

Review

Rehabilitation of Shoulder Disorders: An ICF-Oriented Lexical Network Analysis of the Literature

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Featured Application

We present a method that analyzes the literature from a lexical perspective. The method can represent a support to map different domains across the literature.

Abstract

(1) Background: The continuous growth of rehabilitation literature makes evidence synthesis increasingly challenging. Lexical network analysis may provide quantitative information on the organization of scientific knowledge. This study aimed to characterize the shoulder rehabilitation literature through an International Classification of Functioning, Disability and Health (ICF)-oriented lexical network approach. (2) Methods: PubMed was searched for papers on shoulder rehabilitation published from 2016 to 2025. ICF-related lexical terms associated with the shoulder were selected from the official ICF framework, and their frequency inside the titles and abstracts of the found papers was calculated. A binary text-term matrix was generated and converted into a bipartite network. Graph-theoretical analysis, including feature reduction, was performed to identify representative topological descriptors and relationships. (3) Results: The analysis identified 6424 paper-word connections. SHOULDER, PAIN, and FUNCTION represented the principal lexical hubs of the network. Feature reduction enabled the characterization of the network by eigencentrality and neighborhood connectivity. Participation- and environment-related terms showed comparatively limited representation. PARTICIPATION showed the highest neighborhood connectivity. (4) Conclusions: The proposed ICF-oriented lexical network approach provides a quantitative framework for exploring the lexical organization of rehabilitation literature, providing complementary information to conventional literature reviews and supporting future evidence synthesis and research planning.

Keywords: rehabilitation; shoulder; lexical analysis; graph theory; ICF



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1. Introduction

The continuous growth of the scientific literature has made the synthesis of available evidence increasingly challenging [1]. Conventional narrative and systematic reviews summarize clinical findings but often provide limited information regarding the conceptual organization of research and the relationships among the investigated domains [2,3]. For researchers and clinicians, this issue is particularly relevant because continuous literature appraisal represents the foundation of evidence-based medicine and is essential for optimizing patient management [4]. Rehabilitation represents a particularly suitable field for this context because patient management simultaneously involves anatomical structures, physiological functions, activities, participation, environmental factors, and personal factors [5–9]. Consequently, this multidimensional complexity makes the synthesis of scientific evidence particularly challenging, as it requires the integration of a large amount of heterogeneous information [10,11]. Therefore, quantitative approaches capable of exploring not only the amount of available evidence but also its lexical organization may provide complementary insights to conventional literature reviews [12]. A paradigmatic example of this multidimensional rehabilitation complexity is provided by shoulder disorders, in which complex anatomy and biomechanics are associated with diseases that significantly affect daily functioning [13–17]. Consequently, for rehabilitation, comprehensive information derived from the evidence is needed in order to support the diagnostic formulation and the management of the most appropriate therapy [18]. The challenge is not only the growing volume of available evidence but also the integration of the multiple dimensions characterizing rehabilitation practice and research. Among the available conceptual frameworks, the International Classification of Functioning, Disability and Health (ICF) represents the reference model for describing functioning and disability in rehabilitation. Used together with the International Classification of Diseases, it complements disease diagnosis by focusing on body functions and structures, activities, participation, and contextual factors, thereby supporting a more comprehensive description of patients' functioning [19]. Because the ICF is based on standardized terminology, it provides a suitable framework for computational exploration of rehabilitation literature. Accordingly, lexical analysis may represent a useful approach for quantitatively investigating how ICF-related concepts are represented and interconnected within the scientific literature [20]. Furthermore, this analysis makes it possible to investigate not only the frequency of ICF-related concepts but also their lexical relationships and, potentially, topological organization within the scientific literature. Therefore, this approach enables the characterization of the lexical organization of ICF-related concepts within rehabilitation literature and this may provide useful information for literature review purposes. Specifically, investigating this kind of organization of rehabilitation literature may help to better understand how the papers are distributed across the different ICF domains. For this aim, network-based lexical approaches may provide additional information regarding the relationships among functional concepts, rehabilitation domains, and research trends. Despite these potentialities, quantitative methods specifically designed to characterize the topological organization of ICF-related concepts within rehabilitation literature remain limited [20]. Using shoulder rehabilitation as a representative model of rehabilitation complexity, the present study proposes an ICF-oriented network approach to quantitatively characterize the lexical organization of the scientific literature. Specifically, we investigated which ICF domains are predominantly represented within shoulder rehabilitation literature and how these domains are topologically organized within a lexical network.

2. Materials and Methods

2.1. Literature Search

The literature search was performed on 11 August 2026. To build the corpus for lexical network analysis, we searched PubMed for papers related to the rehabilitation of shoulder diseases, using the following string: “shoulder disorder AND rehabilitation”. Only the PubMed database was selected because it represents the principal biomedical database and provides standardized indexing suitable for reproducible lexical analysis. Publication types were restricted to clinical trials, guidelines, reviews, systematic reviews and meta-analyses to focus on the clinically relevant literature while maintaining methodological homogeneity of the analyzed corpus. Publications from 1 January 2016 to 31 December 2025 were included. No additional restrictions were applied to maximize literature coverage. Shoulder disorders were intentionally considered as a broad rehabilitation category rather than a single diagnostic entity, to investigate the lexical organization of rehabilitation literature across heterogeneous clinical conditions. In order to assess the literature trend and have comparable results among the years, we calculated the relative frequency of papers published each year, dividing the total number of works found per year by the total number of manuscripts belonging to the same publication types published on PubMed during the corresponding year. The results of the search were then exported to a text file as a list of articles, including titles, author information, editorial information, and abstracts [21].

2.2. Lexical Dictionary Construction and Processing

The retrieved corpus was then screened for the occurrence of ICF-related lexical terms associated with shoulder rehabilitation. The terms were selected from the official ICF document to create a standardized lexical dictionary [22]. Terms were identified by systematically searching the ICF document for the keyword “shoulder” and extracting the corresponding terminology from the related sections of the document, including definitions, classification items, inclusion examples and index entries. Titles and abstracts of all retrieved publications were exported to Microsoft Excel (Microsoft Corp., Redmond, WA, USA), where lexical screening was performed using the predefined ICF-derived dictionary. Searches were conducted in a case-insensitive manner. Exact lexical terms were searched as character strings, allowing retrieval of singular and plural forms when the search term was contained within the corresponding word (e.g., JOINT and JOINTS). Lexical truncation was applied only when necessary to capture additional grammatical variants sharing the same lexical root (e.g., ACTIVIT), without specifying the characters following the truncated root. No automatic stemming or other natural language processing procedures were applied. For results presentation the truncated terms were indicated with asterisk (e.g., ACTIVIT*).

2.3. Lexical Network Generation

The standardized lexical dictionary was subsequently assessed using the LEXical Network analyzed by the Graph THEory (LENGTH) method [23]. Titles and abstracts were first organized into a binary text-by-term matrix. Each row represented a single line of text belonging to a publication, whereas columns represented the ICF-derived lexical terms. The first column contained the publication identifier, repeated for all text rows belonging to the same paper. Each lexical term was coded as present (1) or absent (0) within each text row. This procedure preserved repeated occurrences of the same lexical term within individual publications while maintaining a binary representation of lexical presence. The resulting matrix was imported into Gephi 0.11.2 (Université de technologie de Compiègne, Compiègne, France) to generate a bipartite network composed of two node classes: scientific papers and lexical terms. During network construction, rows sharing the same publication identifier were automatically associated with the corresponding paper

node, whereas repeated lexical occurrences generated parallel paper-term edges. Parallel edges were intentionally preserved rather than merged, allowing node degree to reflect the frequency of lexical occurrences within the analyzed literature while maintaining unitary edge weights [23].

2.4. Graph-Theoretical Analysis

The network was analyzed as an undirected bipartite graph and visualized using the ForceAtlas2 layout algorithm. Community detection was performed using the default modularity algorithm implemented in Gephi [24]. This software was used to calculate degree, closeness centrality, harmonic closeness centrality, betweenness centrality, eigenvector centrality, authority, hub score, PageRank, and modularity class. Additional graph-theoretical parameters not implemented in Gephi, including average shortest path length, neighborhood connectivity, partner of multi-edged node pairs, radiality, stress, and topological coefficient, were calculated using Cytoscape 3.10.4 (The Cytoscape Consortium, Seattle, WA, USA). Unless otherwise specified, all graph-theoretical parameters were calculated using the default settings of the corresponding software packages, and raw metric values were retained for all subsequent analyses.

2.5. Feature Reduction

Because graph-theoretical parameters frequently quantify overlapping topological properties, a feature-reduction procedure was performed to identify a subset of representative metrics while minimizing redundancy. Feature reduction was based on hierarchical clustering, variance inflation factor (VIF) analysis, and Principal Component Analysis (PCA), performed using JASP 0.19.7 (University of Amsterdam, Amsterdam, The Netherlands).

Because the objective of the clustering analysis was to identify groups of graph-theoretical parameters rather than lexical nodes, the lexical node $\times$ graph-theoretical parameter matrix was transposed prior to clustering. Consequently, graph-theoretical parameters were standardized and treated as clustering objects, whereas lexical nodes represented observations. Hierarchical clustering was performed using Euclidean distance and average linkage, and the resulting dendrogram was used to identify groups of highly associated graph-theoretical parameters.

Multicollinearity among graph-theoretical parameters was subsequently assessed using the VIF. To obtain the VIF for each parameter, an iterative series of multiple linear regression models was performed, in which each graph-theoretical parameter was successively treated as the response variable and the remaining parameters as predictors. In the present study, this procedure was used exclusively to quantify multicollinearity among graph-theoretical metrics and not for inferential regression modeling. Given the high degree of redundancy among the graph-theoretical parameters, no predefined VIF threshold was used for variable exclusion. PCA was applied to the raw quantitative graph-theoretical parameters of the lexical nodes, excluding modularity class because it represents a categorical community assignment rather than a continuous quantitative metric.

PCA was based on the correlation matrix, thereby accounting for the different scales of the graph-theoretical parameters. Sampling adequacy was assessed using the Kaiser–Meyer–Olkin measure, and the number of components to retain was evaluated using parallel analysis. In addition, to the retained solution, an exploratory two-component solution with oblique Promax rotation was examined to further characterize the residual structure among graph-theoretical metrics. When multiple parameters showed similarly high representation of the same component or cluster, selection was based on their topological interpretability and their ability to provide complementary information on global and local network organization.

2.6. Additional Analysis

To provide complementary information regarding the practical application of the ICF framework within shoulder rehabilitation research, an additional descriptive analysis was performed. The term “ICF” was searched within the titles and abstracts of all included publications. Subsequently, the outcome measures reported in the abstracts were manually extracted independently by two researchers. Any discrepancies were resolved by consensus, and the frequency of the identified outcome measures was summarized descriptively.

3. Results

3.1. Literature Search

The literature search identified 572 papers, including 221 clinical trials. After normalization according to the total number of PubMed publications belonging to the same publication types in each year, the annual publication frequency showed a reduction during the first 5 years, followed by an increase in the subsequent years (Figure 1).

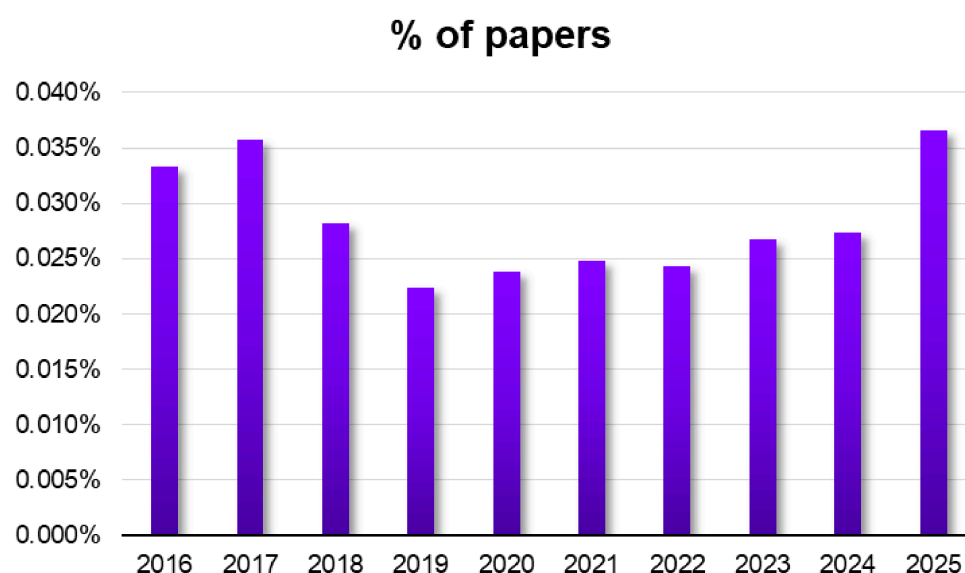


Figure 1. Results of the normalized number of documents present in PubMed considering the publication data filter used. The y-axis indicates the percentage of papers identified each year relative to the total number of manuscripts belonging to the same publication types published on PubMed during the corresponding year.

3.2. Lexical Network and Graph-Theoretical Analysis

A total of 6424 paper-word connections were identified within the bipartite lexical network based on the 24 ICF-derived lexical terms (Supplementary Table S1). SHOULDER and PAIN represented the dominant lexical hubs, showing the highest degree values (Figure 2). Modularity analysis identified eight lexical communities, with a value of 0.309. SHOULDER clustered with FROZEN, LIMITATION, STRUCTURE, and RESTRICTION; PAIN with DISABILIT and FASCIA; STABILITY with BONE, LIGAMENT, DISLOCATION, and SKIN; MOVEMENT with IMPAIRMENT; HEALTH with BODY, PARTICIPATION, and ENVIRONMENT; and MUSCLE with ACTIVIT and MOBILITY. FUNCTION and JOINT each constituted separate lexical communities. The complete community assignment is reported in Supplementary Table S2 and Figure 2.

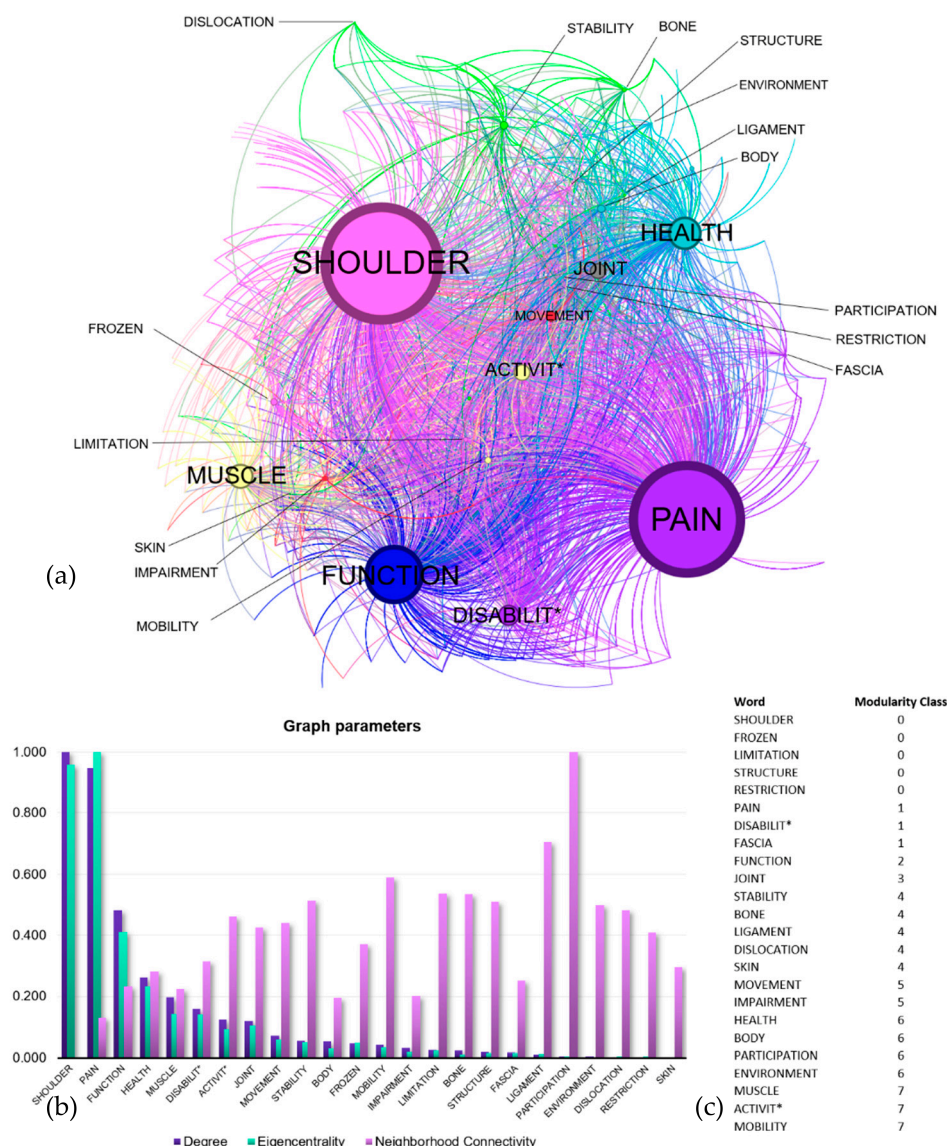


Figure 2. Results of the lexical analysis. Network of connections between papers and words, where the colors represent the modularity class (a); the values of degree (descending order from left to right) and the selected parameters, where the values were normalized from 0 to 1 using min–max normalization (b); the word list with the modularity class (c). Asterisks indicate truncated lexical roots used to include multiple grammatical variants.

3.3. Feature Reduction

Hierarchical clustering and VIF analysis demonstrated substantial redundancy among graph-theoretical metrics, allowing the identification of two major clusters. Average shortest path length, neighborhood connectivity, and topological coefficient were included in the same cluster; the remaining parameters belonged to the second cluster. VIF values showed substantial multicollinearity among several metrics, while neighborhood connectivity showed comparatively lower VIF values than the other metrics, ranging from 2.642 to 20.710 across the iterative regression models. PCA confirmed substantial redundancy among the graph-theoretical metrics. The overall Kaiser–Meyer–Olkin value was 0.674, supporting the adequacy of the data for exploratory component analysis. Parallel analysis supported the retention of a single principal component (eigenvalue = 10.386), which accounted for 86.6% of the total variance. Most graph-theoretical metrics showed high absolute loadings on this component. In the exploratory two-component solution, the major

centrality-related metrics loaded strongly on the first component, whereas neighborhood connectivity and topological coefficient predominantly loaded on the second component. The two components were correlated ($r = -0.632$). These findings were consistent with the pattern identified by hierarchical clustering and VIF analysis. Representative parameters were selected according to the convergence of the statistical analyses and topological interpretability, resulting in the retention of eigencentrality (a measure that combines the quantity and quality of connections by assigning higher scores to nodes connected to influential neighbors) and neighborhood connectivity (a measure of connection that reflects the local topological density surrounding a node) for subsequent analyses. Eigencentrality and neighborhood connectivity showed markedly different patterns for several lexical terms. Eigencentrality analysis identified SHOULDER, PAIN, and FUNCTION as the three most central lexical terms within the literature, whereas terms related to participation, environmental interaction, and social context generally occupied more peripheral positions within the network. In contrast, neighborhood connectivity highlighted a different topological organization, with PARTICIPATION showing the highest value.

3.4. ICF Representation and Outcome Measures

Only five papers explicitly mentioned the ICF framework. These included two scoping reviews concerning rheumatoid arthritis and subacromial pain syndrome, two systematic reviews involving breast cancer and musculoskeletal disorders, and one review focused on multiple sclerosis [25–29]. Overall, outcome measures were predominantly focused on organ dysfunction, structural alterations, pain, range of motion, and activity-related questionnaires, frequently integrating imaging or neurophysiological assessments. In contrast, measures related to participation, environmental factors, and broader social dimensions were considerably less represented. Notably, the most recent scoping review on rheumatoid arthritis specifically investigated ICF domains and concluded that explicit application of the ICF framework remained limited within the analyzed literature [25].

4. Discussion

The present study applied an ICF-oriented network approach to quantitatively characterize the lexical organization of shoulder rehabilitation literature. The analysis showed that the literature is organized around a limited number of dominant lexical communities, while graph-theoretical feature reduction showed that only a small number of representative parameters is probably sufficient to describe its main topological characteristics. This finding improves the interpretability of lexical networks and may facilitate future computational analyses of rehabilitation literature. Compared with previous applications of the LENGTH approach, which primarily used lexical networks to characterize the distribution and relationships of terms within specific medical literature corpora, the present study extends this methodology by integrating an ICF-derived lexical framework with a systematic feature-reduction procedure [12,23]. This approach allows the representation of different information within the same topological framework while reducing the redundancy generated by multiple graph-theoretical descriptors. Accordingly, the added value provided by the network analysis lies not only in the frequency of individual lexical terms, but also in the characterization of their relative topological positions and local versus global connectivity within the analyzed corpus.

The general search found a biphasic behavior of the literature production and the high presence of secondary works, i.e., works such as reviews, compared to a relatively low number of trials in the same period of time [30]. This information is significant because it shows an important interest in rehabilitation problems, but this may imply a risk of leaving some questions unanswered. Indeed, a poor assessment of some complex problems relating to the

alterations of the shoulder, through specific experimental studies, is possible [31]. Therefore, future studies should try to analyze the long-standing effects of a dysfunction, in terms of participation in daily activities, limitations, environment, with proper outcome measures [32]. The limited lexical representation of such dimensions is reflected by our analysis, which showed a predominance of organ- and symptom-related terminology, like the word SHOULDER, whereas terms representing broader ICF domains, particularly participation and environmental factors, were much less frequent. The term PAIN is actually another term dominating the network, because it probably represents an element of relatively easy identification and direct characterization in terms of quantity [33]. In our analysis, PAIN clustered with DISABILITY and FASCIA, a pattern consistent with the recognized relationship between pain and its functional consequences. However, pain should be better specified and better studied also through specific assessment tools, which can precisely identify its origin to properly define its treatment [34]. Despite the notable impact of pain on daily life activities, our analysis showed relatively limited topological connections between PAIN and terms directly representing participation and environmental factors. This finding suggests that these broader dimensions are less explicitly integrated with pain at the lexical level within titles and abstracts. Importantly, lexical co-occurrence does not establish whether these relationships were actually investigated within the full texts of the included studies. Therefore, this finding should be interpreted as indicating limited lexical integration rather than absence of clinical investigation. At the lexical-network level, an apparent partial separation between organ- and symptom-related terms and terms representing consequences of the disease was observed. Therefore, when taken together with the only five publications explicitly mentioning the ICF, the findings of our research suggest that ICF-related terminology is unevenly represented in the analyzed corpus. The environment itself is poorly visible, despite being an element that, from a rehabilitation point of view, has a very significant value [35]. In fact, environmental factors, given the same disease and dysfunction, have a potential facilitating or limiting effect, depending on their characteristics. These elements, typically analyzed and classified within the ICF, should have a higher representation in the scientific literature to better identify possible outcomes and treatment strategies for individual patients [19]. Consistently, our descriptive analysis of outcome measures showed a predominance of measures addressing body structures and functions, whereas measures explicitly addressing participation and environmental dimensions were less represented. Obviously, the ICF also includes the domain of personal factors, but these cannot be categorized and cannot be classified with numbers, because they are often linked to imponderable individual variables. However, this aspect should also be included in patient assessments, despite the extreme complexities and difficulty of having a homogeneous classification [36]. Nevertheless, global centrality and neighborhood connectivity highlighted complementary aspects of the lexical organization. Whereas SHOULDER and PAIN emerged as dominant global hubs, PARTICIPATION showed the highest neighborhood connectivity despite its relatively low frequency. Furthermore, the term PARTICIPATION clustered with the words BODY, HEALTH, and ENVIRONMENT. This result indicates that low lexical frequency does not necessarily correspond to low local topological connectivity, with PARTICIPATION occupying a locally cohesive position within the network. The identification of eight lexical communities further supports the existence of partially differentiated conceptual subdomains within shoulder rehabilitation research, suggesting that the current literature presents some degree of thematic organization rather than a homogeneous conceptual framework. These elements suggest a potential, although partial, interest of the evaluation toward the ICF framework. However, the broader ICF domains remain relatively underrepresented and only weakly connected with body structures and symptoms. A multi-faceted evaluation, in addition to the correct diagnosis, should be

essential because it would also allow a rehabilitation treatment to be truly personalized [37]. Indeed, the role of rehabilitation is also to intervene, where possible, in the patient's living, working, or leisure environment itself. If we consider that the final objective of rehabilitation, also in research, is the achievement of the optimal quality of life, even in the presence of morpho-functional alterations, then, through the ICF and the identification of the most appropriate medical actions, we may better pursue this goal. To do this, however, it may be necessary to partially change the models of scientific studies. Alongside the diagnosis and treatment of the symptom and, when possible, of structural alterations, it is necessary to evaluate the impact that the alteration and the treatment actually have on the patient's life. We should therefore potentially complete patient evaluation in every study with the assessment of the real environment in which the patient lives. Hence, it may be useful to reduce the weight of the laboratory context and transfer the evaluation to the ecological context or, at least, carry out a laboratory evaluation that can better reflect the function in the real-life environment [38]. The role of rehabilitation research is consequently very complicated and should focus on this type of activity. The ICF can thus become an optimal guide for constructing studies aimed at achieving an adequate evaluation and management of the patient. Possibly, this approach should stimulate the development of new tools able to translate the ICF framework into clinical practice. From an editorial perspective, the use of ICF-oriented reporting frameworks or outcome sets could also facilitate a more explicit representation of participation and contextual domains in rehabilitation research.

Beyond the specific clinical findings, a major methodological contribution of this study lies in the application of the LENGTH approach, and the identification of representative metrics, as a potential complementary tool for evidence synthesis. Standard systematic or scoping reviews are inherently resource-intensive, often requiring months of manual screening to map thematic areas within large literature corpora. In contrast, the proposed graph-theoretical workflow may facilitate quantitative mapping of the lexical architecture of large literature corpora, potentially highlighting underrepresented lexical domains and candidate areas for further investigation. Furthermore, our feature reduction strategy showed a high degree of statistical redundancy among graph metrics. These findings suggest that, within the present network, a reduced set of complementary parameters may retain relevant information on different aspects of its topological organization. From a practical perspective, this approach could support researchers in identifying lexical domains that are relatively underrepresented or topologically isolated, thereby helping to formulate questions for subsequent systematic reviews or targeted primary studies. However, such signals should be regarded as hypothesis-generating and require confirmation through direct examination of the underlying literature. Consequently, this mathematical simplification enhances model interpretability and provides clinical researchers with a reproducible pipeline that could be adapted to map functional domains across other medical and rehabilitation fields. Obviously, the proposed method cannot substitute the usual process of revision, but can support the researchers in literature analysis and help scanning the papers on the basis of their title and abstract. Future developments integrating natural language processing techniques could further refine the semantic characterization of rehabilitation literature.

Study Limitations

Our study has some limitations, and the main one is linked to the analysis of only a part of shoulder disorders. The terms used in our work for the search can leave out a series of studies. Additionally, the use of a single bibliographic database and predefined publication-type filters may have excluded relevant studies and limits the comprehensiveness of the analyzed corpus. However, our review aimed to focus only on some specific

terms, precisely to show the consequences of the scientific literature as it is currently and usually constructed. Another important limitation is certainly the restricted use of titles and abstracts for our analyses. Nevertheless, this approach is the method normally used in the analysis of the literature, at least in the initial phase [39]. In fact, we usually consider the abstracts to identify the works coherent with our research. Finally, another limitation concerns the selection of only terms explicitly present in the official ICF documentation. Consequently, synonyms or conceptually related expressions not included in the predefined dictionary could not be captured. The lexical dictionary was constructed by identifying terms associated with the keyword “shoulder” within the ICF documentation. This approach ensured a standardized and reproducible selection procedure but may have excluded relevant ICF concepts whose definitions do not explicitly contain this term, including concepts related to mobility, upper-limb activities, or other functional domains. Therefore, the resulting dictionary should not be considered an exhaustive representation of all ICF concepts potentially relevant to shoulder rehabilitation. Future studies could extend this approach by incorporating terminology derived from relevant ICF Core Sets. Nevertheless, the use of standardized terminology derived from internationally recognized frameworks may facilitate lexical consistency across studies and improve the comparability and reproducibility of literature analyses. A more homogeneous use of ICF-related terminology could potentially support future lexical and network-based investigations aimed at quantitatively exploring rehabilitation research trends and functional domains [40]. Furthermore, lexical co-occurrence and topological proximity should not be interpreted as evidence of semantic, clinical, or causal relationships between the corresponding concepts. On the other hand, because lexical occurrence was coded at the text-line level, multiple occurrences of the same term within a single line were recorded as a single occurrence. Although repeated occurrences across different lines were preserved through parallel edges, this procedure may therefore have underestimated the absolute frequency of some terms. Finally, the approach did not account for contextual meaning or semantic relationships beyond lexical co-occurrence.

5. Conclusions

In conclusion, the presented method, based on a lexical network analysis and on the ICF framework, showed the possibility of quantitatively synthesizing the scientific literature through a topological characterization of standardized lexical items. The proposed workflow reveals a word-based organization of the literature and may facilitate the identification of underrepresented lexical domains and emerging thematic areas. In the case study of shoulder rehabilitation, the literature was predominantly centered on organ alterations and related symptoms. On the other hand, terms indicating participation and environmental domains, which may be highly relevant for assessing the impact of shoulder disorders on daily life, showed a relatively limited representation within the network. Although this result was expected, the main added value of the proposed approach lies in its ability to identify topological behaviors of lexical concepts that are not immediately evident through conventional literature reviews. These quantitative descriptors may support literature interpretation and contribute to the development of more objective approaches to evidence synthesis. In practical terms, lexical domains identified as underrepresented or topologically peripheral may provide candidate areas for subsequent focused literature appraisal rather than being interpreted directly as evidence gaps. Future studies should evaluate the reproducibility of this approach in independent literature corpora and compare network-derived signals with findings obtained through conventional systematic or scoping reviews.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/app16168321/s1>, Table S1: The selected terms and their relationship with the ICF domains. Asterisks indicate truncated lexical roots used to include multiple grammatical variants; Table S2: Raw and normalized values of the selected graph-theoretical parameters for the lexical nodes. Normalized values were obtained using min–max normalization. Asterisks indicate truncated lexical roots used to include multiple grammatical variants.

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Abbreviations

The following abbreviations are used in this manuscript:

ICF	International Classification of Functioning
LENGTH	LExical Network analyzed by the Graph THEory
PCA	Principal Component Analysis
VIF	Variance Inflation Factor

References

1. Drozd, J.A.; Ladomery, M.R. The Peer Review Process: Past, Present, and Future. *Br. J. Biomed. Sci.* **2024**, *81*, 12054. [\[CrossRef\]](#) [\[PubMed\]](#)
2. Siddaway, A.P.; Wood, A.M.; Hedges, L.V. How to Do a Systematic Review: A Best Practice Guide for Conducting and Reporting Narrative Reviews, Meta-Analyses, and Meta-Syntheses. *Annu. Rev. Psychol.* **2019**, *70*, 747–770. [\[CrossRef\]](#) [\[PubMed\]](#)
3. Yu, T.; Enkh-Amgalan, N.; Zorigt, G. Methods to perform systematic reviews of patient preferences: A literature survey. *BMC Med. Res. Methodol.* **2017**, *17*, 166. [\[CrossRef\]](#) [\[PubMed\]](#)
4. Freddi, G.; Romàn-Pumar, J.L. Evidence-based medicine: What it can and cannot do. *Ann. Ist. Super. Sanita* **2011**, *47*, 22–25. [\[CrossRef\]](#) [\[PubMed\]](#)
5. Alcantara, M.A.; De Souza, R.A.; De Oliveira, F.A.; Pinhal, K.C. Using the ICF framework to evaluate the effects of environmental factors on physical disability among people with diabetes mellitus. *Physiother. Theory Pract.* **2020**, *36*, 424–431. [\[CrossRef\]](#) [\[PubMed\]](#)
6. Serban, A.; Grosu-Bularda, A.; Bordeanu-Diaconescu, E.M.; Tache, G.O.; Stoica, M. Early Rehabilitation Versus Conventional Approaches in Post-Traumatic Hand Injuries with Multiple Lesions: Clinical Outcomes and Future Directions. *Medicina* **2025**, *61*, 2063. [\[CrossRef\]](#) [\[PubMed\]](#)
7. Anghel, M.; Marina, V.; Moscu, C.A.; Anghel, A.D.; Dragomir, L. Psycho-Somatic Evolution of Patients with Multiple Traumatic Injuries. *Clin. Pract.* **2024**, *14*, 2419–2432. [\[CrossRef\]](#) [\[PubMed\]](#)
8. Thammachai, A.; Amput, P.; Wongphon, S. Factors Influencing Physical Performance and Quality of Life in Post-COVID-19 Patients. *Diseases* **2025**, *13*, 120. [\[CrossRef\]](#) [\[PubMed\]](#)
9. Gibbs, D.; Mallory, N.; Hoge, C.; Jones, G.; Bishop, J.; Cvetanovich, G.; Rauck, R. Psychological Factors That Affect Return to Sport After Surgical Intervention for Shoulder Instability: A Systematic Review. *Orthop. J. Sports Med.* **2023**, *11*, 23259671231207649. [\[CrossRef\]](#) [\[PubMed\]](#)
10. Swanson, D.R. Medical literature as a potential source of new knowledge. *Bull. Med. Libr. Assoc.* **1990**, *78*, 29–37. [\[PubMed\]](#)
11. Peters, M.D.; Godfrey, C.M.; Khalil, H.; McInerney, P.; Parker, D.; Soares, C.B. Guidance for conducting systematic scoping reviews. *Int. J. Evid. Based Healthc.* **2015**, *13*, 141–146. [\[CrossRef\]](#) [\[PubMed\]](#)

12. Coraci, D.; Giovannini, S.; Loreti, C.; Fusco, A.; Padua, L. Management of neuropathic pain: A graph theory-based presentation of literature review. *Breast J.* **2020**, *26*, 581–582. [CrossRef] [PubMed]
13. Trammell, A.P.; Hao, K.A.; Hones, K.M.; Wright, J.O.; Wright, T.W.; Vasilopoulos, T.; Schoch, B.S.; King, J.J. Clinical outcomes of anatomical versus reverse total shoulder arthroplasty in patients with primary osteoarthritis, an intact rotator cuff, and limited forward elevation. *Bone Jt. J.* **2023**, *105*, 1303–1313. [CrossRef] [PubMed]
14. Jahid, M.; Khan, K.U.; Rehan-Ul-Haq; Ahmed, R.S. Overview of Rheumatoid Arthritis and Scientific Understanding of the Disease. *Mediterr. J. Rheumatol.* **2023**, *34*, 284–291. [CrossRef] [PubMed]
15. Lv, X.; Hu, Z.; Liang, F.; Liu, S.; Gong, H.; Du, J.; Deng, X.; Qian, J.H.; Nie, Q.; Luo, J. Causal relationship between ischemic stroke and its subtypes and frozen shoulder: A two-sample Mendelian randomization analysis. *Front. Neurol.* **2023**, *14*, 1178051. [CrossRef] [PubMed]
16. Coraci, D.; Giovannini, S.; Piccinini, G.; Loreti, C.; Santilli, V.; Padua, L. Suprascapular Nerve and Volleyball: A Potentially Dangerous “Sport Match”. *J. Sport. Rehabil.* **2018**, *27*, 109–110. [CrossRef] [PubMed]
17. Anderson, S.; Peters, A.L.; Lumsden, G.; Alhasso, A.; Cartwright, D.; O’Brien, O.; Marashi, H. Clinical Experience of Axillary Radiotherapy for Node-positive Breast Cancer. *Clin. Oncol.* **2024**, *36*, 98–106. [CrossRef] [PubMed]
18. Agger, N.; Desmeules, F.; Christiansen, D.H. Predicting outcomes across treatment settings in patients with shoulder pain referred to physiotherapy: A secondary analysis of two comparable prospective cohort studies. *BMJ Open Sport. Exerc. Med.* **2023**, *9*, e001770. [CrossRef] [PubMed]
19. Stier-Jarmer, M.; Cieza, A.; Borchers, M.; Stucki, G.; World Health Organization. How to apply the ICF and ICF core sets for low back pain. *Clin. J. Pain* **2009**, *25*, 29–38. [CrossRef] [PubMed]
20. Coraci, D.; Romano, M.; Ragazzo, L.; Restivo, D.A.; Cipriani, M.; Gottardello, F.; Pizzolato, M.; Maccarone, M.C.; Masiero, S. Rehabilitation of Peripheral Neuropathies: From Lexical Analysis of the Literature to Identification of Clinical Protocols. *J. Clin. Med.* **2023**, *12*, 5879. [CrossRef] [PubMed]
21. Zhang, Y.; Chen, M.; Liu, C.; He, B.; Dang, H.; Li, J.; Chen, H.; Liang, Z. Global trends and research hotspots of stroke and magnetic resonance imaging: A bibliometric analysis. *Medicine* **2023**, *102*, e36545. [CrossRef] [PubMed]
22. World Health Organization. *International Classification of Functioning, Disability and Health: ICF*; World Health Organization: Geneva, Switzerland, 2001. Available online: <https://iris.who.int/handle/10665/42407> (accessed on 21 May 2026).
23. Coraci, D.; Loreti, C.; Fusco, A.; Giovannini, S.; Padua, L. Peripheral Neuropathies Seen by Ultrasound: A Literature Analysis through Lexical Evaluation, Geographical Assessment and Graph Theory. *Brain Sci.* **2021**, *11*, 113. [CrossRef] [PubMed]
24. Ahmed, F.; Schumacher, J.; Ahmad, G.; Brand, T. Understanding community resistance to sexuality education and exploring prospective implementation strategies in Pakistan: A content and network analysis of qualitative data. *Front. Psychol.* **2022**, *13*, 864465. [CrossRef] [PubMed]
25. Martinez-De la Torre, A.; Leshetkina, P.; Ahanor, O.; Maritz, R. Integrating and standardizing functioning outcomes in rheumatoid arthritis pharmacological trials: A scoping review informed by the International Classification of Functioning, Disability and Health (ICF). *J. Clin. Epidemiol.* **2026**, *190*, 112093. [CrossRef] [PubMed]
26. Montpetit-Tourangeau, K.; McGlashan, B.; Dyer, J.O.; Rochette, A. Patient education for the management of subacromial pain syndrome: A scoping review. *Patient Educ. Couns.* **2025**, *130*, 108453. [CrossRef] [PubMed]
27. De Groef, A.; Van der Gucht, E.; Dams, L.; Evenepoel, M.; Teppers, L.; Toppet-Hoegars, J.; De Baets, L. The association between upper limb function and variables at the different domains of the international classification of functioning, disability and health in women after breast cancer surgery: A systematic review. *Disabil. Rehabil.* **2022**, *44*, 1176–1189. [CrossRef] [PubMed]
28. Kahraman, T. Performance Measures for Upper Extremity Functions in Persons with Multiple Sclerosis. *Noro Psikiyatr. Ars.* **2018**, *55*, S41–S45. [CrossRef] [PubMed]
29. Verbrugghe, J.; Knippenberg, E.; Palmaers, S.; Matheve, T.; Smeets, W.; Feys, P.; Spooren, A.; Timmermans, A. Motion detection supported exercise therapy in musculoskeletal disorders: A systematic review. *Eur. J. Phys. Rehabil. Med.* **2018**, *54*, 591–604. [CrossRef] [PubMed]
30. Martinez-Garcia, A.; Horrach-Rosselló, P.; Mulet-Forteza, C. Evolution and current state of research into E-learning. *Heliyon* **2023**, *9*, e21016. [CrossRef] [PubMed]
31. Hu, W.; Wu, W.N.; Qiao, Q. Occupational survey-based evidence of health status and welfare problems of workers with pneumoconiosis in China. *Front. Public Health* **2023**, *11*, 1142161. [CrossRef] [PubMed]
32. Ott, N.A.; Barber, C.L.; Jordan, S.E. Trends in Patient-Reported Outcomes Measurement Information System (PROMIS) Utilization in Orthopedic Sports Medicine: A Scoping Review. *Ochsner J.* **2023**, *23*, 304–314. [CrossRef] [PubMed]
33. Expert Panel on Musculoskeletal Imaging; Nacey, N.; Fox, M.G.; Blankenbaker, D.G.; Chen, D.; Frick, M.A.; Jawetz, S.T.; Mathiasen, R.E.; Raizman, N.M.; Rajkotia, K.H.; et al. ACR Appropriateness Criteria® Chronic Shoulder Pain: 2022 Update. *J. Am. Coll. Radiol.* **2023**, *20*, S49–S69. [CrossRef] [PubMed]
34. Lo, C.N.; Leung, B.P.L.; Sanders, G.; Li, M.W.M.; Ngai, S.P.C. The major pain source of rotator cuff-related shoulder pain: A narrative review on current evidence. *Musculoskelet. Care* **2023**, *21*, 285–293. [CrossRef] [PubMed]

35. Assefa, Y.A.; Demeke, Z.D.; Wolde, S.; Guadie, Y.G. Environmental determinants for participation among stroke survivors in Africa, a scoping review. *Front. Rehabil. Sci.* **2023**, *4*, 1136742. [[CrossRef](#)] [[PubMed](#)]
36. Varahra, A.; MacDermid, J.C.; Szekeres, M. A systematic review of biopsychosocial prognostic factors of recovery after a proximal humerus fracture. *J. Hand Ther.* **2023**, *36*, 825–844. [[CrossRef](#)] [[PubMed](#)]
37. Peters, S.E.; Jha, B.; Ross, M. Rehabilitation following surgery for flexor tendon injuries of the hand. *Cochrane Database Syst. Rev.* **2021**, *1*, CD012479. [[CrossRef](#)] [[PubMed](#)]
38. Rose, M.J.; Costello, K.E.; Eigenbrot, S.; Torabian, K.; Kumar, D. Inertial Measurement Units and Application for Remote Health Care in Hip and Knee Osteoarthritis: Narrative Review. *JMIR Rehabil. Assist. Technol.* **2022**, *9*, e33521. [[CrossRef](#)] [[PubMed](#)]
39. Paré, G.; Kitsiou, S. Methods for Literature Reviews. In *Handbook of eHealth Evaluation: An Evidence-Based Approach*; Lau, F., Kuziemy, C., Eds.; University of Victoria: Victoria, BC, Canada, 2017; Chapter 9. Available online: <https://www.ncbi.nlm.nih.gov/books/NBK481583> (accessed on 22 May 2026).
40. Guo, Y.; Li, R.; Li, C.; Li, L.; Jiang, T.; Zhou, D. Hotspots and Trends of Meningiomas Research based on Bibliometrics from 2011–2021. *World Neurosurg.* **2023**, *183*, e328–e338. [[CrossRef](#)] [[PubMed](#)]

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