Bibliometric analysis of the refractive error field

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VIEWPOINT

Bibliometric analysis of the refractive error field

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Introduction

Research into the epidemiology, aetiology and optics of ametropia is a fundamental cornerstone of the correction and management of refractive errors by eye care practitioners. At present, much of this work is driven by the clinical concern that myopia is a common cause of vision loss, with uncorrected myopia the leading cause of vision impairment globally.¹ Holden et al² predict that by 2050, about 50% of the population of the world will be myopic.

The aetiology of myopia continues to be hotly debated,¹ centring around the relative impact of nature (genetic) versus nurture (environment). Research aimed at optimizing optical (spectacles and contact lenses) and surgical (laser refractive surgery) modes of correcting refractive error continues unabated, and novel approaches for arresting the progression of myopia, using ophthalmic lenses, contact lenses (including orthokeratology), pharmacological approaches or lifestyle modification, are also under active investigation.³

As is the case in all fields of investigation, the foundation of these various lines of refractive error research are rooted in the ophthalmic literature. Modern bibliographic search tools enable targeted interrogation of this vast literature⁴ to facilitate identification of the research foundations that underpin our understanding of refractive error. This Viewpoint uses these bibliographic search tools and employs a subject-specific measure of impact to identify key papers, authors, institutions, countries and journals in the field of refractive error research.

Search strategy

The search protocol used here was undertaken using the Scopus database (Elsevier) and was restricted to the titles of all documents published in journals in English until November 29, 2020. Additional qualifiers were used in the title-abstract to ensure that the search output yielded only refractive error-related content. An example is the use of the term “myopic” – a significant literature uses this term outside of eye and vision research. The following search term was derived to ensure (a) high sensitivity, including a wide capture of articles with “refractive error” as the primary theme, and (b) high specificity, so as to rule out irrelevant or peripherally related articles:

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TITLE(("refractive error*") OR (myop*) OR (hyperop*) OR (presbyop*) OR (emmetrop*) OR (nearsight*) OR ("shortsight*") OR (farsight*) OR {refractive status} OR {refractive development} OR {visual impairment}) AND TITLE-ABS(vision) OR (visual) AND (refractive) AND (LIMIT-TO(SRCTYPE, "j")) AND (LIMIT-TO(LANGUAGE, "English"))
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The search revealed 8,881 refractive error-related papers, from which the top 25 most cited papers could be determined by simple sorting within Scopus. A subject-specific h-index for ‘refractive error’ (the “h_{RE}-index”) was derived, to serve as a measure of the *impact* of authors, institutions, countries and journals in the field of refractive error research. The detailed methodology for determining the subject-specific-index and identifying

1 the top-ranked entities in each of these categories is the same as that employed by Efron et al⁵ and will not be
2 repeated here. In considering these data, it is important to consider that the different categories are not
3 necessarily mutually exclusive (i.e. the most prominent papers, authors, countries and institutions are likely to
4 be somewhat associated).

10 **Highly cited papers**

12 The 8,881 articles in this field have a combined h_{RE} -index of 172 (that is, 172 of the 8,881 articles have been
13 cited at least 172 times) and in total have been cited 236,666 times.

17 The 25 most highly cited refractive error papers are listed in Table 1 of the Supplementary Material. These
18 papers have each attracted between 451 and 2,866 citations. Fifteen of these papers were published in
19 ophthalmology journals, seven in medicine or public health journals, two in optometry journals and one in a
20 visual science journal. Although ranking by citation count favours *older* papers due to a greater time period to
21 accrue citations, only eight of the top 25 most highly cited were published prior to 2000.

28 Ranking by citation count does not favour papers published more recently because of the limited time available
29 to accrue citations; this is probably the main reason why the majority of top 25 papers (17) were published in
30 the 2000s and only four were published after 2010. Figure 1 shows the number of refractive error articles
31 published each year over the past half century, which demonstrates an especially steep rise in research activity
32 in this area over the past 30 years.

38 Although there is some overlap in the subject matter addressed in the top 25 papers, the main theme of the
39 papers can be characterised as follows: epidemiology of refractive error, especially the prevalence of myopia
40 world-wide or in specific nations (12 papers); aetiology of myopia, including the impact of excessive near work
41 (4); patterns of eye growth in the ametropic eye (4); refractive surgery (2); pathology associated with myopia
42 (2); and optics of the ametropic eye (1).

48 The second oldest paper among the top 25, published in 1983, is entitled “Prevalence of myopia in the United
49 States”, authored by Sperduto et al⁶ (rank #21). As well as establishing that 25% of the US population was
50 myopic in 1971/72, this paper served as a critical referent for a subsequent paper by the same author (but
51 different colleagues)⁷(#18), which revealed the astonishing finding that myopia had increased in the US to a
52 prevalence of 42% over a period of just 30 years.

59 The top-ranked paper, with 2,866 citations, is “Global data on visual impairment in the year 2002”, authored by
60 Resnikoff et al.⁸ Paradoxically, this paper did not discuss vision loss due to refractive errors in detail; however,
it drew attention to the unmet need for the management of visual impairment due to refractive errors, and called

for a change in the definition of visual impairment to reflect this problem, a modification which was implemented in 2005.⁹ The World Health Organisation definition of visual impairment was also modified as a result of the recommendation of Resnikoff et al.⁸

Most impactful authors

Table 2 of the Supplementary Material lists the 25 most impactful authors, ranked by h_{RE} -index, with ties resolved by paper count (also shown). The most impactful authors in the field have published between 52 and 166 papers specifically related to refractive error, and have h_{RE} -indices ranging from 23 to 58.

Seang-Mei Saw is the top-ranked author (h_{RE} -index = 58) by a wide margin, being separated from the second-ranked author by 12 h_{RE} -index points and from the fourth ranked author by 20 h_{RE} -index points. Dr Saw is currently a professor at the Department of Epidemiology and Public Health, and Vice-Dean (Research), in the Yong Loo Lin School of Medicine at the National University of Singapore. The primary research interests of Professor Saw relate to the epidemiology, genetics and gene-environment interactions for myopia and other eye diseases. She has served as the principal investigator in major epidemiological studies of myopia.

Of the top 25 authors, six are optometrists – Karla Zadnik (rank #4), Donald Mutti (#7), Neville McBrien (#11), Earl Smith III (#12), Jeremy Guggenheim (#24) and Katrina Schmid (#25). The remainder have expertise in ophthalmology, orthoptics, epidemiology, genetics and cell biology.

Six of the top 25 authors are women – Seang-Mei Saw (rank #1), Karla Zadnik (#4), Kyoko Ohno-Matsui (#6), Terri Young (#10), Kathryn Rose (#23) and Katrina Schmid (#25).

Leading institutions

The top 25 institutions from which papers emanated are listed in Table 3 of the Supplementary Material, ranked by h_{RE} -index, with ties resolved by paper count (also shown). Of the top 25 institutions, seven are in the United States; six in Australia; three in China; two each in Hong Kong, Spain and the United Kingdom; and one each in Germany, Japan and Singapore.

Given the extraordinarily high prevalence of myopia in South East Asia, it is not surprising that the #1 ranking institute is located in this region – the National University of Singapore. This university is home to the Singapore National Eye Centre, which hosts the Singapore Eye Research Institute. These facilities are directly affiliated to the Yong Loo Lin School of Medicine at the National University of Singapore, as well the Duke-NUS Medical School.

1 It is evident from Table 3 of the Supplementary Material that the publications produced at the top two ranked
2 universities – the National University of Singapore ($h_{RE} = 70$) and the University of Melbourne ($h_{RE} = 58$) – are
3 very impactful in the refractive error research domain; this is illustrated by considering that the institutional
4 h_{RE} -index gap is 18 between ranks #1 and #3, and 24 between ranks #3 and #25.

10 **Top countries**

12 Table 4 of the Supplementary Material lists the top 25 countries, ranked by h_{RE} -index, with ties resolved by
13 paper count (also shown). The top four countries – USA, Australia, UK and Singapore –stand out in terms of
14 national impact in refractive error research. That the USA (h_{RE} -index = 127) is the leading country by a wide
15 margin in terms of both impact and volume of output is unsurprising in view of the large population size and
16 leading position of the USA in medical research.

22 **Prominent journals**

24 The 25 most impactful journals publishing refractive error-related articles are listed in Table 5 of the
25 Supplementary Material, ranked by h_{RE} -index, with ties resolved by paper count (also shown). Of these,
26 thirteen are ophthalmology-based (i.e. having ‘ophthalmology’ or ‘surgery’ in the journal title), eight are non-
27 discipline-specific vision science journals, three are optometry journals, and one is a general science journal.

33 The most impactful journals are *Ophthalmology* (h_{RE} -index = 96) and *Investigative Ophthalmology and Visual*
34 *Science* (h_{RE} -index = 93). There is then a very large gap to third-ranked *Journal of Cataract and Refractive*
35 *Surgery*, after which incremental decreases in h_{RE} -index are much smaller. Three optometry journals appear in
36 the top 25 listing – *Optometry and Vision Science* (ranked #4), *Ophthalmic and Physiological Optics* (#10) and
37 *Clinical and Experimental Optometry* (#22).

43 **Conclusions**

45 A key area of interest within the refractive error literature is the prevalence of myopia, both world-wide and in
46 South-East Asia in particular.² Other important areas of research include the aetiology of myopia – especially as
47 it pertains to the impact of excessive near work – and the anatomical and physiological determinants of patterns
48 of eye growth ametropia.¹ As well, numerous papers are drawing attention to the various forms of ocular
49 pathology – such as cataract, glaucoma, macular degeneration, retinal holes and choroidal neovascularisation –
50 associated with myopia and high myopia.¹⁰

57 This publication of bibliometrics relating to refractive error has served to identify the leaders in this field of
58 research, who should be acknowledged and celebrated for their contributions. This work has also revealed the
59 most impactful papers, institutions, countries and journals in refractive error research, and can perhaps serve as

a useful baseline reference as well as a benchmark for excellence as developments in the field are monitored in the future.

The present authors have demonstrated previously that optometry dominates the field of contact lens research;⁵ however, optometry is not the primary driver of refractive error research, despite correction and management of refractive errors being a core aspect of optometric clinical practice. Rather, refractive error research is a shared endeavour involving input from optometrists, ophthalmologists, orthoptists and epidemiologists, with a lesser, but still critically important input from geneticists, cell biologists and other disciplines.

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[Figure caption]

Figure 1. Number of papers in the field of refractive error published each year between 1970 and 2020.

For Review

Supplementary Material

Table 1. Top 25 most cited refractive error-related articles, ranked by citation count.

Rank	Title	First author	Journal	Yearvolume & pages	Citations
1	Global data on visual impairment in the year 2002	Serge Resnikoff	Bulletin of the World Health Organization	2004 82; 844-51	2,866
2	Causes and prevalence of visual impairment among adults in the United States	Nathan Congdon	Archives of Ophthalmology	2004 122; 477-85	1,888
3	Global estimates of visual impairment: 2010	Donatella Pascolini	British Journal of Ophthalmology	2012 96; 614-8	1,725
4	Power vectors: An application of Fourier analysis to the description and statistical analysis of refractive error	Larry Thibos	Optometry and Vision Science	1997 74; 367-75	733
5	Global prevalence of myopia and high myopia and temporal trends from 2000 to 2050	Brien Holden	Ophthalmology	2016 123; 1036-42	713
6	Myopia	Ian Morgan	The Lancet	2016 379; 1739-48	675
7	Outdoor activity reduces the prevalence of myopia in children	Kathryn Rose	Ophthalmology	2008 115; 1279-85	631
8	The relationship between glaucoma and myopia: The Blue Mountains Eye Study	Paul Mitchell	Ophthalmology	1999 106; 2010-5	628
9	Homeostasis of eye growth and the question of myopia	Joshua Wallman	Neuron	2004 43; 447-68	605
10	Prevalence and risk factors for refractive errors in adult Chinese in Singapore	Teck Yee Wong	Investigative Ophthalmology and Visual Science	2000 41; 2486-94	590
11	Global magnitude of visual impairment caused by uncorrected refractive errors in 2004	Serge Resnikoff	Bulletin of the World Health Organization	2008 86; 63-70	588
12	Enhanced depth imaging optical coherence tomography of the choroid in highly myopic eyes	Takamitsu Fujiwara	American Journal of Ophthalmology	2009 148; 445-50	562
13	Myopia and associated pathological complications	Seang-Mei Saw	Ophthalmic and Physiological Optics	2005 25; 381-91	540
14	Refractive error and visual impairment in urban children in southern China	Mingguang He	Investigative Ophthalmology and Visual Science	2004 45; 793-9	539
15	Prevalence of myopia in Taiwanese schoolchildren: 1983-2000	Li-Ling Lin	Annals of the Academy of Medicine in Singapore	2004 33; 27-33	524
16	Blindness and visual impairment in an American urban population: The Baltimore Eye Survey	James Tielsch	Archives of Ophthalmology	1990 108; 286-90	517
17	Important causes of visual impairment in the world today	Nathan Congdon	Journal of the American Medical Association	2003 290; 2057-60	508

18	Increased prevalence of myopia in the United States between 1971-1972 and 1999-2004	Susan Vitale	Archives of Ophthalmology	2009 127; 1632-9	502
19	Accommodation, refractive error and eye growth in chickens	Frank Schaeffel	Vision Research	1988 28; 639-57	491
20	Small incision corneal refractive surgery using the small incision lenticule extraction (SMILE) procedure for the correction of myopia and myopic astigmatism: Results of a 6 month prospective study	Walter Sekundo	British Journal of Ophthalmology	2011 95; 335-9	478
21	Prevalence of myopia in the United States	Robert Sperduto	Archives of Ophthalmology	1983 101; 405-7	473
22	Complications of laser in situ keratomileusis for the correction of myopia	Robert Stulting	Ophthalmology	1999 106; 13-20	464
23	Refractive development of the human eye	Robert Gordon	Archives of Ophthalmology	1985 103; 785-9	459
24	The prevalence of refractive errors among adults in the United States, Western Europe, and Australia	John Kempen	Archives of Ophthalmology	2004 122; 495-505	452
25	Myopia and eye enlargement after neonatal lid fusion in monkeys	Torsten Wiesel	Nature	1978 266; 66-8	451

Table 2. Top 25 authors of refractive error-related papers, ranked by author h_{RE} -index.

Rank	Author	h_{RE} -index	Paper count
1	Seang-Mei Saw	58	166
2	Paul Mitchell	47	95
3	Tien Yin Wong	44	106
4	Karla Zadnik	38	58
5	Dennis Lam	35	63
6	Kyoko Ohno-Matsui	34	101
7	Donald Mutti	34	66
8	Frank Schaeffel	33	70
9	Jorge Alió	32	73
10	Terri Young	32	56
11	Neville McBrien	31	42
12	Earl Smith III	30	55
13	Thomas Norton	30	46
14	Jost Jonas	29	76
15	Ian Morgan	29	49
16	Donald Tan	29	47
17	Jianhua Wang	28	39
18	Tin Aung	27	37
19	Gus Gazzard	26	32
20	Ching-Yu Cheng	25	47
21	Hugh Taylor	25	43
22	Ronald Klein	25	31
23	Kathryn Rose	25	31
24	Jeremy Guggenheim	24	63
25	Katrina Schmid	23	52

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Table 3. Top 25 institutions from where refractive error-related papers were published, ranked by institution h_{RE} -index.

Rank	Institution	Country	h_{RE} -index	Paper count
1	National University of Singapore ^a	Singapore	70	315
2	University of Melbourne ^b	Australia	58	269
3	University of Sydney	Australia	52	128
4	Johns Hopkins University ^c	United States	51	182
5	University of Houston	United States	49	149
6	University College London ^d	United Kingdom	48	162
7	National Institutes of Health/National Eye Institute	United States	44	103
8	Chinese University of Hong Kong ^e	Hong Kong	43	151
9	Ohio State University	United States	43	123
10	Brien Holden Vision Institute ^f	Australia	41	169
11	Sun Yat-Sen University ^g	China	40	228
12	Queensland University of Technology	Australia	40	139
13	Hong Kong Polytechnic University	Hong Kong	38	136
14	Cardiff University	United Kingdom	36	93
15	University of Alabama at Birmingham	United States	36	74
16	University of New South Wales	Australia	35	144
17	University of California, Berkeley	United States	35	91
18	New England College of Optometry	United States	34	108
19	Tokyo Medical and Dental	Japan	32	98
20	Institute of Ophthalmology at Alicante	Spain	32	74
21	Australian National University	Australia	32	72
22	Wenzhou Medical University	China	31	146
23	Capital Medical University ^h	China	31	124
24	University of Heidelberg	Germany	30	109
25	Miguel Hernández University of Elche	Spain	28	73

a. Includes National University of Singapore; Faculty of Medicine, Singapore Eye Research Institute; Singapore National Eye Centre; Duke-NUS Medical School Singapore; and Yong Loo Lin School of Medicine.
b. Includes Centre for Eye Research Australia; and Royal Victorian Eye and Ear Hospital.
c. Includes Johns Hopkins Bloomberg School of Public Health; School of Medicine and Wilmer Eye Institute.
d. Includes Moorfield Eye Hospital NHS Foundation Trust; and UCL Institute of Ophthalmology.
e. Includes Hong Kong Eye Hospital.
f. Includes Vision Cooperative Research Centre.
g. Includes Zhongshan Ophthalmic Centre.
h. Includes Beijing Tongren Hospital

Table 4. Top 25 countries from where refractive error-related papers were published, ranked by country h_{RE} -index.

Rank	Country	h_{RE} -index	Paper count
1	USA	127	2,493
2	Australia	90	835
3	UK	79	879
4	Singapore	70	345
5	Germany	65	512
6	China	64	1,284
7	Japan	59	446
8	Hong Kong	54	299
9	Spain	50	473
10	France	44	195
11	Italy	42	252
12	Canada	41	243
13	Taiwan	38	212
14	The Netherlands	38	151
15	Denmark	33	90
16	South Korea	32	297
17	India	31	306
18	Israel	29	102
19	Switzerland	29	82
20	Greece	28	96
21	Turkey	26	187
22	Iran	25	222
23	Brazil	25	106
24	Finland	25	55
25	Ireland	22	63

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Table 5. Top 25 journals publishing refractive error-related papers, ranked by journal h_{RE} -index.

Rank	Journal	h_{RE} -index	Paper count
1	Ophthalmology	96	391
2	Investigative Ophthalmology and Visual Science	93	694
3	Journal of Cataract and Refractive Surgery	64	722
4	Optometry and Vision Science	62	473
5	Journal of Refractive Surgery	58	649
6	British Journal of Ophthalmology	56	263
7	Vision Research	56	163
8	Archives of Ophthalmology/JAMA Ophthalmology	56	136
9	American Journal of Ophthalmology	52	226
10	Ophthalmic and Physiological Optics	41	240
11	Experimental Eye Research	34	97
12	Eye	31	128
13	Acta Ophthalmologica	30	141
14	Graefe’s Archive for Clinical and Experimental Ophthalmology	28	134
15	Molecular Vision	27	89
16	PLOS One	26	159
17	Ophthalmic Epidemiology	26	98
18	Retina	25	66
19	Current Eye Research	24	98
20	Refractive and Corneal Surgery	24	60
21	Acta Ophthalmologica Scandinavica	23	40
22	Clinical and Experimental Optometry	22	135
23	Cornea	22	81
24	Clinical and Experimental Ophthalmology	20	80
25	Japanese Journal of Ophthalmology	20	50

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