

Bibliometric analysis of the top 100 most cited articles on multimorbidity using the Dimensions database

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A – Study Design, B – Data Collection, C – Statistical Analysis, D – Data Interpretation, E – Manuscript Preparation, F – Literature Search, G – Funds Collection

Summary Background. Publications on multimorbidity have been significantly increasing in the last few years, as the interest and importance of MM become an emerging priority.

Objectives. To identify the 100 most-cited articles on multimorbidity in the new scholarly search database *Dimensions* and to analyse their features.

Material and methods. An online search was performed using the keywords “multimorbidity” and “multi-morbidity”, combined with the Boolean operator “OR”, from inception until 3 July 2019. The results were organised by order of number of citations, and the 100 most cited articles were selected after a critical reading of the abstract. Some data was collected from each included article: journal of publication, quartile and impact factor, year of publication, first author’s name, country of origin, number of total and recent citations, Altmetric Attention Score and more.

Results. The number of citations ranged from 2,056 to 74. The 100 most-cited articles were published between 1996 and 2016, and more than half were published after 2010. They were classified as original research ($n = 65$), reviews ($n = 24$), perspective/opinion/commentary ($n = 10$) and position statement ($n = 1$). All articles were written in English and published in 48 journals – 10 of those represented 53% of the articles published, and 61.1% the total of citations. 93 articles were published in first quartile journals. 70 articles were published in Open Access format.

Conclusions. The total number of citations was 19,777. Identification of articles with the most academic reach and influence will assist in generating evidence-based descriptions, comparisons and visualisation of research output on multimorbidity.

Key words: multimorbidity, bibliometrics, primary health care, publishing, database.

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Background

Multimorbidity (MM) is defined as “the complex interactions of several co-existing diseases” by the National Library of Medicine (NLM) controlled vocabulary thesaurus used for indexing articles for PubMed (<https://www.ncbi.nlm.nih.gov/pubmed>), and multimorbidity has been a Medical Subject Headings (MeSH) term since January 2018 [1]. MM also implies that no single disease holds priority over any of the co-occurring diseases; whereas in comorbidity, there is a reference to the index (or initial) disease [1, 2]. Thus, MM is a more patient-centred construct, and comorbidity a disease-based construct; they characterise different perspectives of presenting co-existing diseases in a person [3].

The prevalence of MM currently affects around 13% of the population 18 years and older and 95% in patients aged 65 years and older [4]. MM is, at present, the rule and not the exception in most patients [5]. Publications on MM have been significantly increasing in the last few years [6, 7], as the interest and importance of MM become an emerging priority [8]. This interest has even been accompanied by the creation of a specialised journal on MM (<https://journals.sagepub.com/home/cob>) – an outlet for publications of researchers involved in its study [6].

Bibliometric studies (i.e. number of citations and descriptive analysis) play an important role in the history of a specific scien-

tific field when one is interested in studying the consolidated influence of an article, a researcher or an institution on the progress of scientific knowledge in a given moment or over time.

The relevance and popularity of studies regarding the most-cited articles aimed at scientific and medical communities alike are noticeably obvious [9]. Several reviews have previously been published on the most-cited articles regarding different medical disciplines, following different designs and searches in various databases [10, 11].

To date, only one bibliographic analysis has been published regarding both MM and comorbidity together [7]. This was done before the inclusion of MM as a MeSH term, and it aimed at describing global scientific research in comorbidity and MM until 8 November 2016. The study only analysed data from research articles and review articles, which could be considered as a limitation, as stated by the authors [7]. To the best of the authors’ knowledge, no bibliometric analysis of MM has been done postinclusion of MM as a MeSH word.

Objectives

The objective of the current study was to identify the 100 most cited articles on multimorbidity and to analyse their features. For this purpose, the authors used data from *Dimensions* and Altmetric data within *Dimensions* (<https://www.dimen->



sions.ai/). *Dimensions* is a new inclusive scholarly search database that includes not only publications but also awarded grants, patents, clinical trials and Altmetric attention data, with an easy-to-use and flexible interface [12]. *Dimensions* also has good citation database coverage; by July 2019, it contained around 30% more publications than comparable databases: 102 million publications with over 1.2 billion citations openly accessible [13].

Material and methods

A cross-sectional analysis of the 100 most cited articles on multimorbidity in the scientific literature was done. No ethical approval was required for this type of study, as the analysed data was already available electronically in the databases.

Two reviewers performed a search in the new scholarly search database *Dimensions* from inception until 3 July 2019. In the search field, the keywords “multimorbidity” and “multimorbidity”, combined with the Boolean operator “OR”, were inserted using the “title and abstract” search option. The results were ordered by number of citations, and the search was limited to articles only. No restrictions in languages or publication date were applied to the database search. A list of 4,302 publications was obtained, an, subsequently, two reviewers read the abstracts to see if, in fact, the articles referred to multimorbidity (all potential disagreements were resolved by consensus), thus reaching the top 100 most cited articles.

After the 100 most cited articles were selected, the following data was collected from each included article:

1) from *Dimensions* database: name of the journal in which the article was published, year of publication, first author’s name, affiliation, country of origin, presence of specific financial support, Medical Subject Headings (MeSH) keywords, access type (“Closed” – no freely available copy; “All OA” (Open Access) – freely available copy; “Gold” – free copy available on the publisher page; “Green, Accepted & Submitted” – free copy of accepted or submitted version in an OA repository), total citations (number of times that the article has been cited by other published publications in the *Dimensions* database, including articles, chapters, preprints, or monographs), recent citations (number of citations that were received within the last two years), Field Citation Ratio or FRC (relative citation performance of an article by comparing to articles of the same age in its sub-

ject area. Values greater than 1.0 indicate a higher-than-average citation when defined by the subject field, publication year and age. The FCR is calculated for publications of at least two years of age and published in 2000 or later), Fields of Research (FoR) (classification of major fields and related sub-fields of research and emerging areas of study) and Altmetric Attention Score (weighted count of all the online attention Altmetric have found for individual research output; includes mentions in public policy documents and references in Wikipedia, mainstream news, social networks, blogs and others);

2) from SCImago (<http://www.scimagojr.com/journalrank.php>): the quartile of the category in which the journal was best positioned related to the article’s publication year was recorded;

3) from Journal Citation Reports, Web of Science Group (<http://jcr.clarivate.com/JCRLandingPageAction.action>): 2018 impact factor of the journals;

4) type of article: each article was classified by the authors as original research, review article, position statement, or perspective/opinion/commentary.

The collected data was summarised as frequencies and percentages for categorical items and mean \pm standard deviation (SD) for numerical variable, using IBM SPSS Statistics for Windows, V.21.0 (IBM Corporation, Armonk, New York, USA). The graphs were produced using Excel Office 365 (Microsoft, Redmond, WA) and GraphPad Prism version 8.0.2 for Windows, (GraphPad Software, San Diego, California USA). Like previously published work [7], the frequency of the MeSH keywords was visually represented by a “word cloud”, generated free of charge by using wordclouds.com. It is a simple and clear tool where the most used MeSH keywords in the top 100 articles are those that stand out in the “word cloud”.

Results

The number of citations for the top 100 most cited articles on MM ranged from 74 (100th article) to 2,056 (1st article) (mean 197.8 ± 241.2 citations). The total number of citations was 19,777 (40.5% were received within the last two years). All articles were written in English (Table 1). Most of the articles were classified as original research (65 articles – mean 174.6 ± 255.6 citations), followed by reviews (24 articles – mean 269.5 ± 236.1 citations), perspective/opinion/commentary (10 articles – mean 161.9 ± 107.4 citations), and 1 position statement (343 citations).

Table 1. Top 100 most cited articles on multimorbidity

Rank	Title	Journals	Reference n°	Times cited
1	Epidemiology of multimorbidity and implications for health care, research, and medical education: a cross-sectional study	<i>The Lancet</i>	2012; 380: 37–43	2,056
2	How to measure comorbidity a critical review of available methods	<i>Journal of Clinical Epidemiology</i>	2003; 56(3): 221–229	1007
3	Ageing with multimorbidity: a systematic review of the literature	<i>Ageing Research Reviews</i>	2011; 10(4): 430–439	814
4	Defining comorbidity: implications for understanding health and health services	<i>The Annals of Family Medicine</i>	2009; 7(4): 357–363	607
5	Multimorbidity in general practice: prevalence, incidence, and determinants of co-occurring chronic and recurrent diseases	<i>Journal of Clinical Epidemiology</i>	1998; 51(5): 367–375	579
6	Prevalence of multimorbidity among adults seen in family practice	<i>The Annals of Family Medicine</i>	2005; 3(3): 223–228	539
7	Designing health care for the most common chronic condition – multimorbidity	<i>JAMA</i>	2012; 307(23): 2493–2494	390
8	Multimorbidity and quality of life in primary care: a systematic review	<i>Health and Quality of Life Outcomes</i>	2004; 2(1): 51	382
9	A systematic review of prevalence studies on multimorbidity: toward a more uniform methodology	<i>The Annals of Family Medicine</i>	2012; 10(2): 142–151	368

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Rank	Title	Journals	Reference nº	Times cited
10	Epidemiology and impact of multimorbidity in primary care: a retrospective cohort study	<i>British Journal of General Practice</i>	2011; 61(582): e12–e21	351
11	Guiding principles for the care of older adults with multimorbidity: an approach for clinicians	<i>Journal of the American Geriatrics Society</i>	2012; 60(10): e1–e25	343
12	Morbidity and aging in HIV-infected persons: the Swiss HIV Cohort Study	<i>Clinical Infectious Diseases</i>	2011; 53(11): 1130–1139	339
13	Comorbidity or multimorbidity	<i>European Journal of General Practice</i>	1996; 2(2): 65–70	333
14	Multimorbidity in older adults	<i>Epidemiologic Reviews</i>	2013; 35(1): 75–83	300
15	Managing patients with multimorbidity: systematic review of interventions in primary care and community settings	<i>The BMJ</i>	2012; 345(sep03 1): e5205	298
16	Multimorbidity's many challenges	<i>The BMJ</i>	2007; 334(7602): 1016–1017	292
17	Relationship between multimorbidity and health-related quality of life of patients in primary care	<i>Quality of Life Research</i>	2006; 15(1): 83–91	284
18	Measures of multimorbidity and morbidity burden for use in primary care and community settings: a systematic review and guide	<i>The Annals of Family Medicine</i>	2012; 10(2): 134–141	260
19	The prevalence of multimorbidity in primary care and its effect on health care utilization and cost	<i>Family Practice</i>	2011; 28(5): 516–523	250
20	The measurement of multiple chronic diseases – a systematic review on existing multimorbidity indices	<i>The Journals of Gerontology Series A</i>	2011; 66A(3): 301–311	248
21	Future of multimorbidity research: how should understanding of multimorbidity inform health system design?	<i>Public Health Reviews</i>	2010; 32(2): 451–474	248
22	Adapting clinical guidelines to take account of multimorbidity	<i>The BMJ</i>	2012; 345(oct04 1): e6341	235
23	Multimorbidity in primary care: prevalence and trend over the last 20 years	<i>European Journal of General Practice</i>	2008; 14(sup 1): 28–32	218
24	Prevalence and patterns of multimorbidity in Australia	<i>The Medical Journal of Australia</i>	2008; 189(2): 72–77	218
25	Prevalence of chronic diseases and multimorbidity among the elderly population in Sweden	<i>American Journal of Public Health</i>	2008; 98(7): 1198–1200	217
26	Prevalence, determinants and patterns of multimorbidity in primary care: a systematic review of observational studies	<i>PLoS ONE</i>	2014; 9(7): e102149	217
27	Patterns of chronic multimorbidity in the elderly population	<i>Journal of the American Geriatrics Society</i>	2009; 57(2): 225–230	212
28	Guidelines for people not for diseases: the challenges of applying UK clinical guidelines to people with multimorbidity	<i>Age and Ageing</i>	2013; 42(1): 62–69	210
29	Processes of care desired by elderly patients with multimorbidities	<i>Family Practice</i>	2008; 25(4): 287–293	180
30	Association of cardiometabolic multimorbidity with mortality	<i>JAMA</i>	2015; 314(1): 52–60	175
31	Multimorbidity patterns in the elderly: a new approach of disease clustering identifies complex interrelations between chronic conditions	<i>PLoS ONE</i>	2010; 5(12): e15941	170
32	Which chronic diseases and disease combinations are specific to multimorbidity in the elderly? Results of a claims data based cross-sectional study in Germany	<i>BMC Public Health</i>	2011; 11(1): 101	164
33	The impact of chronic multimorbidity and disability on functional decline and survival in elderly persons. A community-based, longitudinal study	<i>Journal of Internal Medicine</i>	2009; 265(2): 288–295	163
34	The association between chronic illness, multimorbidity and depressive symptoms in an Australian primary care cohort	<i>Social Psychiatry and Psychiatric Epidemiology</i>	2012; 47(2): 175–184	161
35	Managing patients with multimorbidity in primary care	<i>The BMJ</i>	2015; 350(jan20 2): h176	158

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36	Multimorbidity patterns: a systematic review	<i>Journal of Clinical Epidemiology</i>	2014; 67(3): 254–266	158
37	Prevalence of morbidity and multimorbidity in elderly male populations and their impact on 10-year all-cause mortality. The FINE study (Finland, Italy, Netherlands, elderly)	<i>Journal of Clinical Epidemiology</i>	2001; 54(7): 680–686	158
38	Prevalence estimates of multimorbidity: a comparative study of two sources	<i>BMC Health Services Research</i>	2010; 10(1): 111	156
39	Barriers to self-management and quality-of-life outcomes in seniors with multimorbidities	<i>The Annals of Family Medicine</i>	2007; 5(5): 395–402	156
40	Interventions for improving outcomes in patients with multimorbidity in primary care and community settings	<i>Cochrane Database of Systematic Reviews</i>	2016; 3(3): cd006560	151
41	Effects of physical exercise therapy on mobility, physical functioning, physical activity and quality of life in community-dwelling older adults with impaired mobility, physical disability and/or multi-morbidity: a meta-analysis	<i>Ageing Research Reviews</i>	2012; 11(1): 136–149	146
42	Guided care for multimorbid older adults	<i>The Gerontologist</i>	2007; 47(5): 697–704	138
43	The influence of age, gender and socio-economic status on multimorbidity patterns in primary care. First results from the multicare cohort study	<i>BMC Health Services Research</i>	2012; 12(1): 89	135
44	Multimorbidity in primary care: developing the research agenda	<i>Family Practice</i>	2009; 26(2): 79–80	134
45	Multimorbidity is common to family practice: is it commonly researched?	<i>Canadian Family Physician</i>	2005; 51: 244–245	131
46	Psychological distress and multimorbidity in primary care	<i>The Annals of Family Medicine</i>	2006; 4(5): 417–422	131
47	Multimorbidity: redesigning health care for people who use it	<i>The Lancet</i>	2012; 380(9836): 7–9	127
48	Multimorbidity and quality of life: a closer look	<i>Health and Quality of Life Outcomes</i>	2007; 5(1): 52	122
49	Multimorbidity – not just an older person's issue. Results from an Australian biomedical study	<i>BMC Public Health</i>	2010; 10(1): 718	121
50	The increasing burden and complexity of multimorbidity	<i>BMC Public Health</i>	2015; 15(1): 415	115
51	GPs' perspectives on the management of patients with multimorbidity: systematic review and synthesis of qualitative research	<i>BMJ Open</i>	2013; 3(9): e003610	115
52	Problems in determining occurrence rates of multimorbidity	<i>Journal of Clinical Epidemiology</i>	2001; 54(7): 675–679	115
53	Multimorbidity and comorbidity in the Dutch population – data from general practices	<i>BMC Public Health</i>	2012; 12(1): 715	114
54	Deprescribing medication in very elderly patients with multimorbidity: the view of Dutch GPs. A qualitative study	<i>BMC Family Practice</i>	2012; 13(1): 56	114
55	Cumulative Illness Rating Scale was a reliable and valid index in a family practice context	<i>Journal of Clinical Epidemiology</i>	2005; 58(6): 603–608	113
56	Comparative assessment of three different indices of multimorbidity for studies on health-related quality of life	<i>Health and Quality of Life Outcomes</i>	2005; 3(1): 74	112
57	Integrated primary care for patients with mental and physical multimorbidity: cluster randomised controlled trial of collaborative care for patients with depression comorbid with diabetes or cardiovascular disease	<i>The BMJ</i>	2015; 350(feb16 3): h638	111
58	Patterns of multimorbidity in the aged population. Results from the KORA-Age Study	<i>PLoS ONE</i>	2012; 7(1): e30556	109
59	The effect of physical multimorbidity, mental health conditions and socioeconomic deprivation on unplanned admissions to hospital: a retrospective cohort study	<i>Canadian Medical Association Journal</i>	2013; 185(5): e221–e228	109

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60	Shifting priorities in multimorbidity: a longitudinal qualitative study of patient's prioritization of multiple conditions	<i>Chronic Illness</i>	2011; 7(2): 147–161	108
61	Setting and registry characteristics affect the prevalence and nature of multimorbidity in the elderly	<i>Journal of Clinical Epidemiology</i>	2008; 61(11): 1104–1112	107
62	Suicide risk in primary care patients with major physical diseases: a case-control study	<i>JAMA Psychiatry</i>	2012; 69(3): 256–264	106
63	Multimorbidity is associated with better quality of care among vulnerable elders	<i>Medical Care</i>	2007; 45(6): 480–488	105
64	Unpacking the burden: understanding the relationships between chronic pain and comorbidity in the general population	<i>Pain</i>	2012; 153(2): 293–304	105
65	What matters to older people with assisted living needs? A phenomenological analysis of the use and non-use of telehealth and telecare	<i>Social Science & Medicine</i>	2013; 93: 86–94	105
66	Clinical multimorbidity and physical function in older adults: a record and health status linkage study in general practice	<i>Family Practice</i>	2007; 24(5): 412–419	104
67	Multimorbidity, health care utilization and costs in an elderly community-dwelling population: a claims data based observational study	<i>BMC Health Services Research</i>	2015; 15(1): 23	104
68	Multimorbidity patterns in primary care: interactions among chronic diseases using factor analysis	<i>PLoS ONE</i>	2012; 7(2): e32190	103
69	Multimorbidity and survival in older persons with colorectal cancer	<i>Journal of the American Geriatrics Society</i>	2006; 54(12): 1898–1904	102
70	Hospital admissions among people 65+ related to multimorbidity, municipal and outpatient care	<i>Archives of Gerontology and Geriatrics</i>	2008; 46(1): 41–55	101
71	Collaborative care needs and preferences of primary care patients with multimorbidity	<i>Health Expectations</i>	2005; 8(1): 54–63	101
72	Drug-disease and drug-drug interactions: systematic examination of recommendations in 12 UK national clinical guidelines	<i>The BMJ</i>	2015; 350(mar11 2): h949	101
73	Multimorbidity prevalence and patterns across socio-economic determinants: a cross-sectional survey	<i>BMC Public Health</i>	2012; 12(1): 201	100
74	Global multimorbidity patterns: a cross-sectional, population-based, multi-country study	<i>The Journals of Gerontology Series A</i>	2016; 71(2): 205–214	99
75	Beyond diagnosis: rising to the multimorbidity challenge	<i>The BMJ</i>	2012; 344(jun13 2): e3526	98
76	Multimorbidity, service organization and clinical decision making in primary care: a qualitative study	<i>Family Practice</i>	2011; 28(5): 579–587	96
77	The Ariadne principles: how to handle multimorbidity in primary care consultations	<i>BMC Medicine</i>	2014; 12(1): 223	95
78	Co- and multimorbidity patterns in primary care based on episodes of care: results from the German CONTENT project	<i>BMC Health Services Research</i>	2008; 8(1): 14	93
79	Disability, more than multimorbidity, was predictive of mortality among older persons aged 80 years and older	<i>Journal of Clinical Epidemiology</i>	2010; 63(7): 752–759	90
80	Better management of patients with multimorbidity	<i>The BMJ</i>	2013; 346(may02 1): f2510	90
81	The European general practice research network presents a comprehensive definition of multimorbidity in family medicine and long-term care, following a systematic review of relevant literature	<i>Journal of the American Medical Directors Association</i>	2013; 14(5): 319–325	89
82	Seniors' self-reported multimorbidity captured biopsychosocial factors not incorporated into two other data-based morbidity measures	<i>Journal of Clinical Epidemiology</i>	2009; 62(5): 550–557.e1	88
83	Ageing and multimorbidity: new tasks, priorities, and frontiers for integrated gerontological and clinical research	<i>Journal of the American Medical Directors Association</i>	2015; 16(8): 640–647	86
84	Multimorbidity: prevalence, effect on quality of life and daily functioning, and variation of this effect when one condition is a rheumatic disease	<i>Seminars in Arthritis and Rheumatism</i>	2009; 38(4): 312–319	83

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85	Multimorbidity in primary care: a systematic review of prospective cohort studies	<i>British Journal of General Practice</i>	2012; 62(597): e297–e307	83
86	Prevalence of multimorbidity in a geographically defined American population patterns by age, sex, and race/ethnicity	<i>Mayo Clinic Proceedings</i>	2014; 89(10): 1336–1349	82
87	Managing patients with mental and physical multimorbidity	<i>The BMJ</i>	2012; 345(sep03 1): e5559	80
88	The impact of multimorbidity on adult physical and mental health in low- and middle-income countries: what does the study on global ageing and adult health (SAGE) reveal?	<i>BMC Medicine</i>	2015; 13(1): 178	79
89	Comparing measures of multimorbidity to predict outcomes in primary care: a cross sectional study	<i>Family Practice</i>	2013; 30(2): 172–178	79
90	Multiple diseases and polypharmacy in the elderly: challenges for the internist of the third millennium	<i>Journal of Comorbidity</i>	2011; 1(1): 28–44	79
91	Multimorbidity – older adults need health care that can count past one	<i>The Lancet</i>	2015; 385(9968): 587–589	78
92	Examining different measures of multimorbidity, using a large prospective cross-sectional study in Australian general practice	<i>BMJ Open</i>	2014; 4(7): e004694	77
93	Prevalence of polypharmacy in a Scottish primary care population	<i>European Journal of Clinical Pharmacology</i>	2014; 70(5): 575–581	77
94	Multimorbidity patterns in HIV-infected patients	<i>JAIDS Journal of Acquired Immune Deficiency Syndromes</i>	2012; 61(5): 600–605	76
95	A framework for crafting clinical practice guidelines that are relevant to the care and management of people with multimorbidity	<i>Journal of General Internal Medicine</i>	2014; 29(4): 670–679	76
96	Symptom burden in community-dwelling older people with multimorbidity: a cross-sectional study	<i>BMC Geriatrics</i>	2015; 15(1): 1	76
97	The prevalence of chronic diseases and multimorbidity in primary care practice: a PPRNet report	<i>The Journal of the American Board of Family Medicine</i>	2013; 26(5): 518–524	75
98	Multimorbidity of chronic diseases and health care utilization in general practice	<i>BMC Family Practice</i>	2014; 15(1): 61	75
99	Multimorbidity and health-related quality of life in the older population: results from the German KORA-Age study	<i>Health and Quality of Life Outcomes</i>	2011; 9(1): 53	75
100	Patterns of comorbidity and multimorbidity in the oldest old: the Octabaix study	<i>European Journal of Internal Medicine</i>	2013; 24(1): 40–44	74

The top 3 most cited articles were: 1) a cross-sectional study published in 2012 by Barnett et al. [14] in the journal *The Lancet*, describing the epidemiology of multimorbidity in Scottish patients (2,056 citations); 2) a systematic review of MM measures published by de Groot et al. [15] in 2003 in the *Journal of Clinical Epidemiology* (1,007 citations); and 3) a systematic review about multimorbidity in older persons published in 2011 by Marengoni et al. [16] in the journal *Ageing Research Reviews* (814 citations). The highest number of recent citations (i.e. received within the last two years) was found for the study by Barnett et al. [14] with 1,064 total citations (51.8%), followed by the study by Marengoni et al. [16] with 417 total citations (51.2%).

Compared to other publications in the same field, the 100 most cited articles on MM received at least 7.9 times more citations than average. The Field Citation Ratio (FCR) was the uppermost for the study by Barnett et al. [14]; it was extremely highly cited, with approximately 282 times more citations than the average for the Public Health and Health Services field of research. The study by Marengoni et al. [16] received approximately 102 times more citations than the average for the same field of research, and the study by de Groot et al. [15] received 82 times more citations than the average for the Clinical Sciences field of research.

Using Altmetric, the online activity surrounding the top 100 most cited articles had a score between nil and 406. A top 5 High Attention Score compared to outputs of the same age and source was found for the studies of Barnett et al. [14] (99th percentile), Dumbreck et al. [17] (95th percentile), Wallace et al. [18] (92nd percentile), Emerging Risk Factors Collaboration [19] (86th percentile) and Coventry et al. [20] (90th percentile). These articles were published in *The Lancet*, *BMJ* and *JAMA*. Figure 1 shows that the first 15 articles in the top 100 list received more media mentions and have more readers than the bottom 15 articles (i.e. rank 86 to 100).

The 100 most cited articles on MM were published between 1996 and 2016 (Figure 2). The years with the greatest number of published articles were 2012 ($n = 22$), 2011 ($n = 10$), 2013 ($n = 10$) and 2015 ($n = 10$). More than half of the 100 most cited articles on MM were published after 2010. The oldest article was the 13th most cited (333 citations) and was published by van den Akker et al. [2] in 1996. In this review article, the authors suggested a distinction between MM and comorbidity. The most recent article was a Cochrane Review concerning interventions for improving outcomes in patients with multimorbidity [21] with 99 citations – 74th position.

The number of authors that wrote the articles in the top 100 varied between a single author in 3 articles [22–24] and more than

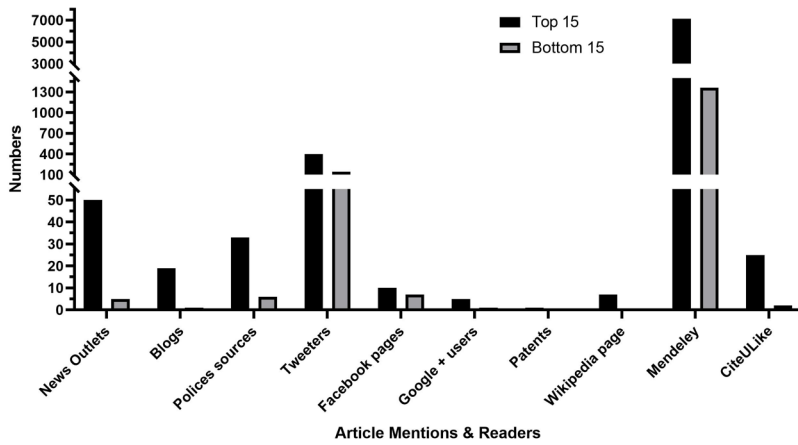


Figure 1. Mentions and readers of the Top 15 and Bottom 15 articles in the Top 100 list

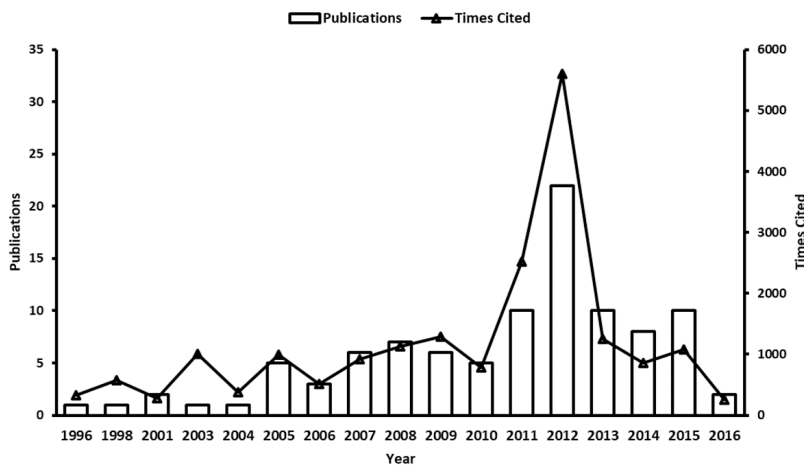


Figure 2. Number of articles published each year and total of citations per year

80 authors in an Emerging Risk Factors Collaboration study published in 2015 in *JAMA* [19] (mean number of authors 7.1 ± 9.0). As first authors, the most proficient researchers (with 3 or more articles in the top 100) were: Martin Fortin (10 articles) [5, 25–33], Alessandra Marengoni (4 articles) [16, 34–36], Elizabeth Bayliss (3 articles) [37–39] and Marjan van den Akker (3 articles) [2, 40, 41].

The first authors of the 100 most cited articles on MM were associated with 61 primary institutions; the 5 most frequent were: Université de Sherbrooke (11 articles), University of Manchester (5 articles), University of Dundee (4 articles), University of Cambridge (4 articles) and University of Bristol (4 articles).

Funding was stated in 53% of the articles.

Thirteen different countries were present in the top 100 list. The greatest number of published articles were from the United Kingdom (24 articles), the United States (16 articles), Canada (13 articles), the Netherlands (11 articles) and Germany (8 articles), establishing a top 5 list that represented 72% of the total articles. Other countries included Sweden, Spain, Ireland, Australia, Switzerland, Italy, New Zealand and India.

The 100 most cited articles on MM were published in 48 journals, but only 10 of these journals represented 53% of the articles published and 61.1% of the total of citations (Table 2).

Table 2. Journals with the highest number of articles in the top 100 list (3 or more articles)

Journal	No. of articles	No. of closed access articles	No. of open access articles	SCImago Journal Rank Quartile	2018 Journal Impact Factor	Total of times cited
<i>The BMJ</i>	9	2	7	Q1	27.604	1,463
<i>Journal of Clinical Epidemiology</i>	9	8	1	Q1	4.650	2,415
<i>Family Practice</i>	6	–	6	Q1	1.986	843
<i>The Annals of Family Medicine</i>	6	–	6	Q1	4.185	2,061
<i>BMC Public Health</i>	5	–	5	Q1	2.567	614
<i>PLoS ONE</i>	4	–	4	Q1	2.776	599
<i>Health and Quality of Life Outcomes</i>	4	–	4	Q1/Q2	2.318	691
<i>BMC Health Services Research</i>	4	–	4	Q1	1.932	488
<i>The Lancet</i>	3	3	–	Q1	59.102	2,261
<i>Journal of the American Geriatrics Society</i>	3	2	1	Q1	4.113	657
Total	53	15	38	–	–	12,092



Figure 3. Word cloud for the most frequently used keywords (mentioned at least 5 times) in classic articles (100 or more citations)

Regarding access to the top 100 articles, the majority (70%) were published in Open Access (OA) format: 56 articles in OA Gold – mean 164.6 ± 1104 citations; 9 in OA Green (accepted & submitted) – mean 179.4 ± 122.2 citations; and 5 in OA Green (published) – mean 209.0 ± 118.1 citations. The remaining articles were published in Closed Access (mean 263.4 ± 403.4 citations).

According to the SCImago Journal Rank, the best quartile related to the publication year was Q1 (quarter of the journals with the highest values) for 93 articles, Q2 (the second highest values) for 3 articles, and 4 journals were not indexed.

From the 100 most cited articles, 97 were indexed with an Impact Factor (IF) in the Web of Science Journal Citation Reports. The journal with the highest IF was *The Lancet* (59.102), and the lowest IF was from the *European Journal of General Practice* (1.617).

The two most common research categories were Public Health and Health Services (76 articles) and Clinical Sciences (7 articles). Other categories included Statistics, Cardiorespiratory Medicine and Haematology, Neurosciences, Nursing, Sociology and other studies in Human Society.

Of the 100 most cited articles on MM, 73 papers can be identified as “classic” (100 or more citations [42]). The most frequently used MeSH keywords (mentioned at least 5 times) extracted from the classic articles are depicted in Figure 3.

Discussion

In the current cross-sectional study, the authors analysed the 100 most cited articles on multimorbidity present in the scientific database *Dimensions*, an inter-linked research information system provided by Digital Science (<https://www.dimensions.ai>), from inception until 3 July 2019. This is the first bibliometric analysis of MM done after its inclusion as a MeSH word in 2018 by the National Library of Medicine. This study uses not only classic bibliometric indicators but also some Altmetric data, which may provide a more complete picture of the influence of multimorbidity research as mentioned in literature [9, 43].

The most obvious finding to emerge from this analysis is that more than half of the articles in the top 100 were published after 2010, revealing the recent interest in this topic – 40.5% of the total number of citations was received within the last two years. This finding is consistent with a recent review by other authors, in which approximately two-thirds of the papers on comorbidity and multimorbidity were published since 2010 [7]. Remarkably, it was only in 1996 that multimorbidity was defined as the co-occurrence of two or more chronic diseases within

a patient without an index disease [2]. The scientific importance of MM research is also noticeable from the current analysis, as the top 100 articles received at least 7.9 times more citations than the average compared to other publications in the same field, especially in the Public Health and Health Services category.

Although thirteen different countries were present in the top 100 list, English was the only language of the 100 widely-cited articles on multimorbidity. This result reflects the known impression that English is the international language of scientific communication [44, 45], and reporting multimorbidity findings is no exception. Actually, English is the language of 80% of Scopus-indexed journals and is noticeably rising in publications by several non-native English speaking countries [45]. English is also the most common Internet language, and with the current increase in medical journals in Open Access electronic format, the publication of articles in English favours circulation on the Internet – 70% of the top 100 articles were published in Open Access format.

In contrast to earlier findings, in which scientific productivity was dominated by the United States [7], almost three-fourths of the 100 most cited articles on multimorbidity were from Europe, the United States and Canada. This is unsurprising given the increase in international competition for recognition and reward of the research done by non-Anglophone researchers [46, 47].

As expected, this study confirms that in multimorbidity, as in other areas, review articles are more often cited than original articles [48–50], even though there was a higher number of original articles in the top 100. A possible explanation for this might be that since multimorbidity is a recent research field and that review articles are comprehensive and summarise existing literature, a researcher who starts working on multimorbidity will go through the existing review articles, adding to the articles’ citation count for any subsequent original article published by that researcher. One unanticipated finding was the presence of a significant number of perspective/opinion/commentary articles in the top 100 most cited articles on MM. These are usually excluded in citation indicators, but in the case of MM, they may be a venue to easily express pioneering ideas [50].

The 100 most cited articles on MM were published in international journals, and almost all were in the first quartile for their category. The most cited articles were concentrated in a few journals, which corroborates earlier similar findings in fields with high citation density [51]. It seems possible that authors follow the notion that the impact factor of the publishing journal is a predictor of future citations [52], and so they choose to publish in journals in the first quartile.

Nonetheless, some journals with less than three papers in the 100 most cited list had a high impact factor according to 2018 Journal Citation Reports.

This research found that in classic multimorbidity articles, not only “aged” ($n = 70$; 96%) and “comorbidity” ($n = 61$; 84%), but also “80 and over” ($n = 24$), “middle aged” ($n = 28$), “chronic disease” ($n = 48$), “prevalence” ($n = 26$), “Primary Health Care” ($n = 23$), “Quality of Life” ($n = 13$) and “Family Practice” ($n = 12$) were very common. This is consistent with previous findings in which articles on comorbidity and multimorbidity frequently used “comorbidity” and “elderly” as MeSH keywords [7]. The reason for this may be the fact that multimorbidity is normally associated with Primary Health Care and Family Practice [53]. Many articles in the top 100 were about the prevalence of multimorbidity and the impact of chronic diseases on quality of life.

The current study has several limitations. First, since multimorbidity is a recent MeSH term, publications with the correct nomenclature will be too recent to reach a relevant number of citations. Consequently, some articles regarding comorbidity and not MM could have been inadvertently included in the top 100. Nonetheless, to reduce this possible bias, the authors chose to search only for “multimorbidity” and “multi-morbidity” and performed a subsequent article selection.

Second, all articles included in the top 100 were published in the English language. This may be because most publications were from English-speaking countries. MM research may not be reaching important non-English speaking areas of the world.

Third, there may be high quality articles published in recent years where the elapsed period of time since publication was

insufficient for them to reach a number of citations equivalent to those already published for a longer period of time.

Lastly, by choosing to include only the first author, some researchers that have co-authored other articles in the top 100 may be underrepresented in the present study.

Conclusions

The current bibliometric analysis provides insights into the 100 most frequently cited articles on MM. Identification of articles that have the most academic reach and influence will assist in generating evidence-based descriptions, comparison, and visualisations of the research output on MM. All the 100 most cited articles on MM were published in English, and most of them were published after 2010 in journals with a high impact factor. The total number of citations was 19,777 (40.5% were received within the last two years). The United Kingdom, the United States and Canada were the countries that led in publications. There was a predominance of review articles. Public Health and Health Services was the most common field of study. A limitation of this analysis, as in all bibliometric studies, but particularly in rapid increasing publication fields such as MM, is that the current results may change in the not so-distant future, as citations will expectably increase. Further research could also be conducted to compare findings between different database, and *Dimensions*.

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