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Review

Water-Based Rehabilitation in the Elderly: Data Science Approach to Support the Conduction of a Scoping Review

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Featured Application: The paper describes the possible application of particular data visualization to understand the interactions of the variables usually considered in scoping reviews. The approach, borrowed from other disciplines, can support the medical scientists in revealing and analyzing the data collected by the literature search. The method can be applied to every medical field and can be implemented in relation to the research questions.

Abstract: Water-based rehabilitation is a well-known approach that is useful for the prevention and management of many conditions. Its application in the elderly is quite common in clinical practice, but scientific evidence is limited. We conducted a scoping review on geriatric water-based rehabilitation using a methodology borrowed from data science to investigate and discuss the extensive literature data. We searched the papers on PubMed and we used the abstracts to collect different data. We imported them into an electronic database and we used its filters to build different graphical representations. The filters allowed the selections of specific modalities of a variable and the following visualization of the values of the other variables linked to that selected modality. A total of 49 papers were found and they confirmed the safety and usefulness of water-based rehabilitation. Our analysis was able to show the relationships among the variables and the differences in the elements considered for the analysis. The current literature shows some limitations, especially concerning the article types in some specific diseases and the outcome measurements. Future research can overcome these limitations by collecting more data on the diseases that affect old people, even with the use of precise outcome measures. Our described methodology can be potentially beneficial and other studies may confirm its utility.

Keywords: rehabilitation; elderly; aquatic therapy; balneotherapy; big data; data science; literature review; scoping review

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1. Introduction

The application of water properties in rehabilitation is well-known and not new [1]. Indeed, water can be used for the treatment of several diseases and produces a large number of benefits [2]. The principle of Archimedes is probably the most famous characteristic of water. This principle, which takes its name from the scientist from Sicily of the third century B.C., explains that water can produce a force that is able to push an immersed body up. This property allows a reduction in body weight in patients under particular conditions. For example, after surgery or in case of strength deficit, the water allows passive and active movements during rehabilitation, reducing the impact of gravity [3]. In a similar way, the same hydrostatic thrust guarantees a safe environment for the patients, preventing the risks of a trauma related to an accidental fall during the exercises. Besides this fundamental property, water can be even used for muscle strengthening in the proper phase of

rehabilitation. In fact, the viscosity of water causes an opposition against the movement that is higher than the air in normal conditions. Hence, a patient immersed in water can use particular tools (such as a paddle) or a particular disposition of the body segment to work in resistant way [4]. Additionally, water is used to improve the proprioception by the constant stimulation of the skin and the turbulence continuously produced when the movement and the exercises are performed in the aquatic environment [5]. The described properties represent the basis of aquatic treatment or hydrokinesitherapy, a relevant rehabilitation program based on the interaction between the mechanical features of water and the patients. In addition to this, water finds application in the so-called balneotherapy, or thermal therapy. In this approach, patients can be treated in hot water with different mineral compositions. This treatment can produce additional benefits at different levels, from cellular to psychological ones [6].

The numerous listed effects of water-based rehabilitation are applicable to old people to manage several conditions [7]. The elderly is a key topic for the medicine of the third millennium, because, luckily, the mean survivor age has increased in the last few decades. However, this condition is related to the required management of patients with complex clinical situations. Indeed, the elderly population is characterized by continuous diminishing of their physical and mental functions [8]. Although inhomogeneous phenotypes of the elderly exist, rehabilitation may play a relevant role in the maintenance of these functions. In this sense, the mechanical features of water may reveal its effects on the numerous problems of the elderly and can be used not only in rehabilitation after a disease, but also to prevent some risk factors. Certainly, the proprioceptive stimulation of the water may increase the balance of the elderly, a key factor to prevent the risks of falls. Furthermore, the non-mechanical properties of water can ameliorate inflammation with a highly positive impact on pain, depression and quality of life [9]. Although these defined benefits exist, real scientific evidence on old people is scarce. This may be explained by the inhomogeneity of the studies and by the relatively low number of specific studies [10].

The "grey literature", that is the literature comprising non-scientific works, shows a constant increase in the use of the terms "aquatic therapy", "balneotherapy" or "water-based exercise" (Figure 1) [11]. This underlines the real interest in this issue in the last few decades, but the problem of the lack of evidence remains.

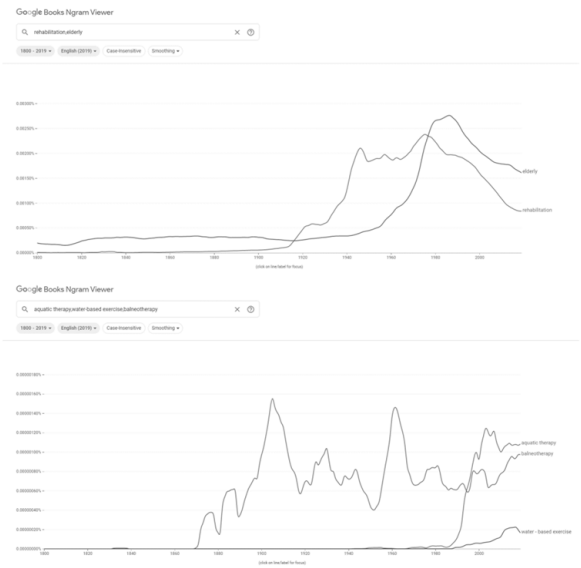

Figure 1. Graph of the frequency of the words: "rehabilitation" and "elderly" (up) and "aquatic therapy", "water-based exercise" and "balneotherapy" (down) in the digitalized worldwide literature. The results were obtained by the Google Ngram Viewer application and they consider the entire production of works, including the non-scientific literature.

In cases where the scientific literature presents this kind of limitation, a useful approach developed in the last few years is represented by scoping reviews. This is a particular form of literature revision that can be used to describe the level of scientific knowledge and to propose the future directions of the research. In 2007, Arksey and O'Malley described the methodology of scoping reviews, defining the four scopes of this kind of study, which are as follows: 1. mapping the current literature; 2. determining the possibility to conduct a systematic review; 3. summarizing the findings of the research; 4. identifying the gaps in the current literature [12]. A scoping review is very useful and should be used with frequency to guide the determination of further study protocols and the construction of the scientific relevance of a study. One of the possible limits of the scoping review is, however, the difficulty faced by the reader to interpret some data. In many scoping reviews, more tables are present to describe the different elements of the analyzed papers. In most cases, the parameters are obviously abundant and not always fully synthetized. Furthermore, the same interaction of the many different variables is not always intelligible to the readers. Hence, for example, the relationships between the year of publication, topics and outcome measures may be not easily accessible [13].

A possible solution to overcome this limit linked to data presentation and interpretations may come from the methodology of data science [14]. The main difference between this approach and a usual statistical analysis is related to the number of variables. In the usual statistical analysis, the sample size can be large, but the association of a relatively low number of variables is studied. For example, in a scatterplot used for correlation analysis, we can directly observe the variation in a variable when another one varies. In data science, a large dataset is assessed to find the possible association among a large number of variables. This approach is common in many research fields, such as business intelligence and prevision analysis [15]. It is based on the application of software that is able to manage a dataset with more filters. In this way, the visualization of the data becomes dynamic, because the analyzer can select a specific value of a variable and automatically observe the variations in the other variables. Considering the different variables of a scoping review, this approach can be useful for synthetic mapping of the literature and its dissemination, limiting the use of tables. Additionally, it can be helpful to find the gaps and to speculate about the indication for further research.

In this work, we applied the approach of data analysis and visualization to describe and assess the current literature about water-based rehabilitation in the elderly. We used the checklist for a scoping review and we discussed the results and the possible implication for future research.

2. Materials and Methods

For the conduction of the review, we followed the methodology presented by Arksey and O'Malley [12]. Our research question was the following: "What is known in the literature about water-based rehabilitation in the elderly?" To answer the question, we searched on PubMed the papers published in the last 10 years, considering the following string of terms: "(balneotherapy OR aquatic therapy OR water-based exercise) AND rehabilitation". The Boolean operators were used to find papers that combined rehabilitation with one of the words defining the different water treatments. We filtered the papers considering the age of subjects > 80 years, in order to include the studies that focused their research on old people. No other filters were applied. The abstracts of the papers obtained by the research were exported and analyzed. We excluded the papers that were not pertinent to the aim of the study. In particular, we did not consider studies in which the water was not part of the treatments or in which water and the related words referred to daily living activities (such as the use of the bathroom) or other behaviors (Figure 2).

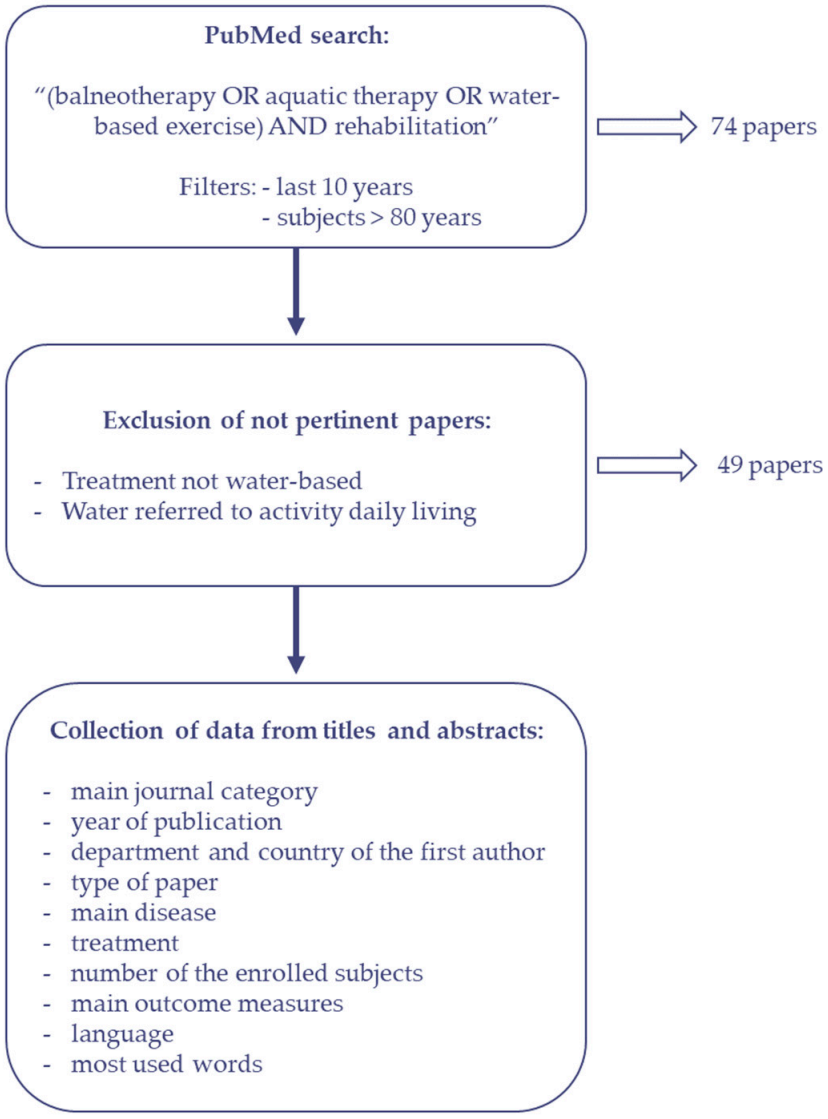

Figure 2. Flow-chart of the literature analysis and paper selection.

After the study selection, we collected the data from the titles and the abstracts, considering the following aspects: the main journal category of the publication; the year of publication; the department and the country of the first author; the type of paper (distinguishing randomized trials, RCT, from the other unspecified trials); the assessed main disease; the treatment used in the study (exercise in water vs thermal water); the number of subjects; the main outcome measures; the language of the publication; the most used words (including aquatic, balneotherapy, elderly, exercise, rehabilitation, SPA, thermal, water).

The data were inserted into a database and the filters were created. The results were summarized with different types of graphs (bar chart, tree map, geographical map, funnel chart, ring and pie chart). In this way, through the spreadsheet, we were able to visualize the whole dataset in a synthetic way (Figure 3). Above all, it can allow the selection of a value of a variable and the visualization of the relative values of the other variables. When a value is selected on a graph, the other graphs change their colors, making the tonality of the portions of the diagrams not related to that value paler as a result.

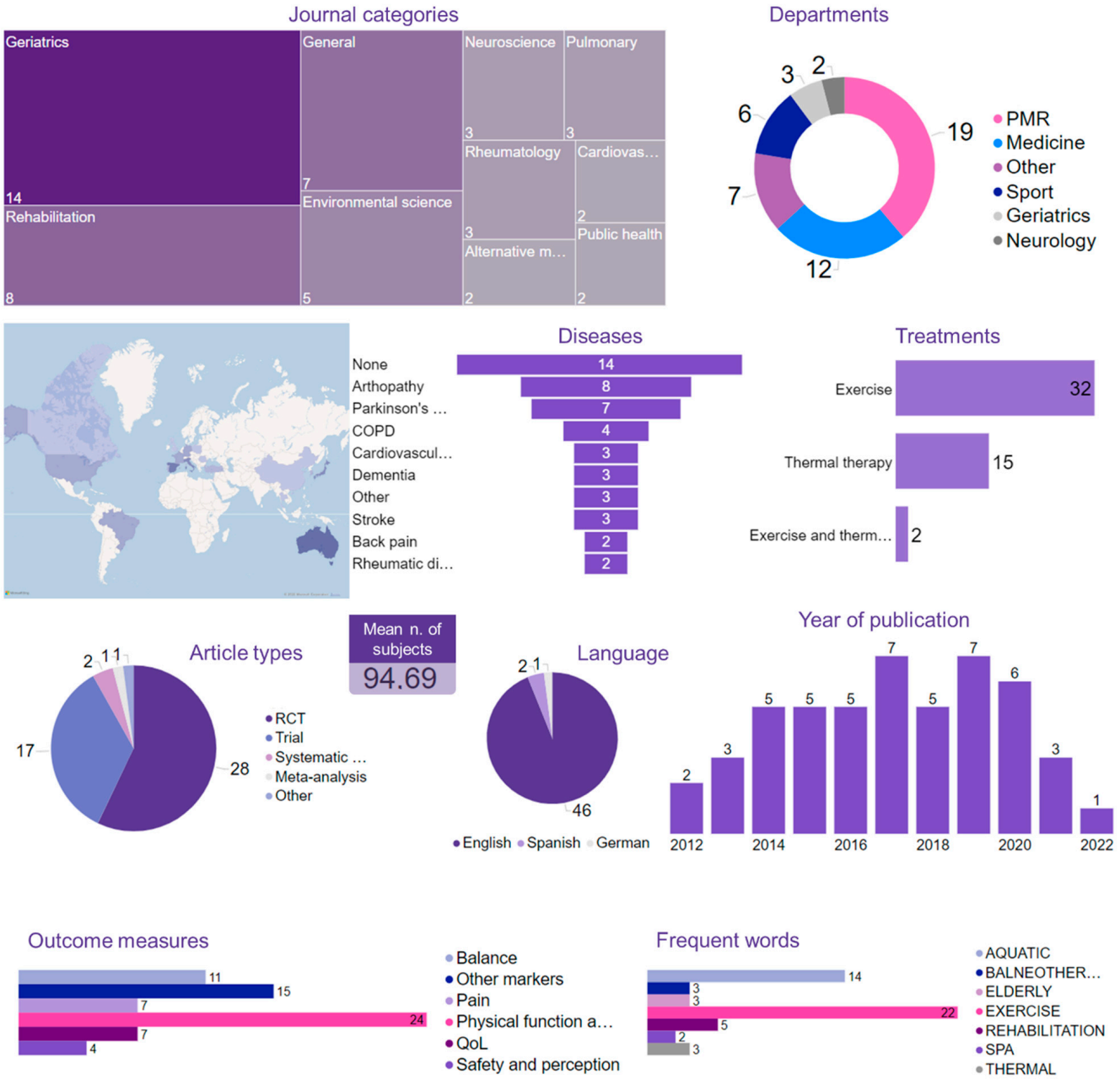

Figure 3. General results. From upper left: journal categories, departments, geographical distribution, main diseases, water treatments, types of articles, mean subjects, language of publication, year, outcome measures; most common words in abstracts.

3. Results

The first literature search found 74 papers, with a production peak in the year 2018–2019. We selected 49 works, which met the inclusion criteria (Table 1) [2,7,9,16–61]. The included papers confirmed the safety and effectiveness of water-based rehabilitation in the elderly.

Table 1. Results of the literature analysis after the selection of the 49 papers.

Authors	Numb. of Patients	Disease	Main Treatment	Main Assessment Scales
Farinha et al., 2022 [16]	102		Water-based exercise	Other markers
Pieniążek et al., 2021 [17]	137	Other	Water-based exercise	Balance
Campos et al., 2021 [18]	1707		Water-based exercise	Other markers
Ferreira et al., 2020 [19]			Water-based exercise	Other markers
Ma et al., 2021 [20]		Arthopathy	Thermal therapy	Pain; physical function and muscle strength; QoL
Sugie et al., 2020 [21]	67	Other	Thermal therapy	Physical function and muscle strength
Terrens et al., 2020 [22]	30	Parkinson's disease	Water-based exercise	Safety and perception
Nissim et al., 2020 [23]	42		Water-based exercise	Balance; pther markers
Kang et al., 2020 [24]	20		Water-based exercise	Other markers
Masiero et al., 2020 [25]	11	Arthopathy	Thermal therapy	QoL
Kittichaikarn and Kuptniratsaikul, 2019 [26]	30	Arthopathy	Water-based exercise	Pain; physical function and muscle strength
Iwasaka et al., 2019 [27]	278		Water-based exercise	Physical function and muscle strength
Sosner et al., 2019 [28]	42	Cardiovascular disease	Water-based exercise	Other markers
Gravel et al., 2019 [29]	21		Thermal therapy	Other markers
Silva et al., 2019 [30]	92	Other	Water-based exercise	Balance; other markers
Uivarosan et al., 2019 [31]	70	Stroke	Water-based exercise and thermal therapy	Physical function and muscle strength
Masiero et al., 2019 [2]	14	Parkinson's disease	Thermal therapy	Balance
Gálvez et al., 2018 [9]	36	Arthopathy	Thermal therapy	Pain; physical function and muscle strength; QoL
Wu et al., 2018 [32]	50	COPD	Water-based exercise	Physical function and muscle strength
Musumeci et al., 2018 [33]	12	Arthopathy	Thermal therapy	Physical function and muscle strength; QoL
Pérez-de la Cruz, 2018 [34]	29	Parkinson's disease	Water-based exercise	Physical function and muscle strength; balance
Chary-Valckenaere et al., 2018 [35]	186	Arthopathy	Thermal therapy	Physical function and muscle strength
Morer et al., 2017 [36]	26	Stroke	Water-based exercise	Physical function and muscle strength; balance
Henwood et al., 2017 [37]	46	Dementia	Water-based exercise	Other markers
Kutzner et al., 2017 [38]	12	Arthopathy	Water-based exercise	Physical function and muscle strength
Palamara et al., 2017 [39]	34	Parkinson's disease	Water-based exercise	Balance
Kavadar et al., 2017 [40]	155	Back pain	Thermal therapy	Safety and perception
Volpe et al., 2017 [41]	30	Parkinson's disease	Thermal therapy	Physical function and muscle strength
Kim et al., 2016 [42]	30		Thermal therapy	Other markers
Barker et al., 2016 [43]	151	Arthopathy	Water-based exercise	Pain; physical function and muscle strength; QoL
Pérez-de la Cruz et al., 2016 [44]	15	Parkinson's disease	Water-based exercise	Pain; physical function and muscle strength; balance
Noack et al., 2015 [45]	169	Cardiovascular disease	Water-based exercise	Safety and perception
Haseba et al., 2016 [46]	24	Cardiovascular disease	Thermal therapy	Other markers
Cancela et al., 2015 [47]	85		Water-based exercise	Physical function and muscle strength
Fedor et al., 2015 [48]	60		Water-based exercise	Other markers
McNamara et al., 2015 [49]	18	COPD	Water-based exercise	Safety and perception
Nishiyori et al., 2016 [50]	21	Stroke	Water-based exercise	Physical function and muscle strength
Henwood et al., 2015 [51]	10	Dementia	Water-based exercise	Physical function and muscle strength
de Oliveira et al., 2014 [52]	74		Water-based exercise	Balance
Onat et al., 2014 [53]	81	Back pain	Thermal therapy	Pain; physical function and muscle strength; QoL
Neville et al., 2014 [54]	11	Dementia	Water-based exercise	Physical function and muscle strength; balance; other markers
Kikuchi et al., 2014 [55]	20	COPD	Thermal therapy	Other markers
Ayán et al., 2014 [56]	25	Parkinson's disease	Water-based exercise	Physical function and muscle strength
Sakurai et al., 2013 [57]	66		Thermal therapy	Physical function and muscle strength
McNamara et al., 2013 [58]	53	COPD	Water-based exercise	Physical function and muscle strength
Al-Qubaeissy et al., 2013 [59]		Rheumatic disease	Water-based exercise	Pain; QoL
Hardt, 2012 [60]		Rheumatic disease	Water-based exercise and thermal therapy	Other markers
Bento et al., 2012 [61]	37		Water-based exercise	Physical function and muscle strength

3.1. General Results

The results of the total 49 included papers showed a predominance of the geriatric journal category, followed by rehabilitation (Figure 3). The other specialties were less represented, while general medicine and public health were just after the first two categories. In the figure, the tree map on the upper left was used to indicate the distribution of these different journal categories, whose dimensions are proportional to the number of papers belonging to each category. Conversely, the geriatric department appeared infrequently, and rehabilitation was the most common, followed by the general medicine department. The frequencies of the departments are represented by the ring chart on the upper right. In the map, in the second line of the figure, the geographical distribution is shown. Australia represented the most productive country. In Europe, more countries of the central and south latitudes were present and no country from the Scandinavian countries was found. In the Asian continent, China, Turkey, South Korea, Thailand and especially Japan were visible. Finally, in America, the United States of America and Brazil offered three papers, while Canada only one paper. The diseases (or absence of disease) were illustrated by a funnel chart to clearly highlight the differences in the amount of manuscripts. In many papers, the assessed elderly patients were healthy subjects, but a relevant number of papers evaluated those with arthropathies and Parkinson's disease. Among the non-orthopedic and non-neurological diseases, chronic obstructive pulmonary disease (COPD) and cardiovascular disease were the most frequent. As shown by the bar chart, most studies were focused on exercises performed in water, which is aquatic therapy or hydrokinesitherapy, while thermal therapy was assessed in about one-third of papers. The two pie charts showed the article types and the languages of the papers. RCTs represented the majority of the works and just two systematic reviews and one meta-analysis were found. In the totality of the included papers, the mean number of subjects of the studies was about 95 and all papers were in the English language, except for 2 in French and 1 in German. The last two bar charts at the bottom indicated the outcome measures used in the works and the most frequent word for each abstract. Physical function (assessed in different modalities) and exercise were the most frequent outcome measure and the most frequently reported word, respectively (Figure 3).

3.2. Relationships of the Variables

The evolution of the publications showed a relatively rapid production of high-quality studies; in 2012, the first considered year, two papers were published and one of them was an RCT. Australia, the most productive country in our research, started the publication in 2013. In this country, however, no study about thermal water was published and was conversely focused on exercise in water. The thermal properties of the water were mainly assessed for arthropathy and only in countries from the northern hemisphere. No application of thermal therapy was found for stroke and dementia. Additionally, for this type of treatment, a balanced number of RCTs and other trials were found. For the studies about exercise in water, the number of RCTs was double in comparison with the other trials and the mean number of recruited subjects was higher than in the study about thermal water. In thermal water treatment, the balance was almost absent, while the effects in QoL were particularly commonly evaluated. As expected, balneotherapy, SPA and thermal terms were only used in papers about thermal therapy (Figure 4).

Considering the single diseases, arthropathies were studied with both types of water-based treatments (exercise and thermal), with a relatively low number of RCTs and with a predominance of physical function and QoL outcomes. For Parkinson's disease, RCTs and other trials were similar in number and, besides physical function, safety was another outcome measure used (Figure 5). The application of water-based rehabilitation in COPD seemed to be a matter of interest for the Australasian countries, with evaluation of physical function, safety and specific markers. Contrarily, cardiovascular diseases were also studied in Europe, with attention to the specific markers. Some diseases were related to single countries. In particular, dementia was present in Australia, only considering exercise in

water and, among the few studies, the majority were not RCTs. Turkey was the only country that performed studies about back pain, with the use of thermal water.

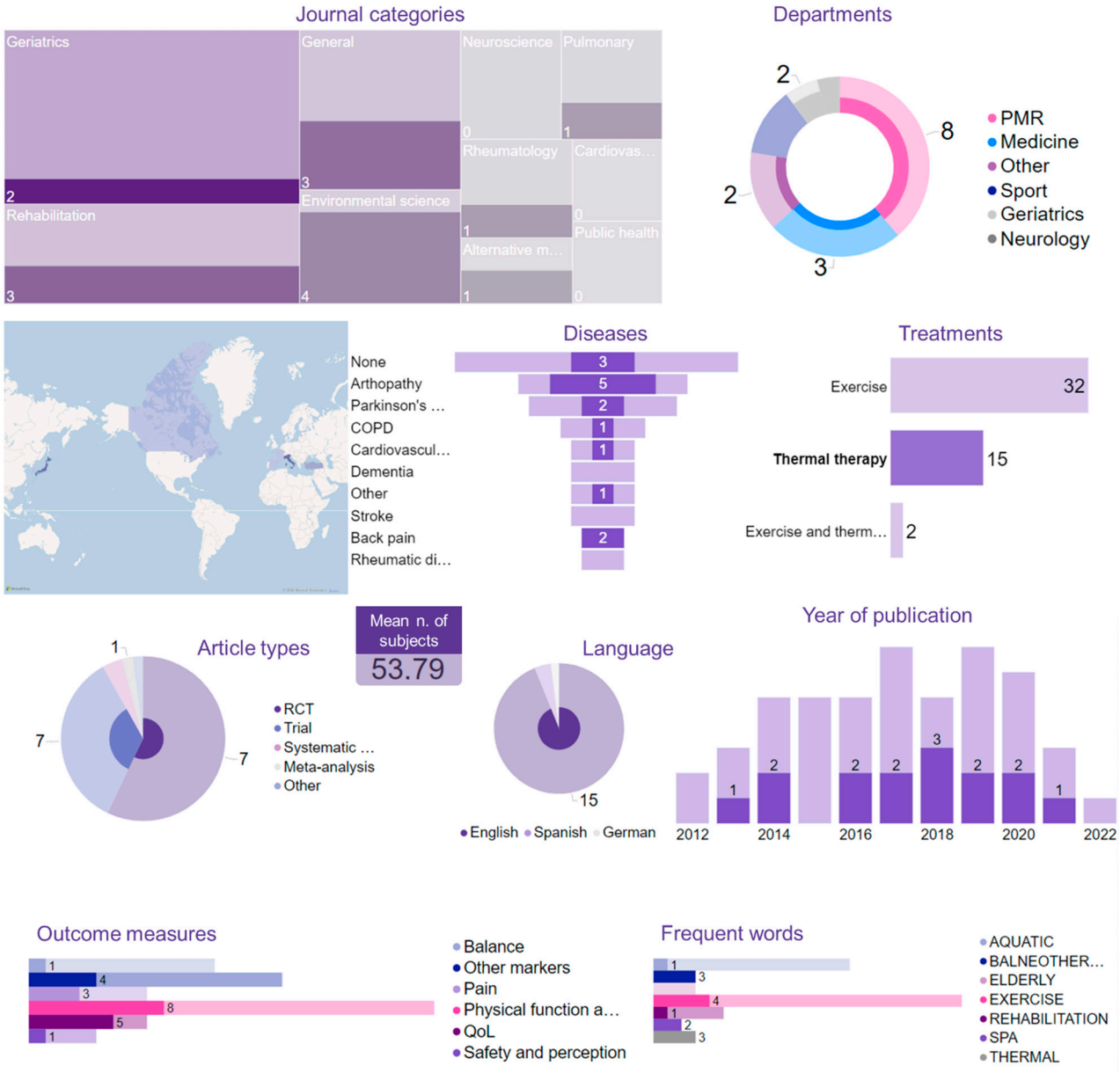

Figure 4. Results focused on the modality: "thermal therapy". By filtering the modality of the variable, the relative results of the other variables are shown (dark colors in the graphs). The shading is the pale portion of the graph, including the results not related to the selected modality.

Finally, no RCT was published in a language different from English.

3.3. Limitations and Gaps in the Literature

The main limitations found in the literature were related to the unbalance between the number of studies about thermal therapy and aquatic therapy. This was associated with the low number of RCTs and the low number of mean subjects in the first treatment. Furthermore, among the diseases included in this review and those that commonly affect old people, hydrokinesitherapy was studied in the majority of these. Despite the common study of physical function, this outcome was assessed in a non-homogeneous way, with different scales and rare application of objective and precise measurements, such as gait analysis. Relatively limited interest in QoL and safety was observed in the papers.

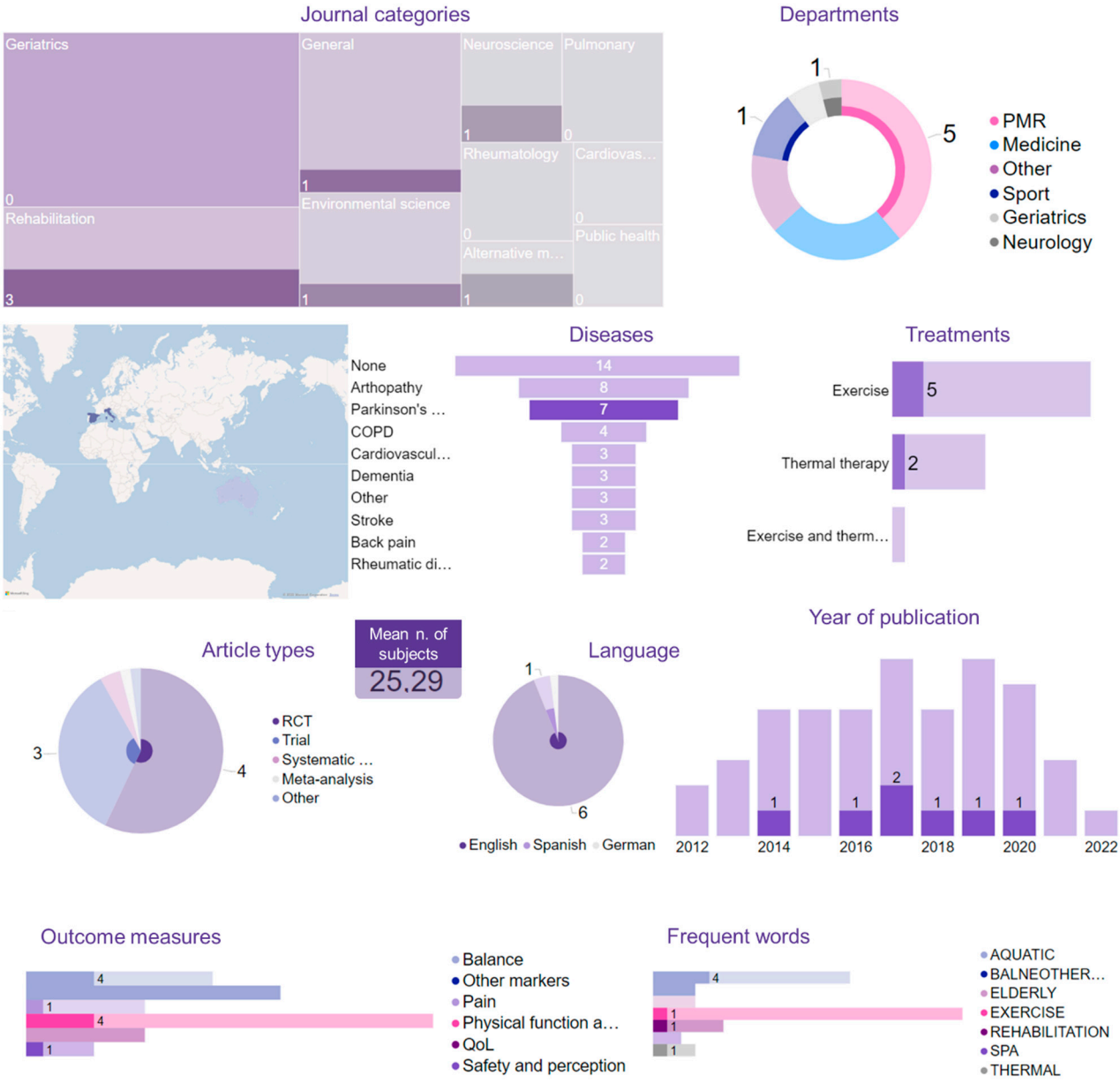

Figure 5. Results focused on the modality: "Parkinson's disease". By filtering the modality of the variable, the relative results of the other variables are shown (dark colors in the graphs). The shading is the pale portion of the graph, including the results not related to the selected modality.

4. Discussion

The current literature shows the worldwide diffusion of scientific publications about water-based rehabilitation with an increase in the first five years and a decrease in the last three. Many diseases of rehabilitation interest have been studied, with peculiar attention to orthopedic and neurologic illnesses. Even if the RCTs represent more than half of the papers included in this review, the percentage of this article type regarding thermal therapy is low. Finally, the outcome measures are not always comparable among the studies [36,50]. However, the current literature confirms the safety and the efficacy of rehabilitation in water, underlining the value in symptom relief and physical performance [25]. The literature indicates that water-based rehabilitation should be applied in the management of different kinds of diseases. Concerning musculoskeletal conditions, exercise in water and thermal therapy may be used to improve pain and function [25,26]. In neurological diseases, evidence is especially present for Parkinson's disease and strokes. In these conditions, the

water may support rehabilitation, reducing the risks of falls and increasing the safety of the exercises [22]. Interestingly, a particular field of application is dementia, where this type of rehabilitation indicates potential usefulness [37]. An important role is played by water-based rehabilitation in cardiopulmonary rehabilitation. Indeed, exercise in water may improve respiratory and peripheral muscle strength and thermal therapy may improve cardiac function [32,46].

Considering the limitation of the current literature, probably, systematic reviews may face great difficulties and may be possible only for restricted areas, providing limited evidence and with the risk of inconclusive results.

However, on the basis of the present data, water-based rehabilitation should be able to benefit healthy old subjects and patients from different points of view. The used outcome measures, although not homogeneous, are linked to the improvement of different functions, including balance, which is fundamental to preventing the risks of falls and, indirectly, mortality [62]. Additionally, water treatment can be a valid therapeutic approach for pain and QoL. This is very relevant because improvement in these parameters should support successful aging, with a great positive impact on health and social participation [63]. This issue is central in rehabilitation and the treatment centers should take into consideration the effects and the applicability of water in rehabilitation. Only in one paper was ineffectiveness on balance found, but the number of weeks of treatment was not defined.

Several gaps are visible in the current literature. The effects of water treatment have been largely studied in healthy subjects, but, for many diseases, the number of studies investigating the use of water in the rehabilitation of old people is low. For some of the diseases, a few studies exist and these are not often RCTs. Thermal therapy presents the main limitations. For this topic, the mean number of subjects is low and the outcome measures used in the other papers are scarcely applied (especially balance and specific markers). An important general limitation is the uncommon use of precise and objective evaluation. In two papers, the computed gait analysis approach was used as an outcome measure, while, in one study, data of a computerized joint prosthesis were used [38,50,56]. In the other cases, questionnaires or measurements that are not precise or reproducible were used.

Considering these data, future research should implement studies about thermal therapy, defining studies with control groups and objective outcome measures, such as gait analysis or neurophysiological measurements.

By the data science approach, we used in this study, we can directly evaluate the relationships among the variables and we have a general overview of the dataset, which can allow us to speculate about the literature. First, the distribution of the journal category shows a clear dominance with regard to the elderly population, but the department directly connected to the same discipline is underrepresented. This could be explained by the high frequency of geriatric patients in the rehabilitation department. Interestingly, in contrast to most of the research, the United States of America is not the most productive country and it is overtaken by Australia and European countries [11]. Many reasons may contribute to this, but this probably indicates a different cultural approach to water in rehabilitation. This may be related to the absence of papers about balneotherapy in the United States of America.

The listed information only represents a small section of the numerous data we can obtain through data science in scientific literature. Furthermore, our approach has some limitations. First, the researcher conducts the synthesis of the information. This may lead to potential bias in categorization. In addition, the papers are selected and analyzed using the abstracts. This is not the main issue. In fact, the approach is focused on the abstracts and they are always available for each scientist. The problem linked to the abstracts is due to the potential lack of clarity. In some cases, the lexicon may not be proper or complete and this may result in a misunderstanding or mistakes in the analysis. For this reason, in our study, we included the evaluation of the most used words in order to investigate how the lexicon of the abstract was correctly related to the topic of the paper. Finally, the approach

does not calculate the real weight or level of a paper, but it may facilitate the visualization and the discovery of tendencies and relationships.

5. Conclusions

Water-based rehabilitation seems to be efficient for the elderly population. It may be applied to improve physical function. In musculoskeletal diseases, it has shown effectiveness in the amelioration of pain and QoL. Additionally, more safe exercises may be recommended. However, the number of specific studies about this topic in the elderly population needs to increase. The use of objective quantitative measurements, besides the specific questionnaires and the clinical parameters, is desirable and it should overcome some of the current gaps in the literature. Concerning our proposed method, we underline that a scoping review analyzes a large number of data, but, sometimes, the relationships between these data are not clear. For these reasons, our method, based on data science, helps with the visualization of the numerous data in a scoping review. The method may help with the dissemination of information and the interpretation of the existing research and to indicate its future developments.

In conclusion, the current data about geriatric rehabilitation in water are promising, but are partially limited. Many common diseases of old people have to be extensively studied in order to make use of the different available outcome measures. The methodology behind data science may be useful for the analysis of the constantly evolving scientific publications and future developments and applications will be able to better define their role in literature revisions.

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