

Sounding Board

The most cited and co-cited COVID-19 articles: Knowledge base for rehabilitation team members

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Abstract.

BACKGROUND: The COVID-19 outbreak pandemic is a situation without a tested action plan. Rehabilitation team members have been called for duty with new responsibilities in addition to their conventional roles in the healthcare system. The infectious disease specialists are updating the knowledge base in limited time in clinical settings. The number of articles in PubMed grows at an increasing rate.

OBJECTIVE: The purpose of this study is to identify core COVID-19 articles by citation and co-citation network analysis in the PMC subset of PubMed.

METHODS: Citation and co-citation network analysis methods were used to identify core articles and knowledge base.

RESULTS: COVID-19 terms query retrieved 15,387 articles in PubMed. These articles formed a citation network with 6,778 articles and 25,163 PMC-PubMed citations. The main article cluster in the co-citation network consists of 2,811 articles and 78,844 co-citations.

CONCLUSIONS: The number of COVID-19 articles in PubMed is increasing at a very high rate. Citation and co-citation network analysis are advantageous techniques to identify knowledge base in a scientific discipline. These techniques may help rehabilitation specialists to identify core articles efficiently.

Keywords: COVID-19, citation network analysis, co-citation network analysis, knowledge base

1. COVID-19 outbreak as a worldwide pandemic

Human coronaviruses are enveloped RNA viruses that mostly cause mild infections [1, 2]. SARS-CoV and MERS-CoV type human coronaviruses caused epidemics with more than 10,000 cumulative cases in the past two decades (mortality rates of 10% for SARS-CoV and 37% for MERS-CoV) [2]. A series of pneumonia cases were reported with a novel human

coronavirus (2019-nCoV, COVID-19, SARS-CoV-2) in December 2019, in Wuhan (11 million city population), Hubei, China [1, 3]. The common feature of the first cases was the relation of these patients with the Huanan seafood market where live wild animals are sold [4]. When less than a thousand cases were reported in Wuhan, the first cases outside of China were reported in Thailand, Japan, South Korea, and the USA [1, 5–8]. The first confirmed cases in Europe were reported on January 31 in Italy (Rome)

and Spain (La Gomera, Canary Islands). While active cases were decreasing in China, Europe became the center of the outbreak. 10,590 active cases were reported in Italy and 2,039 active cases were reported in Spain on March 11, 2020. On this date WHO declared novel human coronavirus outbreak a global pandemic after 118,000 cases in over 110 countries [9].

2. New duties and new responsibilities of rehabilitation team members in the COVID-19 pandemic outbreak

The COVID-19 outbreak pandemic is a situation without a tested action plan. None of the countries' health care systems had sufficient capacity to deal with it. Field hospitals were built, intensive care units were expanded, new ventilators were purchased, mass production of medical masks and protective clothing were increased in an effort to fight it. All healthcare professionals were called for duty, including retired physicians and nurses in some countries. Rehabilitation team members participated in the re-organized healthcare system with extra duties and responsibilities in addition to their conventional roles for COVID-19.

A simple search result for COVID-19 retrieves more than fifteen thousand articles in PubMed. Not only does the number of articles increase daily, but also the publication rate of articles. Infectious disease specialists are generally well-informed and have the experience to identify core articles. Other healthcare professionals have very limited time to update their knowledge on current publications. Citation network analysis and co-citation network analysis are advanced methods that can help to identify core articles in any scientific field.

3. Document citation and document co-citation networks

In scientometrics, bibliometric and informatics article itself is the object of study. Citations and references of an article are the fundamental quantities of most study methods in these "article sciences".

Every scholarly article is connected to previous articles by a simple citation relation. The reference list of an article represents the "important studies" in the article's study topic. Citation network analysis identifies the "importance" of an article according to

the assumption that highly-cited articles are likely to have a greater influence on the scientific literature [10, 11].

Co-citation is the simultaneous appearance of two related articles in the reference list of a third article. Co-citation network analysis may identify "more important and related articles" according to the assumption that the articles which have a high probability to share a common theme are tend to form clusters around the same co-cited article pairs [12, 13]. Jaccard Similarity Index is a similarity measure that represents the thematic similarity of two co-cited articles in percentages. High co-citation frequency (edge weight) represents the high probability of relatedness and it is directly proportional to the strength of co-citation coupling. Co-citation analysis can be used to map the knowledge base in a scientific discipline.

4. PMC subset of PubMed as a non-commercial medical database

PMC is the open-access full-text collection of the National Library of Medicine (NLM since 2000) [14]. PMC articles may be the unique source of scientific information for medical workers who do not have access to commercial databases. For this reason, bibliometric relations in PMC articles may also represent an important non-commercial clinical reasoning foundation.

The number of journals followed by PubMed is slightly lower than commercial databases and citation results can be less than the reported citations [15].

The highest degree in citation network and highest edge weight in the co-citation network may represent higher importance in COVID-19 literature.

5. Entrez APIs

The National Center for Biotechnology Information (NCBI) databases include Entrez Programming Utilities (E-utilities) for developing special queries on PubMed. E-Link functions can be used to retrieve citation relation of a PMC article in PUBMED (PMC-PubMed Citation). The acquired citation dataset can be enriched with the PubMed summary dataset.

There are a few R statistical programming language packages for PubMed that include e-Link functions [16]. E-Link functions retrieve a list of PMC-PubMed citations in PMID-PMID format. This raw data can be processed in social network analysis

software to develop document citation and co-citation networks.

COVID-19 articles raw data was retrieved on 25 May 2020 (query = “COVID-19” OR “SARS-CoV-2”) by using an R script developed with reutils 0.2.3 package. Network analysis was performed with Gephi 0.9.1 and R igraph 0.7.0 package.

6. COVID-19 citation network analysis

Citation network analysis helps to identify and visualize the most cited COVID-19 articles. The degree of an article is the total number of citations and references that article has. In-degree represents the number of citations, out-degree represents the number of references in the citation network (Table 1). Each circle represents a single article and each edge (connection) represents a citation in the graph (Fig. 1). The diameter of a circle represents the number of citations. There can be more than one independent cluster of articles in a network and each cluster is called a connected component.

COVID-19 terms query retrieved 15,387 articles in PubMed. Almost half of the articles do not have any PMC citations and do not contribute to the citation network. The citation network consists of 6,778 articles and 25,163 PMC-PubMed citations. The largest connected component (article cluster) in citation net-

work consists of 6,650 (98.1%) nodes and 25,095 (99.7%) edges. The average degree is 3.774 (PMC-PubMed citations and references), network diameter is 9, the average path length is 2.27, and the average clustering coefficient is 0.035 in the citation network. 9,398 (61%) of articles has a free full text and 120 (0.7%) of articles are systematic review articles.

The articles by Huang et al., 2020, Zhu et al., 2020, and Chen et al., 2020 are the most PMC-PubMed cited articles in the citation networks. All of them give information about the clinical and epidemiological features of the first cases in China. The articles by Holshue et al., 2020 and Rothe et al., 2020 are in twelve most PMC-PubMed cited articles and they also give information about the first cases in the USA and Germany. The fifty most cited COVID-19 articles are presented in Table 1.

7. COVID-19 co-citation network analysis

The clusters in the COVID-19 co-citation network represent possible thematic relations. Highly co-cited article couples are the source of information (knowledge-base) in the network. Circle diameter represents the number of co-citation relations and the thickness of edges (co-citation coupling frequency) represents how many times an article couple is cited by a third article in the graph (Fig. 1). The main arti-

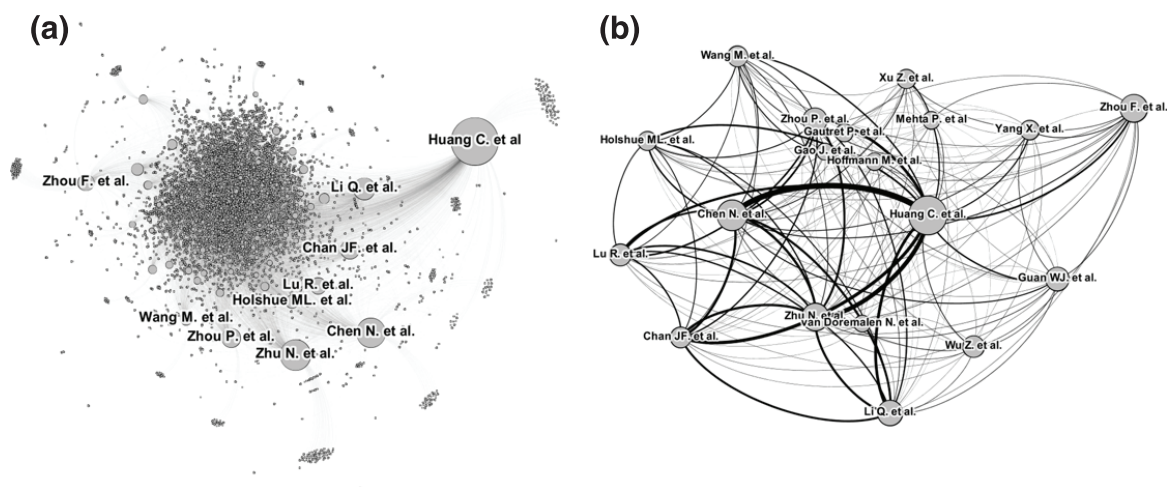


Fig. 1. (a) COVID-19 PMC citation network graph, (b) COVID-19 PMC co-citation network graph. Graphs are in force atlas 2 layout. (a) COVID-19 PMC citation network is a directed network with 6,650 articles (nodes) and 25,095 citations (edges). Each circle represent an article, each arch represents a citation, and diameter of circle represents number of citation in citation network. (b) COVID-19 PMC co-citation network is an undirected network. The main article cluster (connected component) consist of 2,811 nodes and 78,844 edges. Graph is filtered to represent 19 major articles in PMC co-citation network (co-citation degree ≥ 600). Each circle represent an article, each arch represents a co-citation relation, thickness of edges represents co-citation frequencies.

Table 1
Most Cited COVID-19 Articles

ID	Author PMID	Journal (e-Publication Date)	Title	Degree Centrality Measures		
				In-Degree (PMC-PubMed Citations)	Out-Degree (PMC-PubMed References)	Degree (Total)
1	Huang C. et al. (31986264)	Lancet (Jan 2020)	Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China.	1206	0	1206
2	Zhu N. et al. (31978945)	N Engl J Med (Jan 2020)	A Novel Coronavirus from Patients with Pneumonia in China, 2019.	763	0	763
3	Chen N. et al. (32007143)	Lancet (Jan 2020)	Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study.	726	1	727
4	Li Q. et al. (31995857)	N Engl J Med (Jan 2020)	Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus-Infected Pneumonia.	531	3	534
5	Zhou P. et al. (32015507)	Nature (Feb 2020)	A pneumonia outbreak associated with a new coronavirus of probable bat origin.	458	0	458
6	Chan JF. et al. (31986261)	Lancet (Jan 2020)	A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster.	456	0	456
7	Zhou F. et al. (32171076)	Lancet (Mar 2020)	Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study.	384	0	384
8	Lu R. et al. (32007145)	Lancet (Jan 2020)	Genomic characterisation and epidemiology of 2019 novel coronavirus: implications for virus origins and receptor binding.	380	2	382
9	Holshue ML. et al. (32004427)	N Engl J Med (Jan 2020)	First Case of 2019 Novel Coronavirus in the United States.	300	4	304
10	Wang M. et al. (32020029)	Cell Res (Feb 2020)	Remdesivir and chloroquine effectively inhibit the recently emerged novel coronavirus (2019-nCoV) <i>in vitro</i> .	283	1	284
11	Guan WJ. et al. (32109013)	N Engl J Med (Feb 2020)	Clinical Characteristics of Coronavirus Disease 2019 in China.	270	9	279
12	Rothe C. et al. (32003551)	N Engl J Med (Jan 2020)	Transmission of 2019-nCoV Infection from an Asymptomatic Contact in Germany.	221	2	223
13	Wu Z. et al. (32091533)	JAMA (Feb 2020)	Characteristics of and Important Lessons From the Coronavirus Disease 2019 (COVID-19) Outbreak in China: Summary of a Report of 72,314 Cases From the Chinese Center for Disease Control and Prevention.	210	0	210
14	Liang W. et al. (32066541)	Lancet Oncol (Feb 2020)	Cancer patients in SARS-CoV-2 infection: a nationwide analysis in China.	185	2	187
15	Xu Z. et al. (32085846)	Lancet Respir Med (Feb 2020)	Pathological findings of COVID-19 associated with acute respiratory distress syndrome.	180	2	182

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ID	Author PMID	Journal (e-Publication Date)	Title	Degree Centrality Measures		
				In-Degree (PMC-PubMed Citations)	Out-Degree (PMC-PubMed References)	Degree (Total)
16	Epidemiology Working Group for NCIP Epidemic Response, Chinese Center for Disease Control and Prevention (32064853)	Zhonghua Liu Xing Bing Xue Za Zhi (2020)	The epidemiological characteristics of an outbreak of 2019 novel coronavirus diseases (COVID-19) in China.	176	0	176
17	Yang X. et al. (32105632)	Lancet Respir Med (Feb 2020)	Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study.	174	3	177
18	Wu F. et al. (32015508)	Nature (Feb 2020)	A new coronavirus associated with human respiratory disease in China.	174	1	175
19	Wrapp D. et al. (32075877)	Science (Feb 2020)	Cryo-EM structure of the 2019-nCoV spike in the prefusion conformation.	158	10	168
20	Zou L. et al. (32074444)	N Engl J Med (Feb 2020)	SARS-CoV-2 Viral Load in Upper Respiratory Specimens of Infected Patients.	156	1	157
21	van Doremalen N. et al. (32182409)	N Engl J Med (Mar 2020)	Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1.	148	3	151
22	Hoffmann M. et al. (32142651)	Cell (Mar 2020)	SARS-CoV-2 Cell Entry Depends on ACE2 and TMPRSS2 and Is Blocked by a Clinically Proven Protease Inhibitor.	146	3	149
23	Gao J. et al. (32074550)	Biosci Trends (Feb 2020)	Breakthrough: Chloroquine phosphate has shown apparent efficacy in treatment of COVID-19 associated pneumonia in clinical studies.	135	0	135
24	Gautret P. et al. (32205204)	Int J Antimicrob Agents (Mar 2020)	Hydroxychloroquine and azithromycin as a treatment of COVID-19: results of an open-label non-randomized clinical trial.	132	1	133
25	Mehta P. et al. (32192578)	Lancet (Mar 2020)	COVID-19: consider cytokine storm syndromes and immunosuppression.	127	0	127
26	Chen H. et al. (32151335)	Lancet (Feb 2020)	Clinical characteristics and intrauterine vertical transmission potential of COVID-19 infection in nine pregnant women: a retrospective review of medical records.	127	4	131
27	Russell CD. et al. (32043983)	Lancet (Feb 2020)	Clinical evidence does not support corticosteroid treatment for 2019-nCoV lung injury.	111	1	112
28	Ai T. et al. (32101510)	Radiology (Feb 2020)	Correlation of Chest CT and RT-PCR Testing in Coronavirus Disease 2019 (COVID-19) in China: A Report of 1014 Cases.	110	0	110
29	Corman VM. et al. (31992387)	Euro Surveill (2020)	Detection of 2019 novel coronavirus (2019-nCoV) by real-time RT-PCR.	107	0	107

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Table 1
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ID	Author PMID	Journal (e-Publication Date)	Title	Degree Centrality Measures		
				In-Degree (PMC-PubMed Citations)	Out-Degree (PMC-PubMed References)	Degree (Total)
30	Cao B. et al. (32187464)	N Engl J Med (Mar 2020)	A Trial of Lopinavir-Ritonavir in Adults Hospitalized with Severe Covid-19.	96	5	101
31	Wan Y. et al. (31996437)	J Virol (Mar 2020)	Receptor Recognition by the Novel Coronavirus from Wuhan: an Analysis Based on Decade-Long Structural Studies of SARS Coronavirus.	96	2	98
32	Chan JF. et al. (31987001)	Emerg Microbes Infect (Jan 2020)	Genomic characterization of the 2019 novel human-pathogenic coronavirus isolated from a patient with atypical pneumonia after visiting Wuhan.	96	1	97
33	Xu XW. et al. (32075786)	BMJ (Feb 2020)	Clinical findings in a group of patients infected with the 2019 novel coronavirus (SARS-Cov-2) outside of Wuhan, China: retrospective case series.	94	4	98
34	Wu C. et al. (32167524)	JAMA Intern Med (Mar 2020)	Risk Factors Associated With Acute Respiratory Distress Syndrome and Death in Patients With Coronavirus Disease 2019 Pneumonia in Wuhan, China.	89	4	93
35	Chung M. et al. (32017661)	Radiology (Feb 2020)	CT Imaging Features of 2019 Novel Coronavirus (2019-nCoV).	88	0	88
36	Jin YH. et al. (32029004)	Mil Med Res (Feb 2020)	A rapid advice guideline for the diagnosis and treatment of 2019 novel coronavirus (2019-nCoV) infected pneumonia (standard version).	87	3	90
37	Phan LT. et al. (31991079)	N Engl J Med (Jan 2020)	Importation and Human-to-Human Transmission of a Novel Coronavirus in Vietnam.	87	1	88
38	Fang L. et al. (32171062)	Lancet Respir Med (Mar 2020)	Are patients with hypertension and diabetes mellitus at increased risk for COVID-19 infection?	86	4	90
39	Bai Y. et al. (32083643)	JAMA (Feb 2020)	Presumed Asymptomatic Carrier Transmission of COVID-19.	86	3	89
40	Xu X. et al. (32009228)	Sci China Life Sci (Jan 2020)	Evolution of the novel coronavirus from the ongoing Wuhan outbreak and modeling of its spike protein for risk of human transmission.	86	0	86
41	Munster VJ. et al. (31978293)	N Engl J Med (Jan 2020)	A Novel Coronavirus Emerging in China - Key Questions for Impact Assessment.	86	0	86
42	Chen Y. et al. (31967327)	J Med Virol (Feb 2020)	Emerging coronaviruses: Genome structure, replication, and pathogenesis.	86	0	86
43	Zhao S. et al. (32007643)	Int J Infect Dis (Jan 2020)	Preliminary estimation of the basic reproduction number of novel coronavirus (2019-nCoV) in China, from 2019 to 2020: A data-driven analysis in the early phase of the outbreak.	84	2	86

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ID	Author PMID	Journal (e-Publication Date)	Title	Degree Centrality Measures		
				In-Degree (PMC-PubMed Citations)	Out-Degree (PMC-PubMed References)	Degree (Total)
44	Brooks SK. et al. (32112714)	Lancet (Feb 2020)	The psychological impact of quarantine and how to reduce it: rapid review of the evidence.	83	0	83
45	Kampf G. et al. (32035997)	J Hosp Infect (Feb 2020)	Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents.	80	1	81
46	Shi H. et al. (32105637)	Lancet Infect Dis (Feb 2020)	Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: a descriptive study.	78	1	79
47	Remuzzi A. et al. (32178769)	Lancet (Mar 2020)	COVID-19 and Italy: what next?	77	1	78
48	Liu Y. et al. (32048163)	Sci China Life Sci (Feb 2020)	Clinical and biochemical indexes from 2019-nCoV infected patients linked to viral loads and lung injury.	74	5	79
49	Coronaviridae Study Group of the International Committee on Taxonomy of Viruses (32123347)	Nat Microbiol (Mar 2020)	The species Severe acute respiratory syndrome-related coronavirus: classifying 2019-nCoV and naming it SARS-CoV-2.	73	3	76
50	Lai CC. et al. (32081636)	Int J Antimicrob Agents (Feb 2020)	Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease-2019 (COVID-19): The epidemic and the challenges.	68	11	79
mean \pm SD ($n = 50$)				206 \pm 215	2 \pm 3	208 \pm 215

cle cluster (connected component) in the co-citation network consists of 2,811 articles and 78,844 co-citations (edges).

The article by Huang et al., 2020 is one of the first five article couples with the highest weight in the COVID-19 co-citation network. The articles by Chen et al., 2020, Zu et al., 2020, Chan et al., 2020, Li et al., 2020, and Zhou et al., 2020 are other members of the first five article couples. The article by Huan et al., 2020 studied clinical features of early cases in Wuhan and was published in the Lancet. The other five articles are also on clinical and epidemiological properties of the first cases in Wuhan. They were published in the Lancet, New England Journal of Medicine and Nature. These five articles are a member of other highly co-cited couples in Table 2. The details of other article couples are available in Table 1.

8. What do we have? How should we interpret?

In this study, the fundamental properties of citation and co-citation network of COVID-19 PMC articles are presented. Rehabilitation team members are familiar with the most cited article lists in the musculoskeletal rehabilitation literature. COVID-19 PMC articles are arranged around 4 main topics; first cases in Wuhan, clinical properties, epidemiological properties, virus self-characteristics. Structural findings of the network analysis can be enriched by text-mining techniques.

Text-mining results can be improved by expert (infectious disease, genetic, pandemic, virus specialist) physician and rehabilitation team member opinion. The final results in each topic can be a subject of separate articles.

Table 2
Most Co-cited COVID-19 Articles

ID	Co-citation Couple		Co-citation Frequency (Edge Weight)	Citations		Jaccard Similarity Index
	Article I	Article II		Article I	Article II	
1	Huang C. et al. Lancet-Jan 2020 (31986264)	Chen N. et al. Lancet-Jan 2020 (32007143)	459	1206	726	%31.2
2	Huang C. et al. Lancet-Jan 2020 (31986264)	Zhu N. et al. N Engl J Med-Jan 2020 (31978945)	350	1206	763	%21.6
3	Huang C. et al. Lancet-Jan 2020 (31986264)	Chan JF. et al. Lancet-Jan 2020 (31986261)	263	1206	456	%18.8
4	Huang C. et al. Lancet-Jan 2020 (31986264)	Li Q. et al. N Engl J Med-Jan 2020 (31995857)	231	1206	531	%15.3
5	Huang C. et al. Lancet-Jan 2020 (31986264)	Zhou P. et al. Nature-Feb 2020 (32015507)	220	1206	458	%15.2
6	Zhu N. et al. N Engl J Med-Jan 2020 (31978945)	Chen N. et al. Lancet-Jan 2020 (32007143)	200	763	726	%15.5
7	Chen N. et al. Lancet-Jan 2020 (32007143)	Chan JF. et al. Lancet-Jan 2020 (31986261)	194	726	456	%19.6
8	Huang C. et al. Lancet-Jan 2020 (31986264)	Lu R. et al. Lancet-Jan 2020 (32007145)	193	1206	380	%13.9
9	Zhu N. et al. N Engl J Med-Jan 2020 (31978945)	Chan JF. et al. Lancet-Jan 2020 (31986261)	192	763	456	%18.7
10	Zhu N. et al. N Engl J Med-Jan 2020 (31978945)	Li Q. et al. N Engl J Med-Jan 2020 (31995857)	183	763	531	%16.5
11	Chen N. et al. Lancet-Jan 2020 (32007143)	Li Q. et al. N Engl J Med-Jan 2020 (31995857)	181	726	531	%16.8
12	Zhu N. et al. N Engl J Med-Jan 2020 (31978945)	Zhou P. et al. Nature-Feb 2020 (32015507)	169	763	458	%16.1
13	Li Q. et al. N Engl J Med-Jan 2020 (31995857)	Chan JF. et al. Lancet-Jan 2020 (31986261)	165	531	456	%20.1
14	Chen N. et al. Lancet-Jan 2020 (32007143)	Zhou P. et al. Nature-Feb 2020 (32015507)	149	726	458	%14.4
15	Zhu N. et al. N Engl J Med-Jan 2020 (31978945)	Lu R. et al. Lancet-Jan 2020 (32007145)	148	763	380	%14.9
16	Chen N. et al. Lancet-Jan 2020 (32007143)	Lu R. et al. Lancet-Jan 2020 (32007145)	147	726	380	%15.3
17	Huang C. et al. Lancet-Jan 2020 (31986264)	Holshue ML. et al. N Engl J Med-Jan 2020 (32004427)	147	1206	300	%10.8
18	Huang C. et al. Lancet-Jan 2020 (31986264)	Zhou F. et al. Lancet-Mar 2020 (32171076)	142	1206	384	%9.8
19	Zhou P. et al. Nature-Feb 2020 (32015507)	Lu R. et al. Lancet-Jan 2020 (32007145)	137	458	380	%19.5
20	Chen N. et al. Lancet-Jan 2020 (32007143)	Holshue ML. et al. N Engl J Med-Jan 2020 (32004427)	125	726	300	%13.9
21	Huang C. et al. Lancet-Jan 2020 (31986264)	Guan WJ. et al. N Engl J Med-Feb 2020 (32109013)	119	1206	270	%8.8
22	Huang C. et al. Lancet-Jan 2020 (31986264)	Wang M. et al. Cell Res-Feb 2020 (32020029)	118	1206	283	%8.6
23	Chan JF. et al. Lancet-Jan 2020 (31986261)	Lu R. et al. Lancet-Jan 2020 (32007145)	117	456	380	%16.3

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ID	Co-citation Couple		Co-citation Frequency (Edge Weight)	Citations		Jaccard Similarity Index
	Article I	Article II		Article I	Article II	
24	Li Q. et al. N Engl J Med-Jan 2020 (31995857)	Lu R. et al. Lancet-Jan 2020 (32007145)	114	531	380	%14.3
25	Zhou P. et al. Nature-Feb 2020 (32015507)	Chan JF. et al. Lancet-Jan 2020 (31986261)	113	458	456	%14.1
26	Li Q. et al. N Engl J Med-Jan 2020 (31995857)	Zhou P. et al. Nature-Feb 2020 (32015507)	109	531	458	%12.4
27	Zhu N. et al. N Engl J Med-Jan 2020 (31978945)	Holshue ML. et al. N Engl J Med-Jan 2020 (32004427)	108	763	300	%11.3
28	Huang C. et al. Lancet-Jan 2020 (31986264)	Xu Z. et al. Lancet Respir Med-Feb 2020 (32085846)	104	1206	180	%8.1
29	Zhou P. et al. Nature-Feb 2020 (32015507)	Wu F. et al. Nature-Feb 2020 (32015508)	100	458	174	%18.8
30	Huang C. et al. Lancet-Jan 2020 (31986264)	Yang X. et al. Lancet Respir Med-Feb 2020 (32105632)	99	1206	174	%7.7
31	Li Q. et al. N Engl J Med-Jan 2020 (31995857)	Rothe C. et al. N Engl J Med-Jan 2020 (32003551)	94	531	221	%14.3
32	Huang C. et al. Lancet-Jan 2020 (31986264)	Rothe C. et al. N Engl J Med-Jan 2020 (32003551)	91	1206	221	%6.8
33	Chen N. et al. Lancet-Jan 2020 (32007143)	Guan WJ. et al. N Engl J Med-Feb 2020 (32109013)	88	726	270	%9.7
34	Wang M. et al. Cell Res-Feb 2020 (32020029)	Gao J. et al. Biosci Trends-Feb 2020 (32074550)	87	283	135	%26.3
35	Li Q. et al. N Engl J Med-Jan 2020 (31995857)	Holshue ML. et al. N Engl J Med-Jan 2020 (32004427)	87	531	300	%11.7
36	Huang C. et al. Lancet-Jan 2020 (31986264)	Epidemiology Working Group for NCIP Epidemic Response, Chinese Center for Disease Control and Prevention.. et al. Zhonghua Liu Xing Bing Xue Za Zhi- 2020 (32064853)	84	1206	176	%6.5
37	Zhou P. et al. Nature-Feb 2020 (32015507)	Wang M. et al. Cell Res-Feb 2020 (32020029)	84	458	283	%12.8
38	Zhou P. et al. Nature-Feb 2020 (32015507)	Holshue ML. et al. N Engl J Med-Jan 2020 (32004427)	83	458	300	%12.3
39	Lu R. et al. Lancet-Jan 2020 (32007145)	Holshue ML. et al. N Engl J Med-Jan 2020 (32004427)	83	380	300	%13.9
40	Chen N. et al. Lancet-Jan 2020 (32007143)	Zhou F. et al. Lancet-Mar 2020 (32171076)	78	726	384	%7.6
41	Chen N. et al. Lancet-Jan 2020 (32007143)	Wang M. et al. Cell Res-Feb 2020 (32020029)	78	726	283	%8.4
42	Holshue ML. et al. N Engl J Med-Jan 2020 (32004427)	Wang M. et al. Cell Res-Feb 2020 (32020029)	78	300	283	%15.4
43	Chen N. et al. Lancet-Jan 2020 (32007143)	Rothe C. et al. N Engl J Med-Jan 2020 (32003551)	78	726	221	%9

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Table 2
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ID	Co-citation Couple		Co-citation Frequency (Edge Weight)	Citations		Jaccard Similarity Index
	Article I	Article II		Article I	Article II	
44	Chan JF. et al. Lancet-Jan 2020 (31986261)	Holshue ML. et al. N Engl J Med-Jan 2020 (32004427)	78	456	300	%11.5
45	Chan JF. et al. Lancet-Jan 2020 (31986261)	Rothe C. et al. N Engl J Med-Jan 2020 (32003551)	78	456	221	%13
46	Zhou P. et al. Nature-Feb 2020 (32015507)	Wrapp D. et al. Science-Feb 2020 (32075877)	77	458	158	%14.3
47	Huang C. et al. Lancet-Jan 2020 (31986264)	Wrapp D. et al. Science-Feb 2020 (32075877)	77	1206	158	%6
48	Zhu N. et al. N Engl J Med-Jan 2020 (31978945)	Wu F. et al. Nature-Feb 2020 (32015508)	71	763	174	%8.2
49	Huang C. et al. Lancet-Jan 2020 (31986264)	Wu F. et al. Nature-Feb 2020 (32015508)	69	1206	174	%5.3
50	Zhu N. et al. N Engl J Med-Jan 2020 (31978945)	Rothe C. et al. N Engl J Med-Jan 2020 (32003551)	69	763	221	%7.5
51	Chen N. et al. Lancet-Jan 2020 (32007143)	Yang X. et al. Lancet Respir Med-Feb 2020 (32105632)	68	726	174	%8.2
52	Chen N. et al. Lancet-Jan 2020 (32007143)	Xu Z. et al. Lancet Respir Med-Feb 2020 (32085846)	68	726	180	%8.1
	mean \pm SD		131.6 \pm 74.2	–		%13.4 \pm %5.2

The purpose of this study is to give the current state of publications that improve itself every day. The improvement of COVID-19 literature in three months is almost equal to 20–30 years in musculoskeletal rehabilitation literature. The interpretation of findings with the local medical team based on the team goals could be a more suitable approach for details.

Co-citation network studies are rare publications in medical literature and readers might be unfamiliar. This method can help us to improve the findings of the most cited article rank list. Co-citation coupling frequency (edge weight) and Jaccard Similarity Index can help us to identify thematic relations of co-citation couples. The graph of the network could be more useful to understand co-citation coupling results.

The co-citation frequency represents the influence of two articles in COVID-19 literature. Jaccard Similarity Index normalizes the possible thematic relation of two articles. 18 articles and 52 most co-cited articles are presented in Table 2. The reader can clearly see that the arrangement in the most co-cited article table is slightly different than the most-cited article table. If the reader has limited time, the most co-cited article couples are suggested to be read first.

9. Conclusion

The COVID-19 outbreak pandemic is a situation without a tested action plan in real conditions. Rehabilitation team members are called for duty with new duties and responsibilities in addition to their conventional role in the healthcare system. Infectious disease specialists are well-informed and can update their knowledge in limited time in clinical settings. The number of articles in PubMed increases at a very high rate. Citation and co-citation network analysis are advantageous techniques to identify knowledge base in a scientific discipline. These techniques may help rehabilitation specialists to identify core articles and knowledge base in limited time.

Acknowledgments

The number of COVID-19 articles in PubMed increases day by day and update is necessary for structural changes in citation and co-citation networks. Raw and processed data can be directly requested from the author. Also, updated reports are available at <https://www.linkedin.com/pulse/covid-19-most-cited-articles-rafet-irmak>.

Conflict of interest

None to report.

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