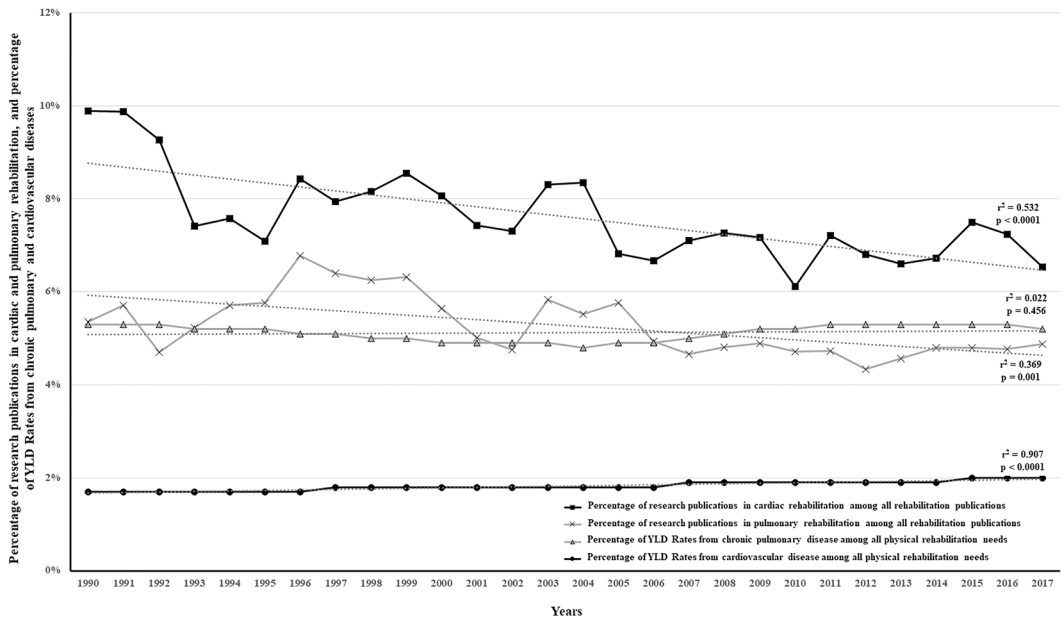


FIGURE 3 Percentage of research publications in cardiac and pulmonary rehabilitation among all rehabilitation publications, and percentage of YLD Rates from chronic pulmonary and cardiovascular diseases among all physical rehabilitation needs from 1990 to 2017.

TABLE 1 Linear regression models with the percentage of research publications in cardiac and pulmonary rehabilitation among all rehabilitation publications needs as the dependent variable.

	<i>b</i> (95% CI)	Standard error	<i>p</i> value	<i>r</i> ²
% research publications in cardiac rehabilitation				
% YLD rates (per 100,000 people) from cardiovascular diseases	-6.08 (-9.26 to -2.91)	1.54	0.001	0.37
% research publications in pulmonary rehabilitation				
% YLD rates (per 100,000 people) from chronic pulmonary diseases	-1.37 (-2.81 to 0.07)	0.70	0.062	0.13

Abbreviation: YLD, years lived with disability.

other conditions amenable to physical rehabilitation combined. For instance, a previous study has shown that neurological rehabilitation had greater research volume as well as greater increases for the rehabilitation research, even though most rehabilitation needs came from musculoskeletal and pain conditions.^{4,5,17,19} On the other hand, there are new areas of rehabilitation practice (e.g., rehabilitation of cancer- and of HIV-related conditions) which may have gained preponderance (from historically residual values) within the range of rehabilitation research.^{20,21} These factors that altogether lead to greater growths of research in other areas of rehabilitation can have contributed for both CR and PR to become less prominent in rehabilitation research volume.

We found a greater amount of research publication on CR, even though rehabilitation needs for CVD were inferior to those of CRD. Hence, a combination of factors other than CVD-based rehabilitation needs may have contributed to this finding; we explore some of them below.

Cardiovascular diseases altogether (including stroke) are the leading cause of disease burden in the world^{1,2}, as such, there is has been an urgent need to focus on implementing cost-effective policies and interventions to address the global burden of CVD.¹ Aligned with this population need, the research over the past decades has provided an

increasingly solid knowledge of the effectiveness and cost-effectiveness of CR, and about how CR approaches can be implemented worldwide in sustainable, equitable and efficient manner—including in low-resource settings where the burden of CVD and their subsequent rehabilitation needs has been escalating, as well.^{4,15,22–25} Hence, historically greater levels of CR research publications may have been justifiable to develop that solid knowledge of the effectiveness and cost-effectiveness of CR.

It is also noteworthy that CR needs are not equivalent to the whole burden of CVD. For instance, stroke and heart attacks lead to Years of Life Lost, beyond YLDs, and these together account for the massive global burden of CVD.¹ Arguably, those who die from a heart attack or stroke do not generate YLDs from those conditions thereby do not generate rehabilitation needs—overall,^{4,15} and in this analysis. Furthermore, those who survive stroke with sequelae often have neurological sequelae amenable to rehabilitation, but not CR needs, rather neurological rehabilitation needs, which is a key consideration in analyses of rehabilitation publication trends per sequelae type.^{4,5} Here, YLDs coming from stroke were not counted as part of the CR needs, but in the denominator of total rehabilitation needs, which contributes to lower (not greater) percent values of CR needs. Additionally, we focused on YLD Rates for CVD (except stroke) as the only contributor to CR needs. However, CR and broader exercise-based interventions have been recently emerging as effective also for other conditions, such as example heart failure.^{26–28} Yet, that evidence is still emerging (i.e., with some methodological gaps yet).²⁹ Within a conservative approach, here we included only YLDs from an underlying CVD cause. Furthermore, heart failure arises from many causes, often occurs with multiple comorbidities, and can be subject to a broader for physical rehabilitation or a combined form of cardiopulmonary rehabilitation—hence potentially relevant for both CR and PR, not necessarily pertaining solely to CR needs.^{28,30,31} All accounted, for computing CR needs, we did not account here for heart failure YLD Rates of unknown causes. This conservative option may result in an underestimation of CR needs.

Pragmatically, CR also fits secondary prevention purposes (i.e., prevents second heart attack) in addition to meeting rehabilitation needs (e.g., improved function).³² Hence, CR research may synergically meet functional sequelae of CVD (considered here as rehabilitation needs) as well as prevent second, acute CVD events. This synergistic factor (i.e., contribution to disease prevention and reduced Years of Life Lost beyond YLDs) can also partly justify the greater preponderance of CR research relative to their rehabilitation needs per se.

We found a negative association from CR needs and CR research publications. In the identified context (i.e., historically higher levels of CR research than CR needs), this trend is working towards a convergence of the percentages of CR needs and research volume. However, this negative association should be further monitored over time. If it further progresses (e.g., beyond a point of intersection), the trend can result in a suboptimal and declining research volume at the backdrop of rising population needs.

Pulmonary rehabilitation is also an effective and cost-effective intervention, including delivered by telerehabilitation means, as increasingly backed by solid evidence.^{33–36} PR can address rehabilitation needs and impairments that are manifest for a prolonged period of time, and hence the rehabilitation needs measured in YLDs (which account for the period of time one has sequelae from a health conditions) were found greater for CRD than were for CVD without stroke. Interestingly, YLD Rates attributed to CRD were aligned with the preponderance of PR research publications. Nonetheless, while the percentage of rehabilitation needs arising from CRD were relatively stable from 1990 to 2017, that for PR publications was decreasing significantly over time. If the trend progresses, a smaller preponderance of PR research publications relative to their respective rehabilitation needs is foreseeable, in this case within a near future. Accounting for imbalances among rehabilitation research publication trends and population needs is likely one component to be considered when developing data-based, population-centred research agendas for rehabilitation-related clinical and health policy, systems, and services research.^{5,8} Moreover, also on the side of conservative needs assessment, the PR needs here did not account—in our data up to 2017—for PR needs arising from infectious conditions. The recent advent of the COVID-19 and its long-term sequelae will raise the need for PR beyond what is covered (e.g., in timing) for this study.^{37,38}

All accounted, our results provide an overview of the relationship among CR and PR needs and the respective publication volumes. These global data trends, especially in relative values, might be considered by policy-makers,

health research planners, and the research community overall as one factor, among others, for the elaboration of population-centred, equitable rehabilitation research priorities and research agendas.⁸ Moreover, researchers might also use the identified trends to emphasise on the global public health significance of their research, including as emphasised by a joint editorial in key rehabilitation journals^{39,40} in a generalist health services research journal.⁴¹ Yet, crucially, other factors might be taken into account in these elaborations, such as but not limited to: local population needs, prominent research questions, the ability to develop research to answer those questions, methodological quality of existing research, whether vulnerable populations have inequitable access to cost-effective treatments, and whether individual patient needs are or can be met. Nonetheless, an outlook over the amount of global needs and how are these met by a certain amount of research is also an important indicator for attaining equity, justice, or global public health goals.^{42–45}

4.1 | Limitations

This study has limitations. The YLD Rates were used as an indicator of rehabilitation needs, not functional measures; yet, YLDs are available as a global population health metric which accounts for the prevalence of the disease or injury but also the resultant sequelae, the time lived with the resultant sequelae, and the severity of that sequelae associated with a disability weight; therefore, the YLD Rates, albeit a proxy indicator, combines diverse indicators of rehabilitation need.^{9,13} We use publications data from PubMed based on its indexation facilities, which does not include research publications not available in this database and does not include a manual screening (over that of PubMed indexers themselves) for the large volume of CR and PR (numerators) and of rehabilitation research overall (denominators). Yet, as the strategy for both numerators and for the denominators was the same (and our analysis conducted with percent values), there are lower bias concerns from our option to analyse proportions. We used data up to 2017, to account the delay in the full PubMed indexation (i.e., avoiding fallacious lower numbers in the recent years) and therefore have used only GBD data up to 2017; updates of rehabilitation-related data from the GBD 2019 have not been showing any substantive changes in the trends from 2017 to 2019.^{19,46} Furthermore, we analysed research production in terms of volume of empirical research, not accounting for specific study designs or the quality of its conduct, which are other important factors in the analyses of the rehabilitation scientific production.^{5,12,47} The volume of CR and PR research publications may not be associated with the impact of research on clinical practice, and future studies should be conducted to understand this association. The data from respiratory infectious conditions (e.g., COVID-19) were not accounted for, and not available yet in the metrics of the GBD study but will imply further PR needs than those analysed.³⁷ Similarly, with a conservative approach, heart failure from conditions other than CVD were also not accounted for in CR or broader cardiopulmonary rehabilitation needs. Hence, the total burden of cardiothoracic conditions was set as conservatory as well as it is likely to raise in the near future. We did not perform regional or country-level analyses, nor included socio-economic covariates in the regression model analysing the association of PR and CR needs and research volume.^{16,45} Finally, the characteristics of our dataset (e.g., single scientific database, lack of seasonality) limits the benefits of using a join point regression approach for the analysis of the data in this study.

5 | CONCLUSION

This ecological study that aims to inform global health research and planning used global public-domain data to analyse the alignment among the volume of CR and PR research publications with the worldwide rehabilitation needs arising from CVD and CRD, from 1990 to 2017. Both CR and PR research publications were becoming less prominent in volume, over time, among total rehabilitation research publications. Pulmonary rehabilitation research publications and the respective rehabilitation needs were relatively aligned with one another, but yearly CR publications were

constantly greater than those of PR while rehabilitation needs from CVD were constantly lower, even though there is a convergence over time. Along with several other factors (e.g., research questions, methodological quality), population rehabilitation needs, their alignment with research volume, and their combined trends over time should be further considered by the research community, health planners, and policy-makers in the design of population-centred, equitable research priorities.

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CONFLICT OF INTEREST STATEMENT

The authors report there are no competing interests to declare.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

ETHICS STATEMENT

Not applicable.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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