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Open access protocol and classification of scientific literature on spirometry

Protocolo de acceso abierto y clasificación de la literatura científica sobre espirometría

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ABSTRACT. Health personnel who perform lung function tests must be well informed about specialized literature to use the equipment, interpret the results, and establish a diagnosis for monitoring lung diseases. Spirometry is the most widely used lung function test, which is why it is essencial to train technical and health personnel for its correct performance. The objective of this research is to create a protocol to organize and classify the technical and research literature on spirometry, allowing fast and efficient processing for both humans and machines. To achieve our objective, semantic annotations were made in 96 specialized documents on spirometry, with 99 tags categorized into seven key variables analyzed: type of document, access, topic, tests associated with spirometry, stage involved in performing spirometry, functional patterns and diseases studied through. These annotations are available online, are open access, semantic and interoperable, and can be processed by both humans and computers on a user-friendly platform (https://web.hypothes.is/). Due to the characteristics of the annotations, physicians and technicians who perform spirometry can interact with them and other users, thus promoting the analysis of key health information in an open and social manner, which can be useful for practice, research and teaching of pulmonology.

Keywords: data, hypothes.is, semantic web, spirometry.

RESUMEN. El personal de salud que realiza pruebas de función respiratoria debe estar informado sobre la literatura especializada para utilizar el equipo, interpretar los resultados y establecer un diagnóstico para el seguimiento de las enfermedades pulmonares. Dentro de estas pruebas, la espirometría es la que tiene una mayor difusión, por lo que es indispensable la capacitación del personal de salud para su correcta realización. El objetivo de esta investigación es crear un protocolo para organizar la literatura técnica y de investigación sobre espirometría, permitiendo un procesamiento rápido y eficiente, tanto para humanos como para máquinas. Se realizaron anotaciones semánticas en 96 documentos especializados sobre espirometría, con 99 etiquetas categorizadas en siete variables clave analizadas: tipo de documento, acceso, tema, pruebas asociadas a la espirometría, etapa implicada en la realización de la espirometría, patrones funcionales y enfermedades estudiadas. Estas anotaciones están disponibles en línea, son de acceso abierto, semánticas e interoperables, y pueden ser procesadas tanto por humanos, como por computadoras en una plataforma amigable (https://web.hypothes.is/). Por las características de las anotaciones, médicos y técnicos que realizan espirometrías pueden interactuar con ellas y otros usuarios, con lo que se fomenta el análisis de información clave en salud de manera abierta y social, lo que es de utilidad para la práctica, investigación y enseñanza de la neumología.

Palabras clave: datos, hypothes.is, web semántica, espirometría.

Abbreviations:

DLCO = Diffusing capacity of the lungs for carbon monoxide
RFT = Respiratory function tests

INTRODUCTION

Respiratory function tests (RFTs) are fundamental in the diagnosis and monitoring of diseases that affect the lungs,

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as they allow us to know the mechanical, ventilatory and gas exchange properties, as well as other markers of inflammation that are related to disease control.

Spirometry is one of the most far-reaching tests, with a history of more than 175 years.[1] This tool has been used to assess the health status and quality of life of individuals over time. Despite advances in technology and tools, automating these tests is impossible.Therefore, the training of technical and health personnel is essential for its correct implementation. Although the technical and interpretation standards are frequently updated and publicly available,[2,3] there are drawbacks in terms of training and updating information among the personnel who perform it, requiring continuous training programs to achieve an impact on the application of the test,[4] so exploring new ways of transmitting knowledge related to this test could be an option to promote the dissemination of spirometry.

Conventionally, the term spirometry is used to designate a type of RFT in which a forced maneuver is performed. Additionally, there is the term slow vital capacity, in both the lungs are completely filled from total lung capacity (TLC), but in the latter the expiration until emptying the lungs is at a slower rate. For the purposes of our study, we designated the term spirometry as a synonym for forced spirometry.

The report of a spirometry must contain the following elements: 1) anthropometric and patient identification data; 2) equation used for interpretation; 3) values obtained in the maneuvers, the best maneuver and its relationship with the prediction equation (with the lower limit of normal [LLN], z-score or percentage of that predicted); 4) graphs of the maneuvers performed; 5) quality of the maneuver; and 6) in case of performing a maneuver after the administration of a bronchodilator medication, the same data mentioned for the post-bronchodilator maneuver.[5]

Digital health research consists of collecting, organizing, annotating and analyzing digital information, mainly data and specialized literature. In this process, computer tools are used to perform specific functions, generate interoperability and automate processes. Among the most common tools are databases designed to structure and retrieve information;[6] bibliographic managers, which facilitate the task of managing references and citations;[7] alerts and feeds, which allow you to face the immediacy and overload of information by receiving news about updates;[8] and text mining tools,[9] big data, network analysis,[10] scientometrics and artificial intelligence, which enhance the analysis of information, both in natural language and in machine language.[11]

In addition, there are tools that work as bookmarks and annotations, allowing you to save the addresses of web pages and make notes in real time on them. In such a way that it is possible to put notes on all types of web pages with text, articles, books, images, videos, audios and data sets that are on the net.

When these annotations incorporate semantic web technology, they are called semantic annotators. The semantic web is a technology promoted by the World Wide Web Consortium (W3C),[12] that allows data of different types to be integrated, through the use of a standardized and interoperable format through links that are applied in the search for information, labeling and the design of knowledge maps.[13] The annotation facilitates the creation, exchange and analysis of the data generated from the contents of the pages, allowing their subsequent analysis, both quantitatively and qualitatively.[14]

Semantic annotation with open web applications such as hypothes.is has been implemented for projects of interest in biosciences such as the e-life journal,[15] *scibot*[16] and *sciscore*.[17] It has also been used in clinical[18] and pathological research,[19] with promising results.

Commonly, these topics of technological innovation are technical and complex, and little is published about them in Spanish. We are interested in disseminating and presenting them through attractive and interesting case studies, taking advantage of technologies accessible to all and open source tools.

The objective of this research is to generate a protocol to manage spirometry information in relation to four dimensions: equipment, procedure, results and disease. Through semantic annotations, we seek to gather and analyze key health information in an open, social, semantic and interoperable way, processable by both humans and computers. This approach will be valuable for research and teaching in our region.

MATERIAL AND METHODS

The literature handling procedure used in this RFT research (technique, interpretation and clinical utility) was divided into three stages. The first stage consisted of the retrieval of relevant literature. The second stage involved the annotation and curation of the scientific-technical literature. Finally, the third stage included the processing, analysis and visualization of the data obtained.

To locate the scientific-technical literature on spirometry, we consulted the official pages of bodies that certify the quality of RFT, such as the European Respiratory Society (ERS) and the American Thoracic Society (ATS). In addition, we are looking for manuals for equipment frequently marketed in Latin America.[20,21]

Key documents were selected as accurate and relevant examples from the bibliography, which served as a guide to identify other similar and related documents, an example is the following document:[2,3] https://hyp.is/go?url=https%2Ferj.ersjournals.com%2Fcontent%2F60%2F1%2F2101499&group=__world

Subsequently, the key terms used to design filters and specific queries that would facilitate the search for literature

Figure 1:

Example of an annotation generated in Hypothes.is for a document on spirometry.

in academic databases were identified. These terms included: «lung function test»[MeSH], «interpretation»[ti], «standard», «technical standard», «manual», «reference values». Five platforms were used to carry out the searches: Google Scholar, Europe PMC, Scielo, Lens and PubMed.

The inclusion criterion was based on the compilation of scientific-technical documents that explicitly address forced spirometry in humans,[22] which may be accompanied by other RFTs.[3] Five exclusion criteria were established for the documents: 1) those dealing with RFTs in animal models;[23] 2) those exploring experimental RFTs that were not standardized or performed in unusual environments;[24] 3) documents focused on mathematical models and equation calculations;[25] 4) documents that lacked variables necessary for analysis (see below); and 5) those documents that did not explicitly address RFTs, but focused only on related topics (such as principles of medical physiology, respiratory diseases, respiratory health, etc.), without addressing technical, theoretical, methodological or analytical aspects of the tests.[26-28]

Annotation and Healing

The second phase involved the exploration and annotation of the literature using Hypothes.is, a public platform and available at the link: https://hypothes.is/search?q=tag%3AAnotacionPFR+TipoDePrueba%2Fmesh%2FD002000%2FForcedSpirometry so that all the annotations of the documents were made in Hypothes.is,[29] a web resource annotator that facilitates the understanding of the information, the discussion and the generation of ideas. It is an open source tool that allows users to place text, underline, comment and add images or videos on the same web page, emulating the idea of «annotate on the edges of the pages of the book», with the advantage that the interactions made by the user can be shared in real time, being able to be analyzed by other users or processed by computers. In addition, the platform offers the option to report any annotation to moderators, who will review the reported annotation and determine if it violates community norms,[29] thus fostering a safe space for the dissemination of knowledge.

The annotation process

Annotation involves generating data associated with items to organize and classify them using labels *(Figure 1)*.

The variables studied covered aspects related to documents and RFT. Regarding the documents, variables such as the type of document, the type of access and the subject were considered. Regarding the RFT associated with spirometry, variables such as the type of test, the stage involved in its performance, the functional patterns and the diseases studied using spirometry were analyzed. The variables on the RFT were made consistent with four dimensions: equipment used to perform the test (spirometer), performance procedure, results displayed in the report and its relationship with the disease. Annotations

Table 1: Seven variables and 99 semantic tags used to analyzethe scientific-technical literature on spirometry on Hypothes.is.

Dimensions	Variables	Annotation
Equipment	Type of test (text)	Typeoftest/mesh/D002000/ForcedSpirometry Typeoftest/mesh/D008451/MaximalVoluntaryVentilation Typeoftest/mesh/D000089142/FractionalExhaledNitricOxideTesting Typeoftest/mesh/D010993/PlethysmographyWholeBody Typeoftest/mesh/D000072277/MaximalRespiratoryPressures Typeoftest/mesh/000070857/WalkTest Typeoftest/mesh/D011653/PulmonaryDiffusingCapacity Typeoftest/mesh/D000403/AirwayResistance Typeoftest/mesh/D001985/BronchialProvocationTests Typeoftest/mesh/D001784/BloodGasAnalysis
	Type of document (label)	spar/fabio/JournalArticle spar/fabio/ResearchPaper spar/fabio/Book spar/fabio/InstructionManual
	Type of access (label)	Open/access Closed/access
	Topic (text)	Topic/mesh/D012137/RespiratorySystem Topic/mesh/D058007/PhysiciansPrimaryCare Topic/mesh/D012890/Sleep Topic/mesh/D010372/Pediatrics Topic/mesh/D013909/Thorax Topic/mesh/D017216/Telemedicine Topic/mesh/D006666/HistoryOfMedicine Topic/mesh/D004389/DurableMedicalEquipment Topic/mesh/D001185/ArtificialIntelligence Topic/mesh/D012016/ReferenceValues Topic/mesh/D000086382/COVID19
Procedure	Test stage (text)	Teststage/Operational* Teststage/Standar* Teststage/Interpretation* Teststage/Clinic*
	Functional test pattern (Text)	FunctionalPattern/Obstruction* FunctionalPattern/PossibleRestriction* FunctionalPattern/MixedPossible* FunctionalPattern/Normal* FunctionalPattern/Bronchodilation* FunctionalPattern/NoBronchodilation* FunctionalPattern/SimpleRestriction* FunctionalPattern/ComplexRestriction* FunctionalPattern/MixedDisorder* FunctionalPattern/NormalVolumes* FunctionalPattern/Hyperinflation* FunctionalPattern/LargeLungs* FunctionalPattern/BloodFlowIncrease* FunctionalPattern/PulmonaryVascularAbnormality* FunctionalPattern/LostLocalizedVolume* FunctionalPattern/AlveolarCapillaryLoss* FunctionalPattern/NormalDiffusion* FunctionalPattern/NormalImpedance* FunctionalPattern/SmallAirwayObstruction* FunctionalPattern/TotalAirwayObstruction* FunctionalPattern/AlterationReactance*

Table 1 continues: Seven variables and 99 semantic tags used to analyzethe scientific-technical literature on spirometry on Hypothes.is.

Dimensions	Variables	Annotation
		FunctionalPattern/LowEosinophilicInflammation* FunctionalPattern/ModerateEosinophilicInflammation* FunctionalPattern/HighEosinophilicIn ammation* FunctionalPattern/NegativePCD* FunctionalPattern/PositivePCD* FunctionalPattern/MaximumNormalInspiration* FunctionalPattern/MaximumAlteredInspiration* FunctionalPattern/MaximumNormalExpiration* FunctionalPattern/MaximumAlteredExpiration* FunctionalPattern/PositiveBronchialChallenge* FunctionalPattern/NegativeBronchialChallenge* FunctionalPattern/Normoxemia* FunctionalPattern/Hypoxemia* FunctionalPattern/RespiratoryAcidosis* FunctionalPattern/MetabolicAcidosis* FunctionalPattern/RespiratoryAlkalosis* FunctionalPattern/MetabolicAlkalosis*
Disease	Disease (text)	Disease/mesh/D001249/Asthma Disease/mesh/D001987/Bronchiectasis Disease/mesh/D001991/Bronchitis Disease/mesh/D000086382/COVID19 Disease/mesh/D002925/PrimaryCiliaryDyskinesia Disease/mesh/D029424/ChronicObstructivePulmonaryDisease Disease/mesh/D017563/InterstitialLungDisease Disease/mesh/D003550/CysticFibrosis Disease/mesh/D001997/BronchopulmonaryDysplasia Disease/mesh/D009468/NeuromuscularDisease Disease/mesh/D017564/RadiationPneumonitis Disease/mesh/D011009/Pneumoconiosis Disease/mesh/D011649/PulmonaryAlveolarProteinosis Disease/mesh/D013121/SpinalCurvatures Disease/mesh/D012600/Scoliosis Disease/mesh/D054990/IdiopathicPulmonaryFibrosis Disease/mesh/D000081029/PulmonaryArterialHypertension Disease/mesh/D006469/Hemoptysis Disease/mesh/D011655/PulmonaryEmbolism Disease/mesh/D012891/SleepApneaSyndrome Disease/mesh/D008175/LungNeoplasm Disease/mesh/D011656/PulmonaryEmphysema Disease/mesh/D011014/Pneumonia Disease/mesh/D014376/Tuberculosis Disease/mesh/D019896/Alfa1AntitripsinDeficiency Disease/mesh/D011015/PneumoniaAspiration Disease/mesh/D015615/CysticAdenomatoidMalformationLung Disease/mesh/D000092122/BronchiolitisObliteransSyndrome Disease/mesh/D012130/RespiratoryHypersensitivity Disease/mesh/D012829/Silicosis

*Originally in Spanish.

were designed using the project tag and the name of the variables. To classify the type of document, the FaBiO ontology was used,[30] while, for variables related to the type of test, the subject and the disease, the MeSH thesaurus was used *(Table 1)*.[31]

Processing, analysis and visualization

The Hypothes.is annotations were extracted in JSON and CSV format using two digital tools designed by Jon Udell: https://jonudell.info/h/tools.html and https://jonudell.

info/h/facet Subsequently, the data were processed programmatically in Bash, the analyses were carried out and the corresponding graphs were made in R. For this purpose, the readr, dplyr, ggplot2, RColorBrewer and Viridis packages were used, which are available for the generation of graphs and the analysis of results.

In addition, a repository was created on GitHub https://github.com/lmichan/PFR with the details of this project and in which updates, data and the code used will be published. For images, we opted to use color palettes such as viridis_d32 to ensure accessibility for people with visual impairment (color blindness), and the rainbow color palette was reserved for cases where multiple variables were present.

RESULTS

96 documents were analyzed, retrieved and annotated, these were labeled with the name of the project «AnnotationRFT» and with the text «TypeOfTest/mesh/D002000/ForcedSpirometry», in relation to the data generated from the seven variables and the 99 labels. These labels were made in a manner consistent with the four dimensions analyzed *(Table 1)*. The complete collection can be consulted openly and under the Creative Commons license at the following link: https://hypothes.is/search?q=tag%3AAnotacionPFR+TipoDePrueba%2Fmesh%2FD002000%2FForcedSpirometry

Of the annotations made, 78 documents (81.25%) were found to offer open access, while 18 documents (18.75%) required a subscription, 84 were research articles, four books, two manuals, two data repositories, two websites, a catalogue and a standard one.

The topics addressed in the papers were 13 in total, this provides insight into the use of spirometry currently and the perspective of how information is generated *(Figure 2)*. Respiratory system (25 articles), quality control (19 articles) and reference values (14 articles) were observed to be the three most frequent topics. The remaining topics such as COVID-19, health education, medical equipment, history of medicine, artificial intelligence, first contact doctors, neuromuscular, pediatrics, telemedicine and chest were distributed among the other ten topics analyzed.

The results of this analysis include 96 articles exclusively related to spirometry, among which nine other RFTs are also mentioned *(Figure 3)*. Where plethysmography, with 26 documents and the diffusing capacity of the lungs for carbon monoxide test (DLCO), with 25 documents, are the most mentioned tests; the bronchial challenge test that sometimes requires a forced spirometry maneuver was

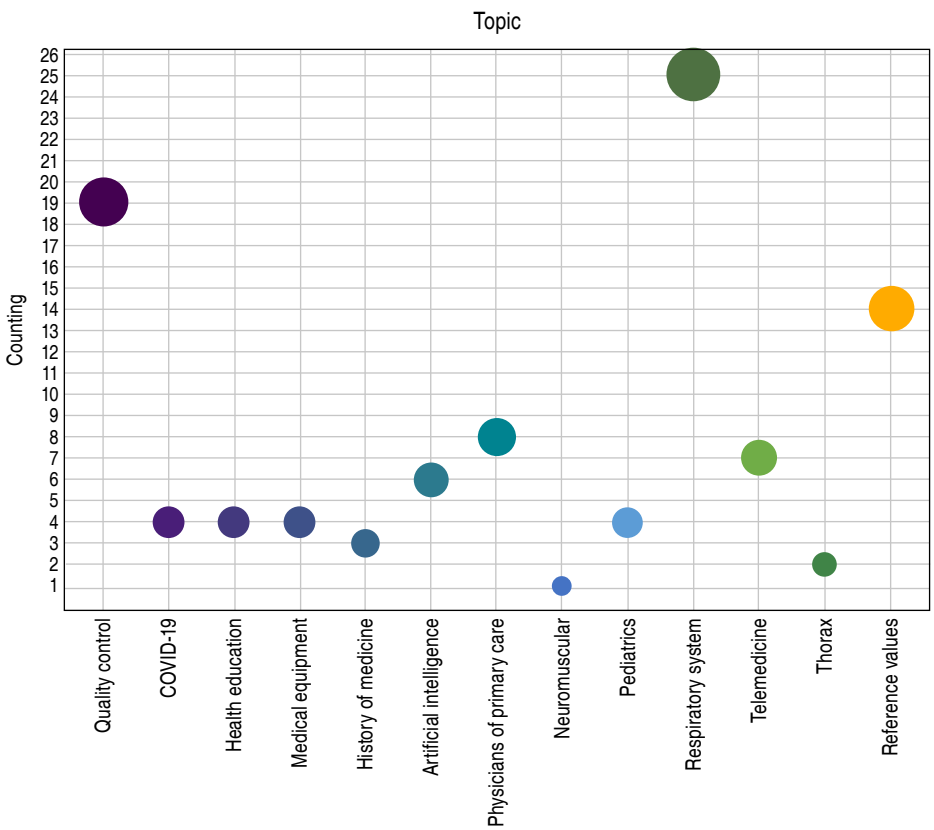

Figure 2:

Topics mentioned in the documents on spirometry.

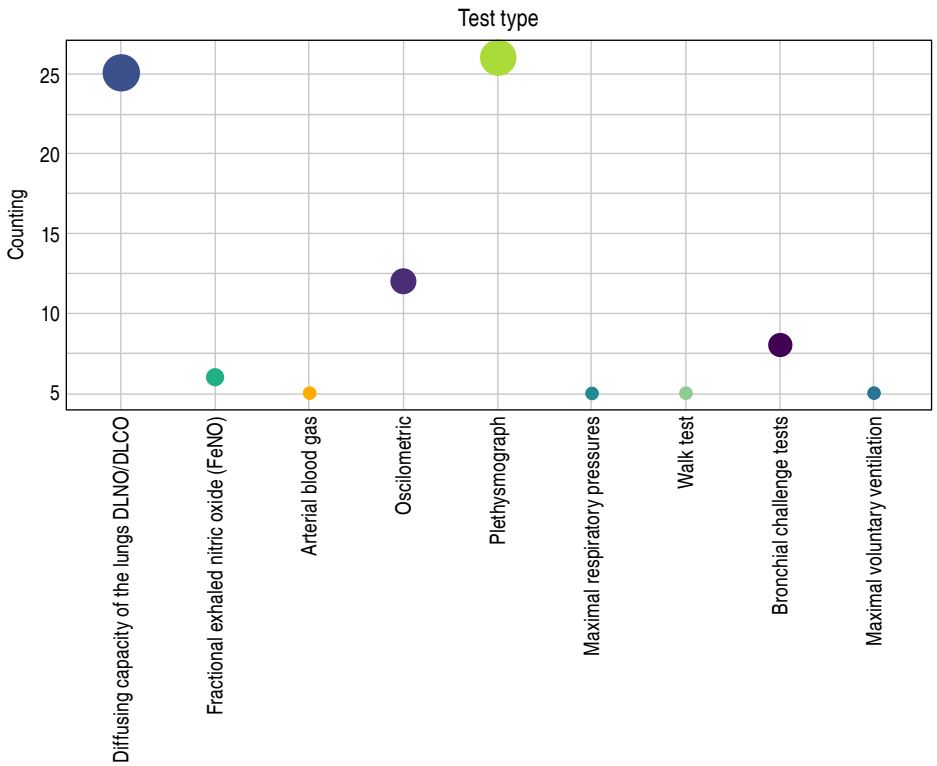

Figure 3:

Types of tests mentioned in spirometry documents.
DLCO = diffusing capacity of the lungs for carbon monoxide.
DLNO = diffusing capacity of the lungs for nitric oxide.

mentioned in eight documents. These results provide an overview of the most common and frequently mentioned respiratory function tests in the articles studied.

The functional patterns of spirometry were identified in 83 of the documents, in addition to other functional patterns of tests related to spirometry, coinciding plethysmography and DLCO patterns *(Figure 4)*.

To study what spirometry involves, we classified the documents according to the stage of the study, of which four were identified: 40 documents referring to interpretation, 19 that mention technical standards for performing the test, 19 in the operational stage that refers to technical and equipment aspects, and 14 in the clinical stage that were directly related to the use of the test in the disease.

The last variable evaluated for the documents was the relationship of spirometry with different diseases in the literature *(Figure 5)*. Asthma was the most common disease, mentioned in 41 papers, followed by chronic obstructive pulmonary disease (COPD), diffuse interstitial lung disease (IDPD), neuromuscular disease, cystic fibrosis, bronchitis, and spinal disorders.

DISCUSSION

In this research we created an annotation protocol to describe and analyze the scientific-technical documents on spirometry, this allowed us to integrate a large amount of information on 96 relevant texts, with 99 categorized labels to extract the information on four types of document, two types of access, 11 research topics, four stages involved in the performance of spirometry, 38 functional patterns and 30 associated diseases. All this data allowed us to know the structure and trends of this information, and from the label used for the project (AnnotationRFT), it is easy to locate it in a simple, accurate and efficient way so that it can be reused; thus avoiding information overload,[33] infodemia[34] and misinformation.[35]

The semantic annotations that are made in Hypothes. is allow you to take advantage of technology to interact with information, being able to extract the published data and process them by means of algorithms to generate new information.

This platform, which can be used in any area of knowledge, has previously been used in the area of health. In 2016, it worked for the registration of different research resources (reagents, materials and tools) used in scientific articles;[36,37] later Goller[38] and collaborators used it for the teaching of Goller metagenomics;[38] and recently Saleipour[39] and his team used it to annotate phenotypic variants and their genetic correlation in a rare disease of wide heterogeneity of presentation, Von Hippel-Lindau disease (VHL) Saleipour.[39]

The process of designing and structuring the annotations was detailed, long and meticulous, we had to carry out several tests to ensure consistency and define the correct protocol. In addition, annotations must be standardized

so that the retrieval of the generated data is relevant, consistent and processed correctly. To fulfill this purpose, we used systems of knowledge organization (SOC), a type of specification that facilitates the modeling of the structure of meaning implicit in an information domain, through the use of classes, labels, definitions, relationships and properties of concepts.[40-42] These tools were extremely useful in our research to annotate and structure data, they facilitated the search, interpretation, exchange and retrieval of digital content, in addition to facilitating the classification of the dimensions, categories and variables extracted from documents, as well as to visualize the scope, structure, hierarchy and semantic relationships of annotations, both manually and through algorithms. All this is summarized in *Table 1* and constitutes, together with the protocol, the most relevant methodological contribution of this article.

At present, access to scientific information and transparency in the knowledge generation process is very important, the accessibility and reproducibility of the results, both of the data and of the methods and results of a research must be openly available so that other researchers can access them, evaluate them and replicate the results.[43] Tools such as Hypothes.is encourage collaboration and the exchange of information between researchers, which promotes a faster and more effective advancement of scientific knowledge, the principles of open science also allow society in general to access information that is relevant and reliable.

As we are interested in practicing and promoting open science, we made sure that the information we generated was available to anyone, without the need to create an account. For this, all the annotations were made in the public group, in such a way that they can be seen by all interested parties and are reusable because they have an open license in the public domain.[44] We invite all specialists interested in spirometry and respiratory function tests to consult, reuse and make annotations to generate a greater set of information and knowledge on this important topic of pulmonology.

Limitations

The most important limitation of the protocol is that the analysis and selection of the documents was carried out only by a doctor with a high specialty in respiratory function; while the organization and processing of the data was in charge of specialists in the management of the information, this could limit the spectrum of the qualification of the articles and create a selection bias. However, we hope that, by making the invitation for cooperation with other specialists, better feedback can be generated from the selected documents, ideas can be shared, other documents

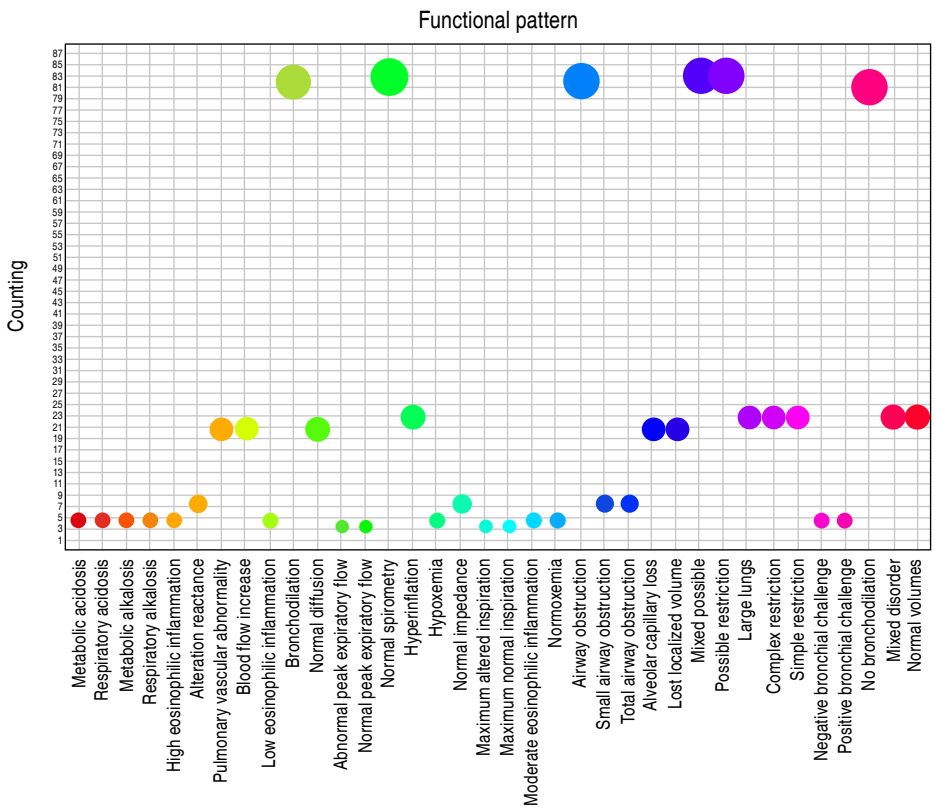

Figure 4:

Functional pattern mentioned in the documents on spirometry.

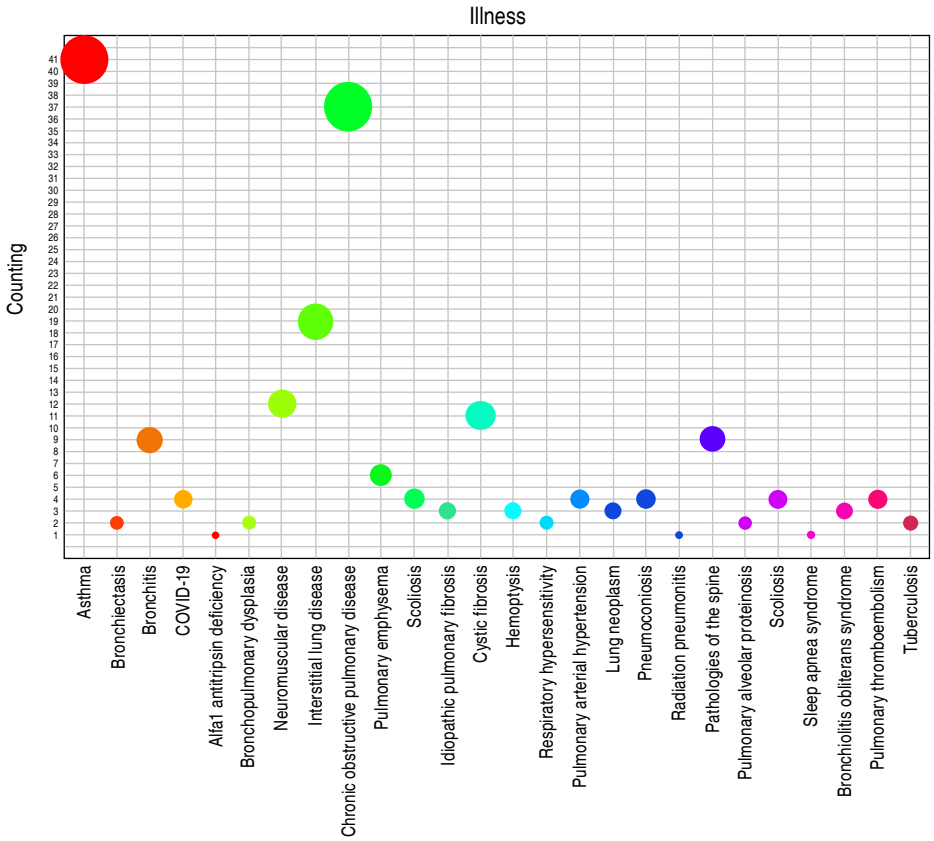

Figure 5:

Types of diseases mentioned in the documents on spirometry.

can be integrated into the compendium achieved to date, with the same approach for the realization, interpretation and teaching of the RFT.

Using the main tag, when in an open access format, anyone who has access to the Hypothes.is website can add information that, such as the translator's footnotes in a book, contribute more to the original text, with the advantage that this information can also be processed by computer systems, in order to promote not only research, but also the dissemination and teaching of this knowledge.

CONCLUSION

Semantic annotationson pages suchas Hypothes.is, allow the classification of documents focused on spirometry, so that other users can use them for educational and dissemination purposes of this respiratory function test.

Conflict of interests: the authors declare no conflict of interests.

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