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What does medical research on Ramadan intermittent fasting tell us? Bibliographic mapping analysis of seven decades (1952–2021) and future directions

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Abstract

There is a large body of research focused on various aspects related to Ramadan intermittent fasting (RIF) and human health and disease. This study aimed to quantify the bibliometric parameters of RIF medical research over the past seven decades and explore these parameters qualitatively via text mining analysis. We used the Scopus search engine to identify published articles related to RIF from inception to December 31, 2021. All types of research articles were included. Scientometric and bibliometric parameters were determined using Excel, Biblioshiny, and VOSviewer. The Scopus search returned 1916 relevant articles. Most citations pertained to publications from the last two decades, and most publications were original research articles. These publications had received around 27,000 citations, and the 20 most prolific publishing journals had an h-index of 112.25. More than one-third of all medical publications were in open-access journals. There was a 13-fold increase in medical research on RIF over the past few decades. We identified the 10 most prolific publishing countries, institutes, journals, and authors. This is the first comprehensive bibliometric analysis of medical research related to RIF. The research gaps identified will inform future research directions and foster collaborative research activities.

Introduction

Currently, Muslims constitute the world's second-largest religious group. There are an estimated 2.0 billion Muslims, accounting for about 25% of the 8 billion global population (WorldPolulationReview 2022). Every year, the Islamic holy month of Ramadan is observed by more than 1.5 billion Muslims worldwide (Abdelrahim et al. 2021). During Ramadan, Muslims must refrain from eating, drinking, smoking, and sexual activity from dawn to dusk each day, for about 11–22 hours depending on the geographical location and solar season. This holy month is also a dedicated time for Muslims to practice humility and increase their acts of worship and spirituality. Ramadan has attracted extensive research attention over the years because of its impact on human health, especially given its unique intermittent fasting (IF) model.

Intermittent fasting (IF) has been linked with numerous positive health effects such as prevention of metabolic, inflammatory and degenerative diseases (Mattson, Longo, and Harvie 2017; Patterson and Sears 2017; De Cabo and Mattson 2019; Di Francesco et al. 2018). Different regimens are presented for IF, including time-retracted feeding, alternate-day fasting and religious forms, including Ramadan IF (RIF) (Patterson and Sears 2017). A growing body of evidence, including original research and meta-analyses supports the disease-preventing and health-improving effects of RIF on healthy as well as overweight/obese adults. These effects include reducing body weight (Faris, Jahrami, BaHammam, et al. 2020), changing body composition and lowering body fat (Fernando et al. 2019) with emphasis on visceral adiposity (Faris, Madkour, et al. 2019), improving liver functions (Faris et al. 2021), ameliorating the metabolic syndrome components, improving cardiometabolic risk factors (Jahrami et al. 2021), normalizing glucometabolic markers (Faris, Jahrami, BaHammam, et al. 2020), and alleviating inflammatory and oxidative stress markers (Faris, Jahrami, et al. 2019; Faris, Kacimi, Al-Kurd, et al. 2012; Faris, Hussein, et al. 2012). Alongside, the drastic shifts in dietary and lifestyle habits accompanying the

changes in circadian rhythm (BaHammam and Almeneessier 2020), sleep quality (Faris, Jahrami, Alhayki, et al. 2020) and food selections (Shatila et al. 2021), are also concomitant with changes in the gene expressions of multiples genes that are related circadian rhythm such as *CLOCK* gene (Ajabnoor et al. 2017), antioxidant and metabolism-controlling genes (*SIRT1, SIRT3, TFAM, SOD2 and Nrf2*)(Madkour et al. 2019) and fat mass and obesity-associated protein gene *FTO* (Mohamed I. Madkour Zaher 2022).

Pregnant and lactating women, children before puberty, and those with certain health conditions such as patients with diabetes are exempt from fasting during Ramadan; however, some of these groups still choose to fast during Ramadan and may face complications (Abdelrahim et al. 2021). Therefore, the impact of RIF has been extensively researched regarding medical recommendations for these population groups (Hassanein et al. 2022; Mahmood et al. 2022). In addition to food restriction, Ramadan involves changes in sleeping habits (Faris, Jahrami, Alhayki, et al. 2020), eating behaviors and food selections (Shatila et al. 2021), and increased acts of spirituality (Pathy et al. 2011; Ali Khan et al. 2018). The large body of health topics related to RIF mean that there is broad research potential on physiological and behavioral changes during this Islamic holy month (Faris and Assaad-Khalil). An enhanced scientific approach to RIF may therefore offer a potential turning point for the health of those who observe this holy month.

Assessing existing literature on RIF may offer clear directions for further research on Ramadan. To date, there has been no comprehensive quantitative and qualitative analysis of existing research on RIF in the general context of health. Therefore, this study explored existing scientific literature on RIF and its impact on health via a bibliometric analysis and text mining. Bibliometrics is a systemic statistical analysis of existing literature in a given field, its general scientific nature, and its course of development over time (Wallin 2005). Such an analysis can be used to shed light on the most prolific research countries, institutions, and authors, as well as the most cited relevant publications. Bibliometrics can be coupled with text mining, which refers to the analysis and modeling of unstructured natural language text present in literature through machine learning and linguistics (Talabis et al. 2015). Text mining can help in processing a large amount of textual data from a scientific database, create text clusters, and extract meaningful patterns or concepts for the overall existing body of scientific literature. The key objectives of this study were to analyze quantitative and qualitative trends in Ramadan medical research, including: annual growth rates; numbers of publications and citations; top contributing authors, institutions, and countries; highest publishing journals for research on RIF; and thematic research hotspots on RIF in terms of health. This comprehensive analysis will provide insights for future researchers on medical and health topics related to RIF that have been explored and highlight any gaps that remain to be addressed.

Materials And Methods

Design

The present study used general bibliometric methods for a quantitative analysis of the scientific output of the literature on RIF. This was complemented by text mining, which provides a qualitative outlook on the

research patterns of RIF, thematic fields, and top publishing authors and countries. The methodology and analysis were based on several previous bibliometric studies (Talabis et al. 2015; Ho et al. 2020; Kalantari et al. 2017; Song, Wu, and Wang 2021; Beshyah and Beshyah 2019).

Data collection and search strategy

The bibliographic database on RIF research was extracted from the Scopus platform (MacKellar and Vigerust 2016), on November 14, 2021. Scopus provides a comprehensive database of source-neutral abstracts and citations, with over 25,100 titles from more than 5000 international publishers in different research fields (Elsevier 2020). Figure 1 presents the data extraction and analysis steps. The search strategy used for this study (Fig. 2) included the word “Ramadan” and different spellings, such as “Ramadhan” and “Ramazan.” We also included other phrases that are commonly used to refer to the Ramadan month of fasting, such as “Islamic fasting,” “diurnal fasting,” “consecutive 30 days of fasting,” and “religious fasting.” The search query template (TITLE-ABS-KEY) offered by Scopus was used to search these terms in the titles, abstracts, and keywords of publications in the database. To restrict the search to publications related to RIF and health, we excluded non-medical subject areas, such as social sciences, arts and humanities, agricultural sciences, environmental sciences, mathematics, engineering, economics, computer sciences, physics, chemistry, earth, and planetary sciences, decision sciences, and other similar fields. We did not restrict the time frame, and the scope of the publication years ranged from 1952 to 2021, with the first publication on RIF in the Scopus database dating 1952. The search returned 1916 publications.

Data management and statistical analysis

The Scopus database of relevant publications was extracted and analyzed using the Bibliometrix package (Biblioshiny software) in R (Aria and Cuccurullo 2017) and converted into a bibliometrix file for further analysis and chart creation in Microsoft Excel 2016. The quantitative parameters analyzed included yearly output, document type, number of citations, publication language, the most cited publications, and the most prolific countries, institutions, journals, and authors. The measurements were ranked using Standard Competition Ranking (SCR), as used in other bibliometric publications. The quality of the presented journals was assessed by the SCImago Journal Rank (SJR). Although Scopus provides sophisticated algorithmic profiling of its publishing authors, not all publications are accurately matched to a single author profile if an author has different abbreviations for their name. This results in authors seemingly having fewer publications on the Scopus platform than they actually do, as their publications are dispersed among their different author profiles. For example, abbreviations for Alawadi F. (10 Ramadan-related publications): Al-awadi F. (one publication), Al awadi F. (two publications), Al awadi FF. (two publications) all pertain to a single author (Al-Awadi, Fathehya Fardallah; 15 publications) on Scopus. Therefore, a thesaurus of all author name abbreviations and the number of relevant publications was extracted using VOSviewer software (Eck and Waltman 2007) and used to merge author names by cross-checking their respective Scopus profiles. This helped in obtaining a more accurate report of the number of publications contributed by each author in the Scopus database. To identify the themes

covered by the most prolific authors, the top keywords in their publications were identified using Scival, which is functionality for in-depth analysis offered by Scopus.

In addition, text mining was performed using the VOSviewer software, and is presented in collaboration or co-occurrence networks for different parameters (authors, countries, and index words) with different analytical visual overlays. To create a map of diverse thematic hotspots of RIF research, the top 500 index words (those with at least 16 occurrences) were used as a unit of analysis; however, 461 index words were included in the final map after selective filtering. Generic and non-thematic index words (e.g., human, male, female, age, article, and others), country names, and journal names were excluded to provide a clear presentation of research hotspots. Different spellings of medical terminology (e.g., hypoglycemia and hypoglycemia) were merged using the VOSviewer thesaurus functionality. In the resulting map, the distance between the index words indicated the strength of co-occurrence in the same publications. Collaboration network maps of the most prolific authors (those with at least 15 publications) and countries (those with at least 25 publications) were also created (Waltman 22 July 2021). Color-coded clusters of all maps were generated using VOSviewer, with a resolution level of 1.00. Finally, the world map charts were created using Datawrapper, based on the data from the Scopus analysis results.

Results And Discussion

Document type, yearly output, publication language, and citations

Globally, there were 1916 medical research publications on RIF over the last seven decades, with the first publication from 1952 and the majority (97%, n = 1865) of publications during the last three decades (1989–2021) (Fig. 3). The peak of citations was for publications from 1975, but the majority of citations (85%, 22,565 citations) pertained to publications from the last two decades (1997–2019). Figure 4 presents an abstract assortment of the general bibliometric nature of the publications. The annual production growth rate was calculated as 8.9%. Most publications were original research articles (74.4%), followed by reviews (10.2%), letters (6.4%), notes (1.9%), editorials (1.8%), short surveys (1.6%), conference papers (1.4%), erratum (1.3%), book Chaps. (0.9%), and books (0.1%). Most publications were in the English language (91%), followed by French (3%) and German (1.1%). Medicine was the dominant subject area for filtered publications (60.2%), followed by biochemistry (10.7%), nursing (9.8%), agricultural and biological sciences (5.3%), health professions (3.9%), pharmacology (2.9%), neuroscience (2.3%), multidisciplinary (1.4%), psychology (1.4%), immunology and microbiology (1.2%), and others (0.8%). The 1916 identified publications had received around 27,000 citations in total, and the top 20 journals publishing these articles had an h-index of 112.25.

On January 31, 2022, 35% of the publications on Ramadan were with open-access (OA) journals. There was a steep increase over the last two decades from 16% of OA publications in 2000–2006 to around 50% in 2016–2021. This may be explained by governmental support for OA publishing in many Arab and

Islamic countries as part of the endeavor to improve the ranking and branding of universities in those countries (Khallaf 2017; Boufarss 2020).

Authors and sources

Ramadan research increased over the last three decades from about 10 publications per year during the 1990s to an average of 130 publications for 2020/2021. As shown in Fig. 5, RIF has been extensively researched all over the world with publications from 90 countries/regions as of January 31, 2022, especially in Muslim-dominated countries. The most contributed publications were from the UK and Saudi Arabia (around 250 and 200 publications, respectively). This was followed by the US and Iran (around 180 publications each), Turkey (around 160 publications), Tunisia (around 150 publications), and the United Arab Emirates (around 130 publications).

International co-authorship networks were identified in four clusters, as presented in Fig. 6. The analysis is based upon the frequency of co-authorship between Ramadan researchers and represented in terms of the authors' respective affiliated countries. Several clusters appeared to consist of regionally close countries, particularly the green- and blue-colored clusters. The green cluster comprised countries located in South/South-east Asia, along with the geographically nearby Australia. This cluster also contained Turkey, which is located in West Asia/Middle East and is strongly linked to the other Middle Eastern countries in the blue cluster. Similarly, the blue cluster mostly included the countries bordering Saudi Arabia. The red cluster contained regionally close countries surrounding the Mediterranean Sea, including Italy, Spain, Tunisia, and France. Many authors affiliated with France had particularly strong links with authors from Tunisia, Morocco, and Canada, which may be attributed to French being the second most common language of Ramadan-related publications. Iran-affiliated authors appeared to have the highest co-authorship solely with US-affiliated authors, which was represented by the strong link between the two countries. US- and UK-affiliated authors appeared to have strong links with all countries presented in the figure.

Figure 7 adds a visual overlay of the average publication years for the aforementioned countries, which mostly fell in 2012–2016, as analyzed by VOSviewer software. The majority of publications from Canada, the United Arab Emirates (UAE), Bahrain, Italy, Indonesia, and Bangladesh were relatively recent compared with those from the UK, Iran, and Saudi Arabia, which were the highest publishing countries. Figure 8 shows an overlay of average citations received per publication. France, Morocco, Kuwait, Lebanon, and Algeria had the highest average citations per publication, with Kuwait having the most with an average of 31 citations per publication. Most other countries had 15–20 citations per publication on average. To correct for the fact that older documents had had more time to receive citations, the data were normalized in VOSviewer and presented in Fig. 9. After normalization, the UAE, Bahrain, Jordan, Kuwait, and Italy had the highest citations per publication annually, with the UAE and Bahrain leading at around 1.9 citations per publication per year.

In terms of institutions producing Ramadan-related research (Table 1), Tehran University of Medical Sciences (Iran) and King Saud University (Saudi Arabia) were the top two institutions. These institutions

were followed by Dubai Hospital (UAE) and Baqai Medical University (Pakistan). Table 2 details the top 15 journals that published on RIF during 1952–2021, along with their citations, citation/article ratio, SJR (SCImago Journal Rank), and h-Index. *Diabetes Research and Clinical Practice*, *Saudi Medical Journal*, *Nutrients*, *Tunisiaie Medicale*, and *PLoS ONE* were the top five journals for publishing Ramadan research. However, on a citation basis, *Diabetes Care* was in the lead (1074 citations), followed by *Diabetes Research and Clinical Practice* (906 citations) and *Journal of Sports Sciences* (591 citations).

Table 1
Top 10 prolific institutions in terms of published Ramadan-related medical research over the last seven decades (1952–2021).

SCR	Affiliation	Articles
1	Tehran University of Medical Sciences (Iran)	68
2	King Saud University (Saudi Arabia)	66
3	Dubai Health Authority (UAE)	47
4	Baqai Medical University (Pakistan)	37
5	Kuwait University (Kuwait)	32
6	University of Genoa (Italy)	31
7	University of Sharjah (UAE)	31
8	Shahid Beheshti University of Medical Sciences (Iran)	30
9	Cairo University (Egypt)	29
10	Universiti Putra Malaysia (Malaysia)	27
*SCR: Standard Competition Ranking (ranking in which equal institutions were given the same ranking number).		

Table 2
Top 20 publishing journals on Ramadan medical research over the last seven decades (1952–2021)

SCR[1]	Source	Articles		Citations	C/A[2]	SJR[3]	H-index
		n	%				
1	Diabetes Research and Clinical Practice	77	4.02	906	11.77	1.605	114
2	Saudi Medical Journal	33	1.72	511	15.48	0.437	51
3	Nutrients	25	1.30	284	11.36	1.418	115
4	Journal of Sports Sciences	24	1.25	591	24.63	1.208	137
5	PLoS ONE	23	1.20	142	6.17	0.99	332
5	Tunisie Medicale	23	1.20	400	17.39	0.199	18
6	Pakistan Journal of Medical Sciences	21	1.10	149	7.10	0.316	30
7	Eastern Mediterranean Health Journal	20	1.04	250	12.50	0.442	47
8	Annals of Saudi Medicine	19	0.99	391	20.58	0.373	44
8	The British Medical Journal	19	0.99	312	16.42	1.831	429
9	International Journal of Clinical Practice	18	0.94	105	5.83	0.756	98
9	Practical Diabetes International	18	0.94	420	23.33	0.172*	0
10	Biological Rhythm Research	16	0.84	211	13.19	0.252	33
11	Diabetes and Metabolic Syndrome: Clinical Research and Reviews	15	0.78	580	38.67	0.684	40
12	Diabetic Medicine	15	0.78	95	6.33	1.474	145
13	Asian Journal of Sports Medicine	14	0.73	144	10.29	0.216	27
13	British Journal of Nutrition	14	0.73	311	22.21	1.073	118
13	Journal of the Pakistan Medical Association	14	0.73	589	42.07	0.242	43
15	Diabetes Care	13	0.68	1074	82.62	6.636	363
16	Singapore Medical Journal	12	0.63	545	45.42	0.452	61

[1]SCR: Standard Competition Ranking (ranking in which equal journals were given the same ranking number).

[2]C/A: citations and articles ratio (citation frequency divided by the article frequency for each journal).

[3]SJR: SCImago Journal Rank.

Among the top 20 cited publications, diabetes management during Ramadan was the most cited topic, followed by the impact of Ramadan on human health and its effects on body weight and metabolism. Other highly cited research fields included the impact of Ramadan on human circadian rhythms, cardiometabolic profile, and athletic physical performance. This reflected the growing attention to diverse research on human health during Ramadan, especially as Muslims are one of the most prominent religious populations worldwide. The most cited publications were the EPIDIAR study (Salti, Bénard, Detournay, Bianchi-Biscay, Le Brigand, Voinet, Jabbar, et al. 2004), a diabetes management article (Al-Arouj et al. 2010), and a study on metabolic and weight changes during Ramadan (Ziaee et al. 2006) (Table 3).

Table 3
Top cited articles on Ramadan medical research over the last seven decades

SCR[1]	Authors	Title	Citations	Journal	Document type
1	Salti, Bénard, Detournay, Bianchi-Biscay, Le Brigand, Voinet, and Jabbar 2004	A population-based study of diabetes and its characteristics during the fasting month of Ramadan in 13 countries: Results of the Epidemiology of Diabetes and Ramadan 1422/2001 (EPIDIAR) study	450	Diabetes Care	Article
2	Al-Arouj et al. 2010	Recommendations for management of diabetes during Ramadan: Update 2010	241	Diabetes Care	Note
3	Ziaee et al. 2006	The changes of metabolic profile and weight during Ramadan fasting	192	Singapore Medical Journal	Article
4	Trepanowski and Bloomer 2010	The impact of religious fasting on human health	190	Nutrition Journal	Review
5	Ati, Beji, and Danguir 1995	Increased fat oxidation during Ramadan fasting in healthy women: An adaptative mechanism for body-weight maintenance	189	American Journal of Clinical Nutrition	Article
6	Al-Arouj et al. 2005	Recommendations for management of diabetes during Ramadan	176	Diabetes Care	Review
6	Leiper, Molla, and Molla 2003	Effects on health of fluid restriction during fasting in Ramadan	176	European Journal of Clinical Nutrition	Article
7	Bogdan, Bouchareb, and Touitou 2001	Ramadan fasting alters endocrine and neuroendocrine circadian patterns. Meal-time as a synchronizer in humans?	168	Life Sciences	Article

SCR[1]	Authors	Title	Citations	Journal	Document type
8	Adlouni et al. 1997	Fasting during Ramadan induces a marked increase in high-density lipoprotein cholesterol and decrease in low-density lipoprotein cholesterol	157	Annals of Nutrition and Metabolism	Article
9	Bravis et al. 2010	Ramadan education and awareness in diabetes (read) programme for Muslims with type 2 diabetes who fast during Ramadan	156	Diabetic Medicine	Article
9	Roky et al. 2004	Physiological and chronobiological changes during Ramadan intermittent fasting	156	Annals of Nutrition and Metabolism	Review
10	Hassanein et al. 2017	Diabetes and Ramadan: Practical guidelines	152	Diabetes Research and Clinical Practice	Review
11	Trepanowski et al. 2011	Impact of caloric and dietary restriction regimens on markers of health and longevity in humans and animals: A summary of available findings	139	Nutrition Journal	Review
12	Roky et al. 2001	Sleep during Ramadan intermittent fasting	129	Journal of Sleep Research	Article
13	Faris, Kacimi, Al-Kurd, et al. 2012	Intermittent fasting during Ramadan attenuates proinflammatory cytokines and immune cells in healthy subjects	126	Nutrition Research	Article
15	Sweileh et al. 1992	Body composition and energy metabolism in resting and exercising Muslims during Ramadan fast	124	Journal of Sports Medicine and Physical Fitness	Article

SCR[1]	Authors	Title	Citations		Journal	Document type
16	Iraki et al. 1997	Ramadan diet restrictions modify the Circadian time structure in humans. A study on plasma gastrin, insulin, glucose, and calcium and on gastric pH	120		Journal of Clinical Endocrinology and Metabolism	Article

[1]SCR: Standard Competition Ranking (ranking in which equal journals were given the same ranking number).

The top 17 authors (top 10 by SCR) with the most publications focused on Ramadan are presented in Table 4. The most prolific author (Hassianein M.) had published 51 Ramadan-related articles, followed by Chtourou H. (44 publications) and Chamari K. (34 publications). Three other authors (Bahammam AS., Bragazzi NL., and Souissi N.) published around 30 articles each, followed by seven authors with around 20 articles each and four authors with around 15 publications each. The remainder (approximately 6493 authors) had published less than 13 articles each. An analysis of the top keywords used in the publications showed that the majority of the most prolific authors explored Ramadan in the context of diabetes or athletic performance. Fewer authors were interested in relationships between RIF and circadian rhythms and weight change. The collaboration networks of the top 25 authors with at least 13 publications are presented in Fig. 10, with five color-coded clusters indicative of frequent collaboration among specific authors. From the authors' respective affiliations, it could be inferred that most authors' clusters were based locally. For example, the yellow author cluster (Chtourou H., Aloui A., and Souissi N.) in Tunisia and the red cluster (Hassanein M., Hanif W., Ghouri N., Chowdhury TA., and Beshyah SA.) were predominantly affiliated with the UK, the UAE, or both. The greatest extent of international collaboration was seen among authors in the green cluster, as they were affiliated with an array of countries (e.g., Chamari K.: Qatar, Tunisia, Ireland; Chaouachi A.: Vietnam, New Zealand, Tunisia; Aziz AR.: Singapore). The level of international collaboration was lower than expected, especially as RIF is practiced globally. In addition, the variation in fasting daytime hours (Azahhaf 2021), Muslim ethnicities, and cultures across the world call for more collaborative controlled studies to allow better assessment of the impact of Ramadan.

Table 4
Top authors with the highest number of publications on Ramadan medical research over the last seven decades

SCR[1]	Authors	Articles		Citations[4]	Countries of affiliation	Top three key-phrases[5]
		(authors' name variations merged[2])	In Scopus[3]			
1	Hassanein M.	51	45	1495	UK, US, UAE	Insulin and non-insulin-dependent diabetes; Diabetes
2	Chtourou H.	42	40	628	Tunisia	Soccer player; Athletes; Athletic performance
3	Chamari K.	34	33	861	Tunisia, France, Italy, Qatar, Ireland	Athletic performance; Anaerobic exercise; Soccer player
4	Bahammam AS.	29	10	594	Canada, KSA	Sleep; Disorders of excessive somnolence; Circadian rhythm
5	Bragazzi NL.	28	25	290	Italy, France, Russia, Canada, Morocco, Palestine,	Systemic review; Athletes; Chronic kidney failure
5	Souissi N.	28	27	600	France, Tunisia	Soccer player; Athletic performance; Circadian rhythm
6	Chaouachi A.	23	23	671	Tunisia, Vietnam, New Zealand	Soccer player; Athletic performance; Time of day
7	Trabelsi K.	21	19	222	Tunisia, Bahrain, Austria	Strength training; Sleep pattern; Dietary carbohydrate.
8	Beshyah S.	19	19	255	UK, UAE	Hypoglycemia; Diabetes; Non-insulin-dependent diabetes

SCR[1]	Authors	Articles		Citations[4]	Countries of affiliation	Top three key-phrases[5]
		(authors' name variations merged[2])	In Scopus[3]			
8	Aloüi A.	19	18	229	Tunisia	Soccer player; Athletic performance; Physical capacity
8	Ahmedani MY.	19	16	189	Norway, Pakistan	Diabetes; Pakistan; Eating habits
9	Faris ME.	17	11	333	Jordan, KSA, UAE	Caloric restriction; Meta-analysis; Weight control
9	Aziz AR.	17	15	399	Singapore	Athletes; Athletic performance; Fitness
10	Kalra S.	16	16	68	India, Canada, Pakistan	India; Patient care; Diabetes
10	Hanif W.	15	16	505	UK	Diabetes; Non-insulin dependent diabetes; Insulin replacement therapy
10	Bener A.	15	15	402	US, UK, KSA, Kuwait, UAE, India, Turkey, Qatar	NA
10	Al-Awadi FF.	15	10	121	UAE	Diabetes type 2; Continuous glucose monitoring; Diabetes

SCR[1]	Authors	Articles (authors' name variations merged[2])	Articles In Scopus[3]	Citations[4]	Countries of affiliation	Top three key-phrases[5]

[1]SCR: Standard Competition Ranking (ranking in which authors with an equal number of publications were given the same ranking number).

[2]Several authors had different variations of how their names appeared in the Scopus database. These names with their respective publications were merged to calculate the accurate number of publications for each author.

[3]Number of publications presented by the available analysis functionality in Scopus.

[4]Number of citations corresponding to the merged number of publications for the respective author.

[5]Top key phrases identified via the Scopus Scival function. This corresponds to the author's publications number identified by the Scopus artificial intelligence and was limited to 2011–2021. Scival was not able to identify the keywords used by Bener A.

Figure 11 show an overlay of the average production year. The VOSviewer software showed that most of the top prolific authors had their Ramadan-related publications clustering around 2010–2018. The majority of these authors had recent publications (Faris ME., Bragazzi NL., Ahmedani MY., Ghouri N., Al-awadi FF., and Kalra S.). In addition, six authors (Hassanein M., Chowdhury TA., Beshyah SA., Hanif W., Chtourou H., and Bahammam AS.) tended to publish around 2015–2016. This corresponded to the exponential growth in publications over the last three decades.

- Research hotspots and categories

Figure 12. Thematic clusters of the top index words in Ramadan medical research over the last seven decades. The size of the circles and their links reflect the frequency and strength of the connections, respectively. Index words with the same color belong to the same thematic cluster, which reflects their co-occurrences in the same publications.

Table 5
Top 10 indexed words for each thematic cluster of Ramadan medical research over the last seven decades

Cluster	Top 10 occurring index words	Occurrences	Average citations	Average normalized citations	Average publication year
METABOLIC PROFILE (GREEN CLUSTER)	Glucose blood level	389	18.5	1.4	2012.9
	Body weight	353	22.2	1.6	2013.3
	Blood pressure	167	17.6	1.2	2013.6
	Metabolism	145	19.8	1.7	2013.3
	Triacylglycerol blood level	142	26.8	1.6	2011.5
	Cholesterol blood level	141	26.4	1.4	2010.9
	HDL cholesterol	141	27.3	1.6	2012.3
	Pathophysiology	135	14.8	1.4	2015.9
	LDL cholesterol	131	27.0	1.7	2012.9
	Lipids	84	26.5	1.8	2011.5
	Overall	**4345**	**20.6**	**1.5**	**2013.4**
PHYSIOLOGY (YELLOW CLUSTER)	Physiology	227	15.4	1.4	2014.6
	Energy intake	134	30.4	1.8	2011.7
	Food habits	120	27.5	1.5	2010.1
	Physical activity	116	22.1	1.6	2014.7
	Circadian rhythm	114	30.5	1.7	2010.0
	Time	113	28.3	1.7	2011.0
	Dehydration	106	21.9	1.3	2011.7
	Exercise	103	27.2	1.6	2012.4
	Feeding behavior	80	28.6	1.6	2009.1
	Sleep	73	30.9	1.7	2011.5
	Overall	**4309**	**26.4**	**1.5**	**2011.7**
DIABETES (BLUE CLUSTER)	Diabetes mellitus type 2	313	17.9	1.4	2014.1

Cluster	Top 10 occurring index words	Occurrences	Average citations	Average normalized citations	Average publication year
	Hypoglycemia	289	18.2	1.4	2014.5
	Insulin aspart	242	20.1	1.4	2013.4
	Hemoglobin a1c	200	16.6	1.4	2014.9
	Hypoglycemic agents	175	20.3	1.5	2014.3
	Diabetes mellitus type 1	139	18.1	1.3	2014.3
	Glycemic control	115	11.1	1.2	2016.7
	Hyperglycemia	115	18.6	1.4	2014.7
	Metformin	110	22.3	1.7	2014.6
	Sulfonylurea	109	24.0	1.8	2014.2
	Overall	**4224**	**22.4**	**1.7**	**2013.8**
PUBLIC HEALTH[1] (RED CLUSTER)	Diabetes mellitus	238	15.3	1.1	2012.2
	Risk factors	144	16.2	1.4	2013.8
	Lifestyle	98	21.7	1.6	2013.0
	Risk assessment	93	20.3	1.4	2013.7
	Psychology	92	9.7	0.8	2014.4
	Religion and medicine	83	16.4	1.0	2008.1
	Child	78	11.2	0.9	2011.5
	Disease severity	77	10.5	0.9	2014.4
	Incidence	74	21.3	1.4	2014.1
	Adverse event	68	5.7	0.9	2018.1
	Overall	**3743**	**13.3**	**1.1**	**2013.4**
PREGNANCY (PURPLE CLUSTER)	Pregnancy	130	16.6	1.0	2011.1
	Body height	32	10.8	0.9	2015.7
	Gestational age	32	16.3	0.9	2011.8
	Birth weight	25	20.4	1.2	2010.0

Cluster	Top 10 occurring index words	Occurrences	Average citations	Average normalized citations	Average publication year
	Newborn	25	18.1	1.2	2011.3
	Maternal nutrition	23	12.7	0.8	2011.7
	Pregnancy diabetes mellitus	20	13.1	1.5	2017.6
	Echography	17	6.8	0.6	2013.6
	Pregnancy outcome	15	14.6	0.9	2010.4
	Lactation	14	31.0	1.0	2004.5
	Overall	**496**	**16.0**	**1.0**	**2012.2**

[1]Generic words (Ramadan fasting, adult, Islam, Muslim) omitted from the top occurring public health index words list and overall cluster parameter calculations as they were not specifically relevant.

Diabetes

As a consequence of urbanization, population growth, and population aging, diabetes mellitus has continued to rise as a global health burden (Wild et al. 2004), including in Muslim countries. Although the observance of RIF has no adverse effects on glucose homeostasis markers in healthy people, the situation differs for patients with diabetes (Faris, Jahrami, BaHammam, et al. 2020). Diurnal intermittent fasting during Ramadan may impact glucose blood levels and increase the risk for hypoglycemia among people with diabetes (Faris, Jahrami, BaHammam, et al. 2020). Therefore, Islamic law allows unwell individuals for whom fasting may aggravate their condition to be exempt from fasting (Jaleel et al. 2011). However, 79% of Muslims with type 2 diabetes still fasted during Ramadan, as noted in an epidemiological study involving 13 Muslim countries (EPIDIAR) in 2004 (Salti, Bénard, Detournay, Bianchi-Biscay, Le Brigand, Voinet, Jabbar, et al. 2004). This motivated the International Diabetes Federation in collaboration with Ramadan and Diabetes International Alliance to formulate and release special practical guidelines on Ramadan and diabetes in 2021–2022 (Hassanein et al. 2022). This was evident in the high occurrence of relevant keywords in our analyses, including diabetes mellitus type 2 (313 occurrences), hypoglycemia (289 occurrences), and hemoglobin A1C or HbA1c (200 occurrences). Diabetes management including the adjustment of hypoglycemic agents (175 occurrences), insulin (242 occurrences), metformin (110 occurrences), and gliclazide (75 occurrences) were common keywords in this cluster. Ramadan research also focused on the efficacy of patient education (83 occurrences) including blood glucose monitoring (109 occurrences) and patient compliance (67 occurrences). The possible improvements in metabolic status observed during RIF (Tahapary et al. 2020), which is further elaborated below, may be attributed to the intensive research on diabetes.

Metabolic profile

The potential of Ramadan diurnal intermittent fasting to improve body composition and metabolism has also attracted attention in Ramadan many studies (Jahrami et al. 2021; Faris, Jahrami, BaHammam, et al. 2020; Jahrami et al. 2020; Jaleel et al. 2011). In this cluster, Ramadan fasting (373 occurrences) was strongly linked to several keywords: metabolism (145 occurrences), blood glucose level (389 occurrences), blood pressure (167 occurrences), blood triacylglycerol level (142 occurrences), blood cholesterol level (141 occurrences), and body weight (353 occurrences). This suggested that these were the metabolic parameters most commonly addressed by Ramadan researchers, as they were collectively associated with the pathophysiology (135 occurrences) of metabolic diseases, such as obesity (66 occurrences). Furthermore, the impact of RIF on inflammatory markers (Faris, Kacimi, Ref'at, et al. 2012; Mo'ez Al-Islam et al. 2019) (e.g., interleukin-6: 20 occurrences) and oxidative stress (24 occurrences) caused by obesity-related derangements were also evident in Ramadan research. Given the steep rise in metabolic syndrome (18 occurrences) globally (Saklayen 2018), understanding the positive effects of Ramadan on these biological markers (51 occurrences) may be a breakthrough for the health of Muslim populations. As RIF includes abstention from fluids consumption, indicators of kidney function (43 occurrences), such as blood creatinine level (74 occurrences), blood albumin level (26 occurrences), blood potassium levels (34 occurrences), and glomerular filtration rate (24 occurrences) were also comprehensively explored, particularly in fasting patients with kidney disease (11 occurrences) or kidney failure (32 occurrences). Blood parameters that may affect the development of kidney stones and change during RIF, such as blood uric acid levels (77 occurrences) were also frequently researched topics.

Human physiology

Ramadan research was also directed toward the effects of diurnal intermittent dietary abstention and changes in food habits (120 occurrences) during Ramadan on human physiology (227 occurrences) in different biological aspects. An area of particular interest was the change in athletic performance (49 occurrences) in fasting Muslim athletes (51 occurrences) during Ramadan, as shown in this cluster. Most studies explored fasting athletes' adaptation (31 occurrences) and (optimization of) exercise (103 occurrences) to maintain their usual physical performance (29 occurrences) during Ramadan (Maughan et al. 2012). Ramadan research also addressed the changes in body clock or circadian rhythm (114 occurrences) related to fasting, which is strictly time-specific (keyword: time, 113 occurrences) from pre-dawn to dusk. As circadian rhythms are also highly affected by sleep (73 occurrences), sleep time (41 occurrences), fatigue (41 occurrences), and somnolence (20 occurrences) were frequently addressed by Ramadan researchers. In addition, Ramadan research intensively explored changes in dietary consumption among fasting Muslims, particularly energy, carbohydrates, and fluid intakes (134, 70, and 46 occurrences, respectively), physical activity (116 occurrences), and overall body composition (69 occurrences) during Ramadan. Finally, Ramadan research also frequently targeted the topic of dehydration (106 occurrences) during RIF, which was shown to be strongly linked to diabetes-related keywords.

Public health

Ramadan research was also clustered around the relationship between Ramadan and public health (20 occurrences), as reflected by several keywords: disease severity (77 occurrences), disease duration (65 occurrences), disease incidence (74 occurrences), hospitalization (68 occurrences), and prevalence (55 occurrences). Many of the published papers focused on the epidemiology, particularly of diabetes mellitus (238 occurrences), which was shown by its strong link to the keyword “risk factors” (144 occurrences) in this cluster. The lifestyle changes (98 occurrences) that accompany RIF were also of interest in Ramadan epidemiological studies, which may explain the observed changes in health parameters. This was reflected by its strong links to the keywords “body weight,” “blood glucose level,” and “diabetes mellitus type 2” in the other two clusters. As Ramadan involves avoiding immorality, practicing self-control, and focusing on increased acts of worship as well as dietary abstention, the effects of Ramadan on Muslims’ psychological status (92 occurrences) and mental health (Koushali et al. 2013) were also a focal point of this cluster. Finally, Ramadan studies also explored Muslim patients’ attitude (66 occurrences) toward health education (34 occurrences), and the cultural competence of healthcare personnel (65 occurrences) to properly care for fasting Muslim patients during Ramadan, especially in predominantly non-Muslim countries (Abolaban and Al Moujahed 2017).

Maternity

Although the Islamic regulations exempt pregnant and lactating women from fasting, many women opt to observe fasting during Ramadan for personal, religious, or cultural reasons (Faris and Al-Holy 2014; Kridli 2011). Therefore, Ramadan studies also considered the impact of RIF on pregnancy outcomes (130 occurrences), such as newborns’ birth weight (25 occurrences) and gestational age (32 occurrences). Pregnancy was also strongly linked to diabetes-related keywords such as blood glucose level, diabetes mellitus type 1, and diabetes mellitus type 2; this reflected their frequent co-occurrence in Ramadan research.

In terms of citations, there were publications with particular index words that received more citations on average than others in the same cluster, as presented in Fig. 13 after normalization for publication year. For example, in the diabetes cluster, the index words “diabetic medications” (e.g., metformin and sulfonylurea) and “side effects” (e.g., headache, vomiting, nausea, diarrhea, weight gain) attracted the most citations. Index words indicative of lipid profile (e.g., triglycerides, lipids), inflammatory status (e.g., oxidative stress, interleukin 6, inflammation), body weight change (e.g., weight loss, obesity, body mass index) were the most prominent hotspots in the metabolic profile cluster. In the human physiology cluster, most index words received a relatively high number of citations annually on average, especially index words related to dietary habits (e.g., energy intake, carbohydrate intake, protein intake) and circadian rhythms. In the public health cluster, the index words “COVID-19” and “epidemiology” received the highest normalized average citations. An overlay of the publication year, presented in Fig. 14, shows that most of these clusters were thoroughly explored, particularly from the start of the last decade onwards, except for a few index words. Index words that addressed inflammatory status and susceptibility to develop cancer (e.g., tumor necrosis factor, oxidative stress, interleukin 6, inflammation) were some of the commonly

used words in recent research on RIF. In addition, words supportive of the current COVID-19 pandemic (e.g., COVID-19, adverse events, healthcare personnel) were also relatively recently researched fields.

Overall, the fields of diabetes and metabolic disease in the context of RIF have been thoroughly addressed from many different perspectives compared with the other hotspots. The impact of Ramadan on human physiology and public health also appeared to have been intensively studied, although not as expansively. Although the text mining analysis was performed using index keywords, it was surprising not to find the term “chrononutrition.” Chrononutrition is an emerging scientific field that refers to the interplay between nutrition, timed eating patterns, and metabolic health (Flanagan et al. 2021). Given the strict timed nature of RIF, chrononutrition has potential for research in the scope of Ramadan and may be interrelated with both metabolic health, wellness, and sleep quality (BaHammam and Almeneessier 2020). Another neglected area of research is the study of mental health, especially in the context of spirituality during Ramadan (Gilavand 2018).

Various gaps were apparent in the available research concerning the relationship between observing RIF and disease outcomes for patients with chronic illnesses who opt to observe Ramadan. These include cancer, autoimmune and inflammatory bowel diseases, mental health problems, and patients with immune-compromised diseases such as HIV/AIDS who self-decide to observe RIF. This is consistent with the call to direct RIF research toward clinical and basic studies in different health and disease conditions other than nutrition and metabolic disorders (Bandarian et al. 2021).

Future directions

With the innovation of omics techniques that can elaborate on the biological changes accompanying different human life processes, it is rational to apply this multi-disciplinary approach in studying the various changes accompanying RIF. Among these, genomics, proteomics, metabolomics, metagenomics, and transcriptomics are the main omics of interest. Applying these techniques in studying RIF will help in collectively characterizing and quantifying the pools of biological molecules that are released during fasting. This will expand our understanding of the effect of RIF on different health and disease conditions and will help physicians care for Muslim patients in making the right decisions regarding their patient’s fasting during Ramadan. In the non-RIF model, intermittent prolonged fasting showed significant changes in more than 370 metabolites, including plasma amino acids, glycerol, free fatty acids, and ketone bodies which reflect changes in the body’s fuel management under fasting conditions (Rubio-Aliaga et al. 2011). However, only one study showed the various metabolomic changes that accompanied the practice of RIF (Mathew et al. 2014). Our lab work on the metabolomic and lipidomic changes in RIF revealed variable changes in the serum metabolites pertaining to caffeine, amino acids, and fatty acid metabolism, and different ceramides and sphingolipids after starting RIF compared with pre-fasting levels (unpublished data).

At the proteomic level, examining the impact of intermittent fasting (Harney et al. 2019), LC – MS/MS analysis of human plasma for participants on an 8-week intermittent fasting regimen revealed that this pattern was associated with significant changes in different apolipoproteins involved in lipoprotein

metabolism with a significant decrease in plasma triglycerides after intermittent fasting. However, In the context of RIF, Mindikoglu and colleagues published two important works that showed RIF triggered an anticancer serum proteome response (Mindikoglu et al. 2020) and upregulated key regulatory proteins for the circadian rhythm, lipid and glucose metabolism, circadian clock, cytoskeleton remodeling, DNA repair, and the immune system and cognitive function in healthy subjects. Further research is warranted to explore the other metabolic and inflammatory markers related to RIF, and apply other omics techniques (genomics, epigenomics, lipidomics, and transcriptomics) that may be affected by the dietary and lifestyle modifications associated with RIF.

The human gut microbiome and its fundamental role as a determining factor in human health and disease, as well as its ability to modulate variable biochemical and physiological changes has been well established (Bull and Plummer 2014; Kho and Lal 2018). Therefore, it is important to examine the changes in gut microbiota during RIF and elaborate on their metabolic and inflammatory impacts, especially considering the various dietary and lifestyle modifications accompanying Ramadan fasting. Recently, few studies examining the effect of RIF on human gut microbiota have been published, which showed significant improvements and changes in different types of microbial flora (Ali et al. 2021; Su et al. 2021; Ozkul, Yalinay, and Karaka ; Zeb et al. 2020).

Artificial intelligence (AI) and its multiple forms and applications (including machine learning and neural networks) is the most distinguishing feature of the current and coming eras and offer essential tools that could be applied in examining the relationship between the practice of RIF and outcomes related to health and disease. One paper applied AI with patients with type 2 diabetes for the first time in an attempt to predict the occurrence of hypoglycemic events during their fasting (Elhadd et al. 2020). However, more extensive application of AI is warranted to help other patient populations, such as tools to assist patients with kidney and gastrointestinal diseases who opt to observe RIF.

With the globalization of the COVID-19 pandemic and the role of Ramadan fasting in the yearly worship of Muslims, it is necessary to elaborate on the impact of observing RIF on innate and adaptive immunity among various population groups, especially sensitive and high-risk groups such as pregnant and lactating women, children, and older people who opt to fast during Ramadan, especially given the increased susceptibility to COVID-19 infection when fasting. Of the few studies that investigated the impact of observing intermittent fasting on immunity, autophagy, and other related mechanisms, two reports revealed that intermittent fasting could be used as a priming tool for host defense against SARS-CoV-2 infection by modulating the autophagy and immune response (Hannan et al. 2020; Gnoni, Beas, and Vásquez-Garagatti 2021). An important review presented the interplay of intermittent fasting, obesity, and COVID-19 infection, and showed how fasting mitigated the obesity-induced predisposing factors that lowered the efficacy of immunity against infection (Ealey, Phillips, and Sung 2021). For RIF and COVID-19, few studies discussed the plausible impacts of observing RIF on immunity. The first study was a narrative review by Faris and colleagues (Faris, Salem, et al. 2020), which reported the expected beneficial effect of observing RIF based on the published literature concerning the immunity-related factors of RIF. This work

was followed by a few articles showing the same expected beneficial effect of RIF on immunity against SARS-CoV-2 infection (Moghadam et al. 2021; Bhatti and Mindikoglu 2022; Akbari et al. 2021).

Strengths and limitations

The present work is the first comprehensive bibliometric study that quantitatively and qualitatively analyzed the medical Ramadan fasting literature. The analysis was based upon the Scopus database, which is one of the most comprehensive international multidisciplinary databases available that covers a broad spectrum of universal journals. Scopus is characterized by the ability to find 93% of citations that were covered by Web of Science, while Web of Science found 83% of citations covered by Scopus. Further, Scopus covers 57% of citations from six databases (Scopus, Microsoft Academic, Google Scholar, Web of Science (WoS), Dimensions, and OpenCitations), in comparison with Web of Science which covers 52% of all citations (Martín-Martín et al. 2021). In addition, Scopus covers a larger number of documents that are not covered by CWTS WoS, including documents with substantial numbers of citations and references (Visser, Van Eck, and Waltman 2021).

There was no time restriction for the sample of publications to be analyzed, therefore we considered a large number of articles and provided representative quantitative, thematic, and temporal trends of Ramadan research over the last seven decades. The present study also systematically quantified the most prolific authors and countries and assessed their collaborations and productivity trends with various parameters, such as publication frequency, citation frequency, and average publication year. Finally, the database considered in this study underwent exhaustive data cleaning and organization to enhance the accuracy of the data presentation, particularly in terms of authors' publications and thematic hotspots of Ramadan scientific literature. A limitation of this study was that we did not include scientific literature published in journals that were not indexed in Scopus. Although most authors tend to publish in international journals, some choose to publish in emerging journals out of institutional or national loyalty (Germenis, Kokkinides, and Stavropoulos-Giokas 1997; Beshyah 2019). This might have affected the accuracy of our representation of the available literature on Ramadan fasting, and the extent of authors' works and collaborations. Our study was able to partially compare the results with similar bibliometric work on Ramadan fasting in the scope of diabetes, although many differences were found because of the generality of our scope and restriction only to the Scopus database (Beshyah and Beshyah 2019). Therefore, future bibliometric work on Ramadan literature should consider including more than one database.

Conclusion

This study presents a systematic overview of the scientific literature on RIF in the Scopus database over the last seven decades. Our productivity analysis identified the most prolific authors, journals, and countries. Using the provided Scopus analysis tools (e.g., Scival), this study also attempted to observe the most prolific authors' interests in their works focused on Ramadan fasting. The complementary text mining of the database gave an overview of these authors' collaboration networks and productivity trends. It also allowed us to produce a conceptual map of the most frequently explored themes in

Ramadan fasting, along with their temporal trends and citation frequency. In addition to assisting researchers with determining the gaps in knowledge on Ramadan fasting, our findings may foster collaborations and help determine future research directions.

Declarations

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10.5t38.5 56.5z"/></g > < g transform="matrix(.016,0,0,-.016,19.457,20.013)"><path id="x74" d="M298 36l-68 -35q-25-13-42 -13q-98 0–98 119v290h-69l-4 11l28 29h45v72l65 67l14 -2v-137h113q8 -8 6 -21t-12 -19h-107v-256q0 -96 59 -96q29 0 61 17z"/></g> </svg>-Isoprostane', *Journal of nutrition and metabolism*, 2012: 802924.

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Figures

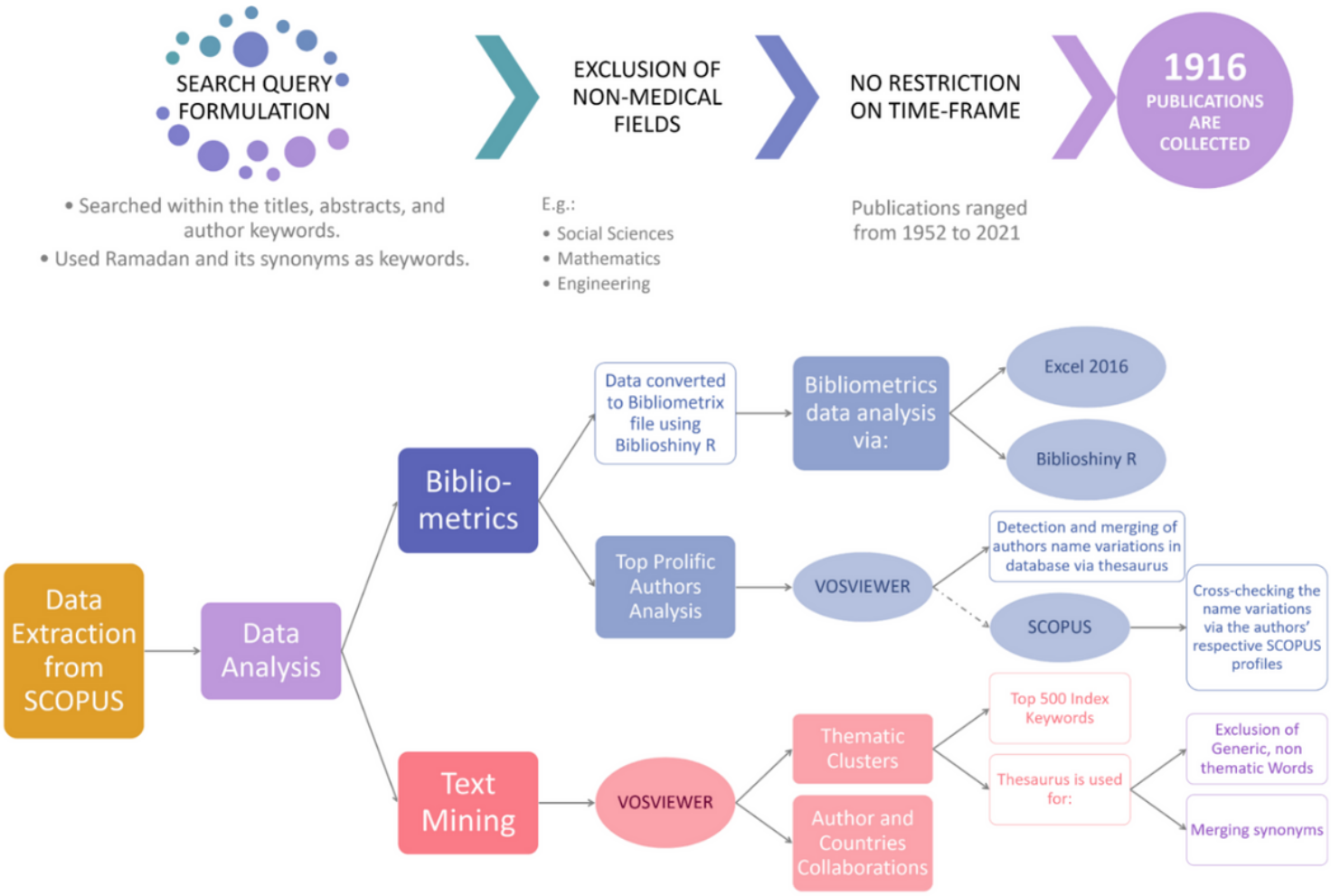

Figure 1

Workflow of data extraction and data analysis steps.

(TITLE-ABS-KEY (ramadan) OR TITLE-ABS-KEY (ramadhan) OR TITLE-ABS-KEY (ramazan) OR TITLE-ABS-KEY ("Islamic fasting") OR TITLE-ABS-KEY ("diurnal fasting") OR TITLE-ABS-KEY ("Ramadan intermittent fasting") OR TITLE-ABS-KEY ("Ramadan diurnal intermittent fasting") OR TITLE-ABS-KEY ("consecutive 30 days of fasting") OR TITLE-ABS-KEY ("religious fasting")) AND (EXCLUDE (SUBJAREA , "ARTS") OR EXCLUDE (SUBJAREA , "BUSI") OR EXCLUDE (SUBJAREA , "CENG") OR EXCLUDE (SUBJAREA , "CHEM") OR EXCLUDE (SUBJAREA , "COMP") OR EXCLUDE (SUBJAREA , "EART") OR EXCLUDE (SUBJAREA , "ECON") OR EXCLUDE (SUBJAREA , "ENGI") OR EXCLUDE (SUBJAREA , "ENVI") OR EXCLUDE (SUBJAREA , "MATE") OR EXCLUDE (SUBJAREA , "MATH") OR EXCLUDE (SUBJAREA , "PHYS") OR EXCLUDE (SUBJAREA , "SOCI"))

Figure 2

Search query used for searching for medical (health) research on Ramadan fasting in the Scopus database.

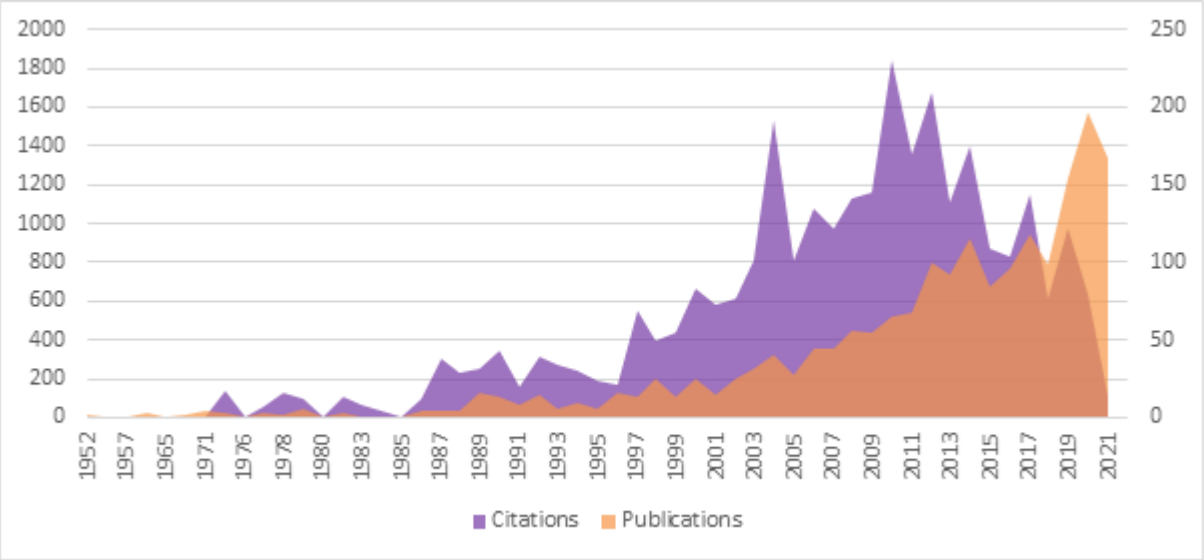

Figure 3

Annual publication frequency of medical Ramadan research.

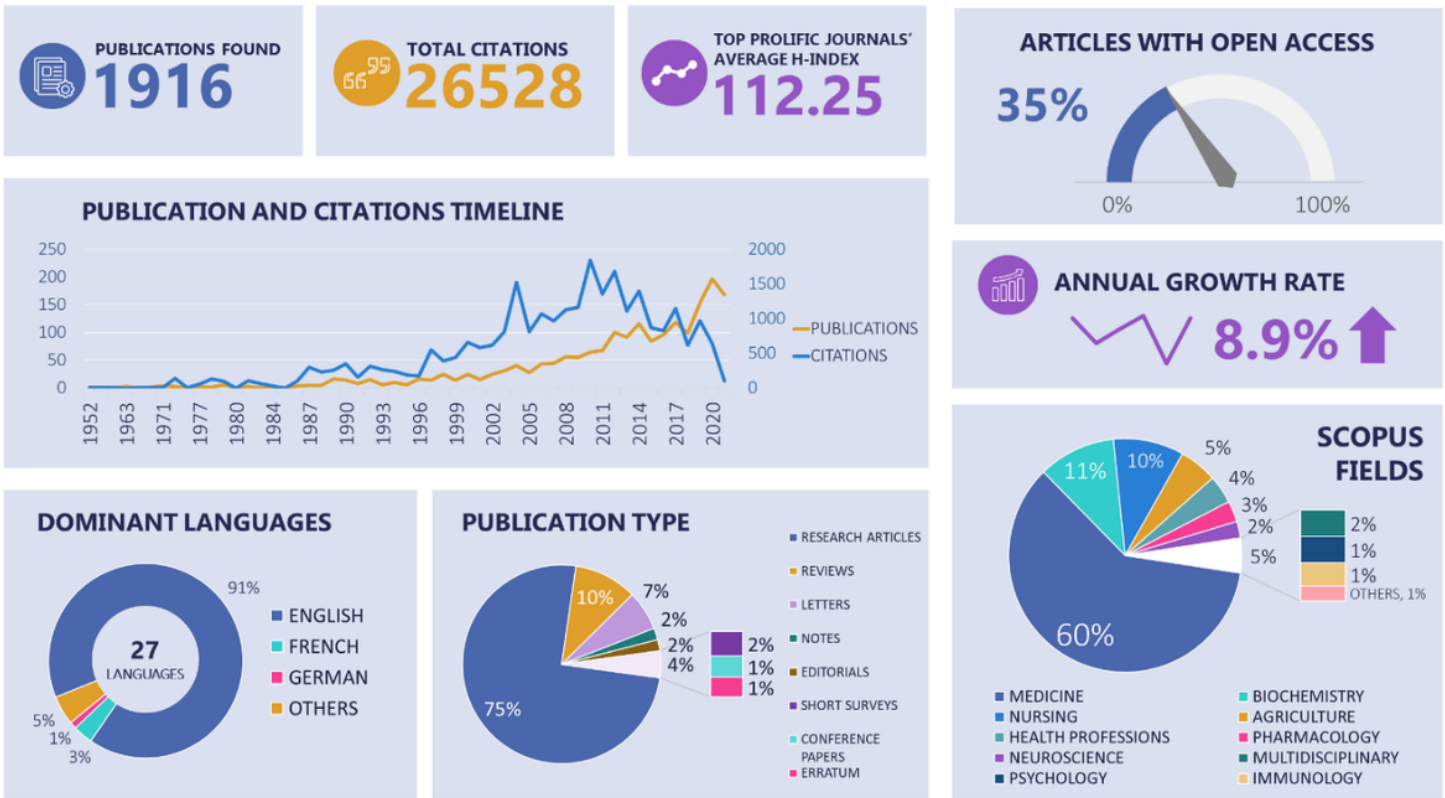

Figure 4

Abstract assortment of general bibliometric qualities of medical publications on Ramadan fasting.

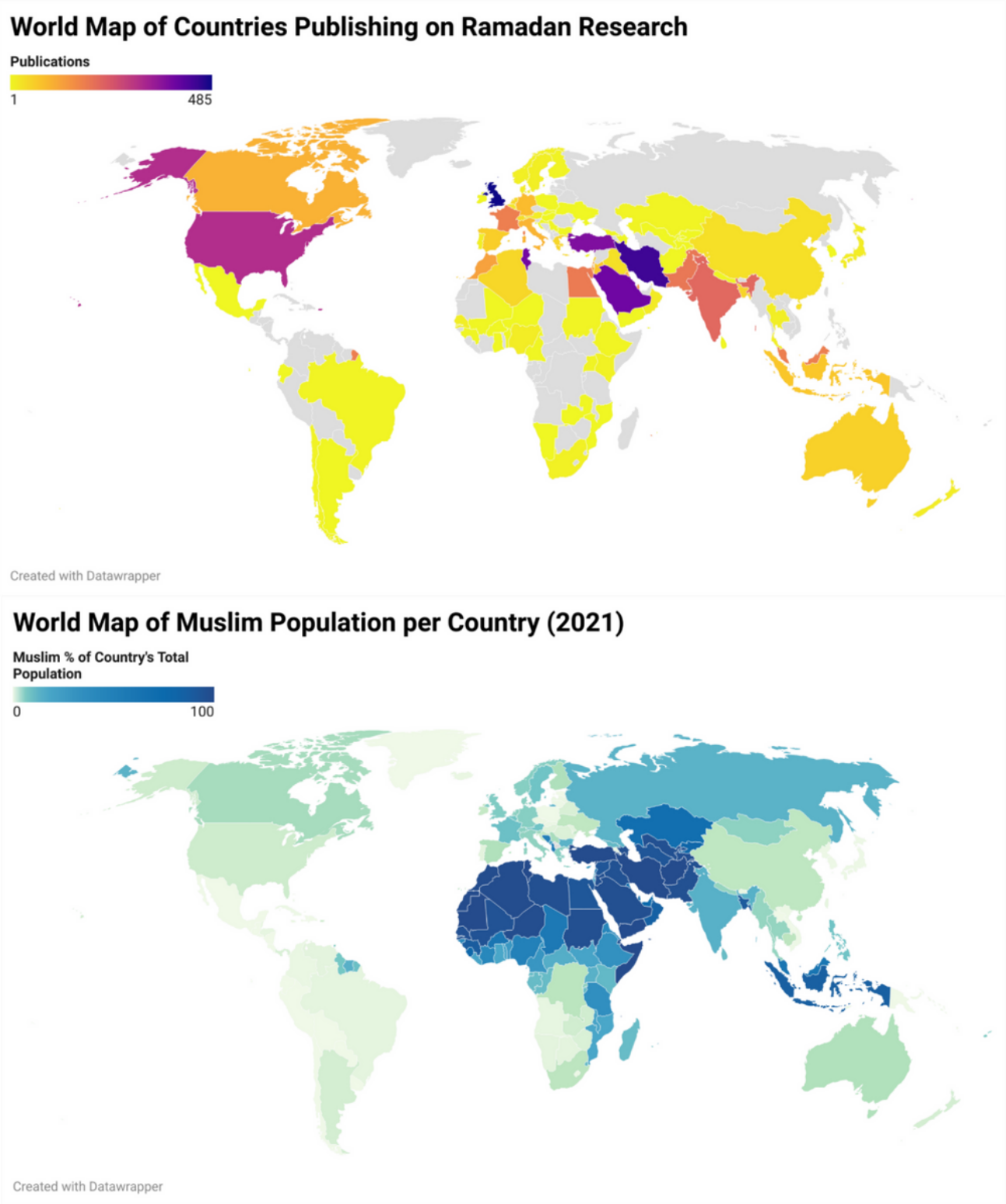

Figure 5

Two comparative color-coded world maps of countries that published Ramadan research and the percentage of the Muslim population in those countries in 2021 (Nag 2019; De Cabo and Mattson 2019).

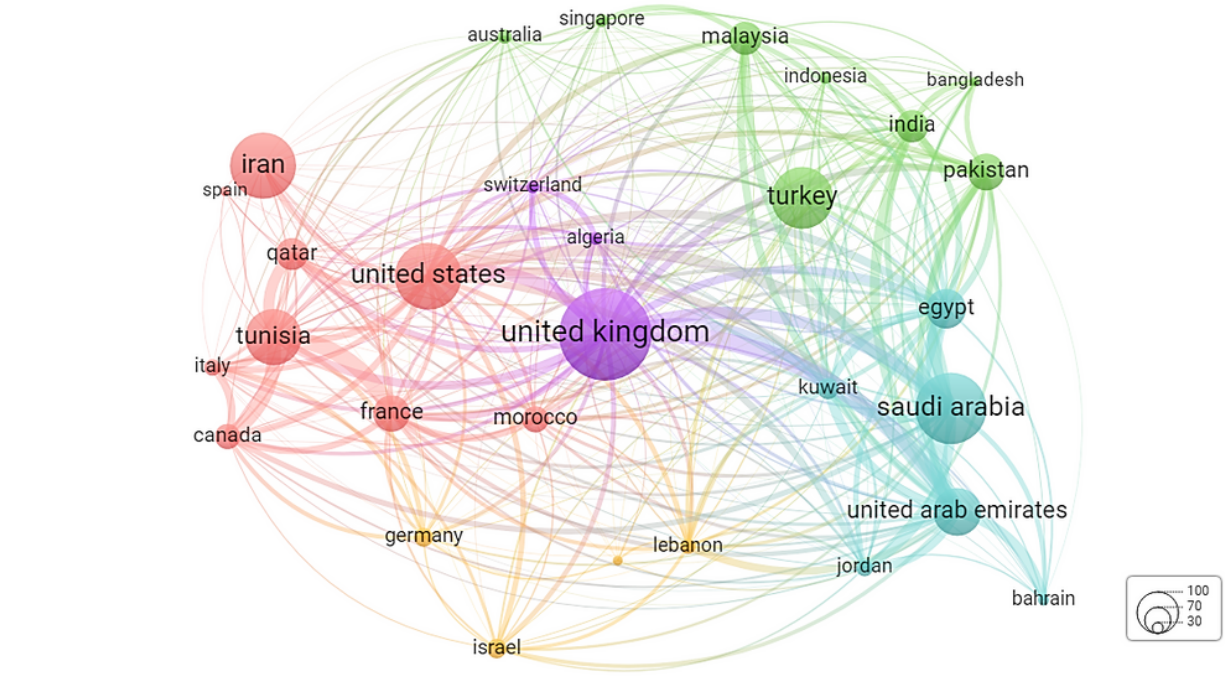

Figure 6

Co-authorship network of 30 affiliated countries over the last seven decades (1952–2021). The size of the circles and their links reflect the publication frequency and the strength of their connections respectively. The countries of the same color belong to the same collaboration cluster, which reflects the frequent collaboration of the authors of the same publications affiliated with these countries.

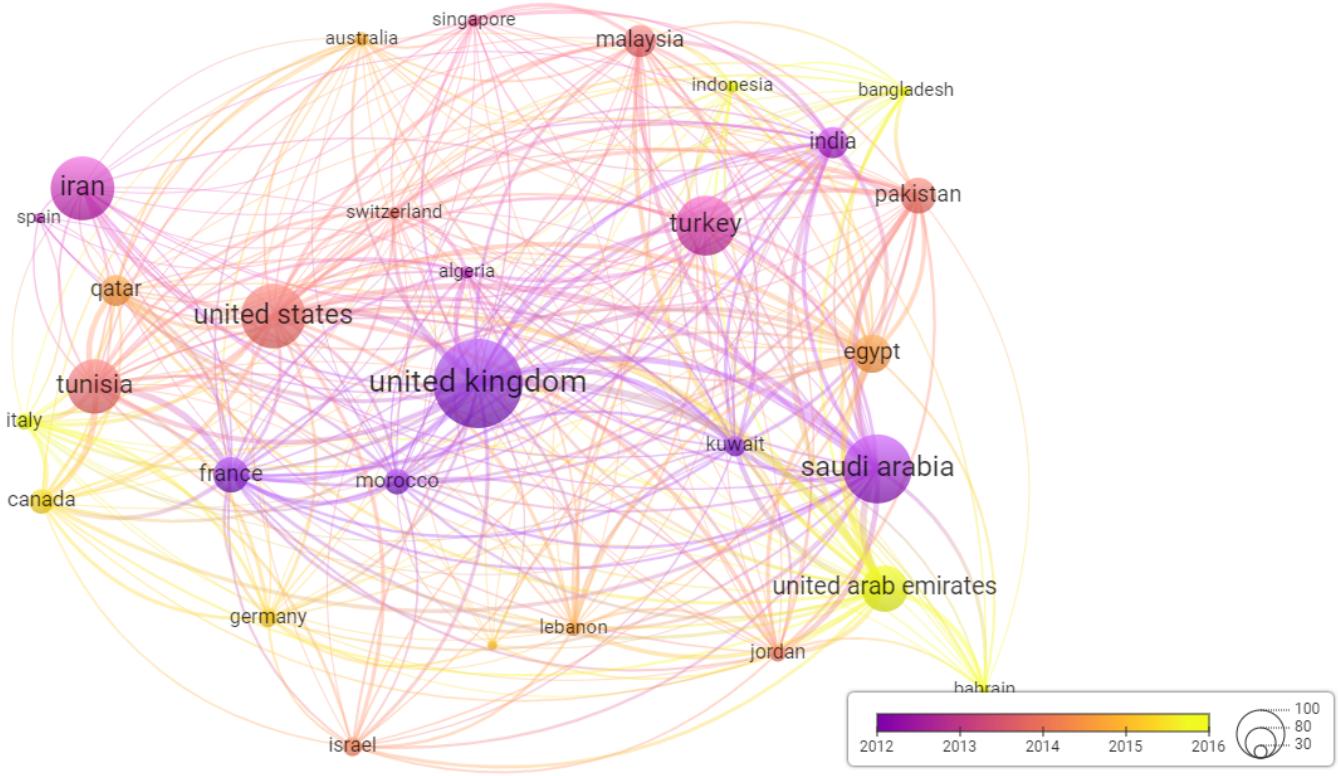

Figure 7

Average publication year of the top 30 affiliated countries (2012–2016). The circles of the presented countries are color-coded on a spectrum from violet = near 2012 to yellow = near 2016, according to their average publication year.

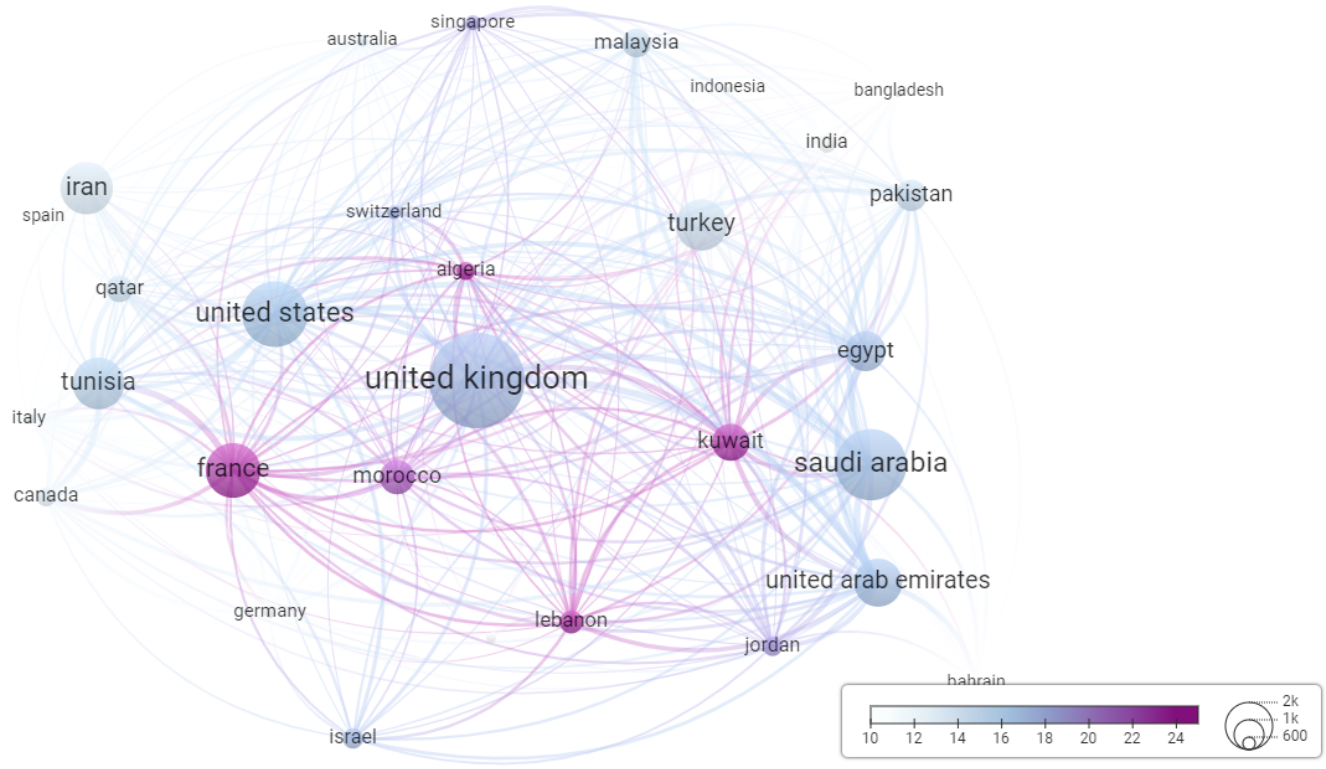

Figure 8

Average number of citations for the top 30 affiliated countries on a scale of 10–25 citations. The circles of the presented countries are color-coded on a spectrum from white = near 10 citations to violet = near 25 citations, according to the average citations received per publication. The size of the presented country's respective circles reflects their total citations received.

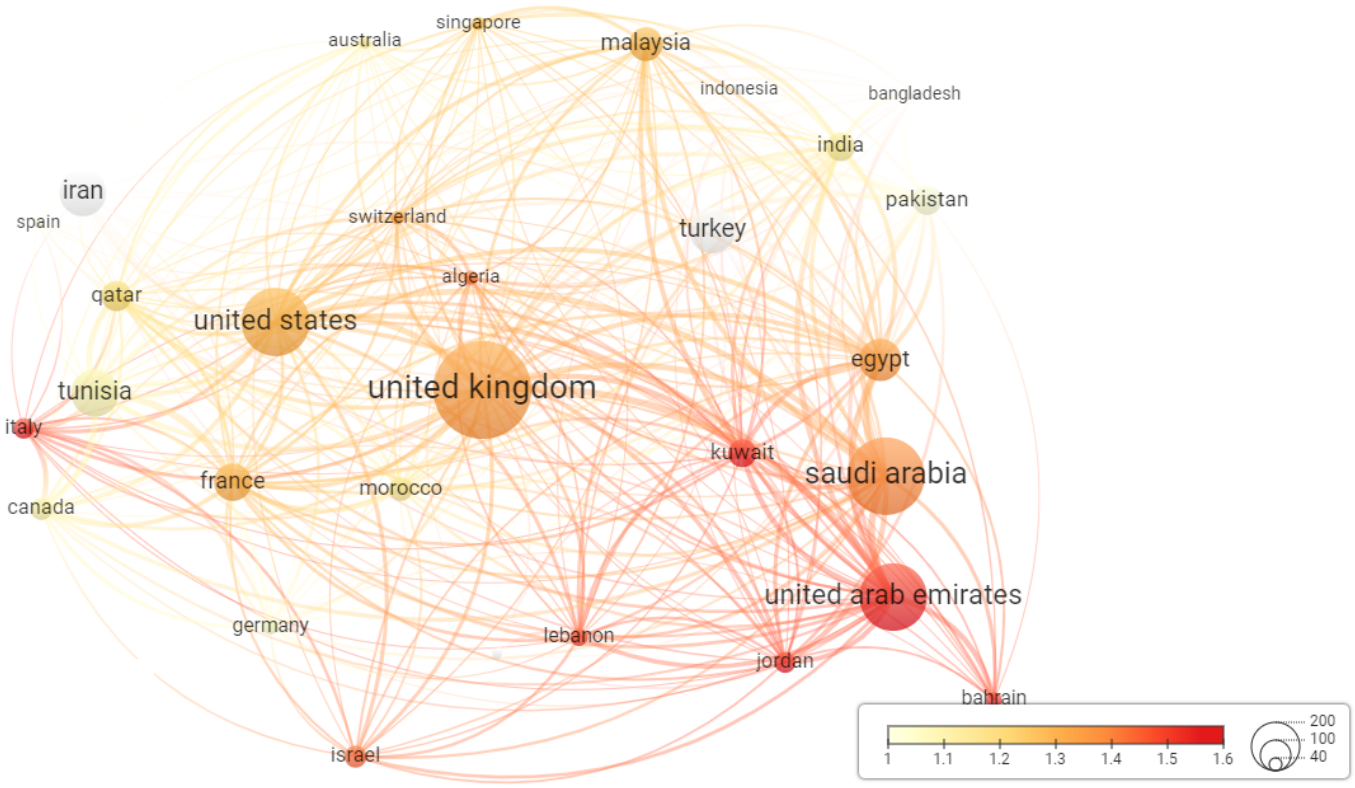

Figure 9

Average normalized citation numbers for the top 30 affiliated countries on a 1.0–1.6 normalized citations scale. The circles of the presented countries are color-coded on a spectrum reflecting their average normalized received citations per publication from pale yellow = near 1.0 normalized citations to red-orange = near 1.6 normalized citations. The size of the circles reflect the country's total received normalized citations.

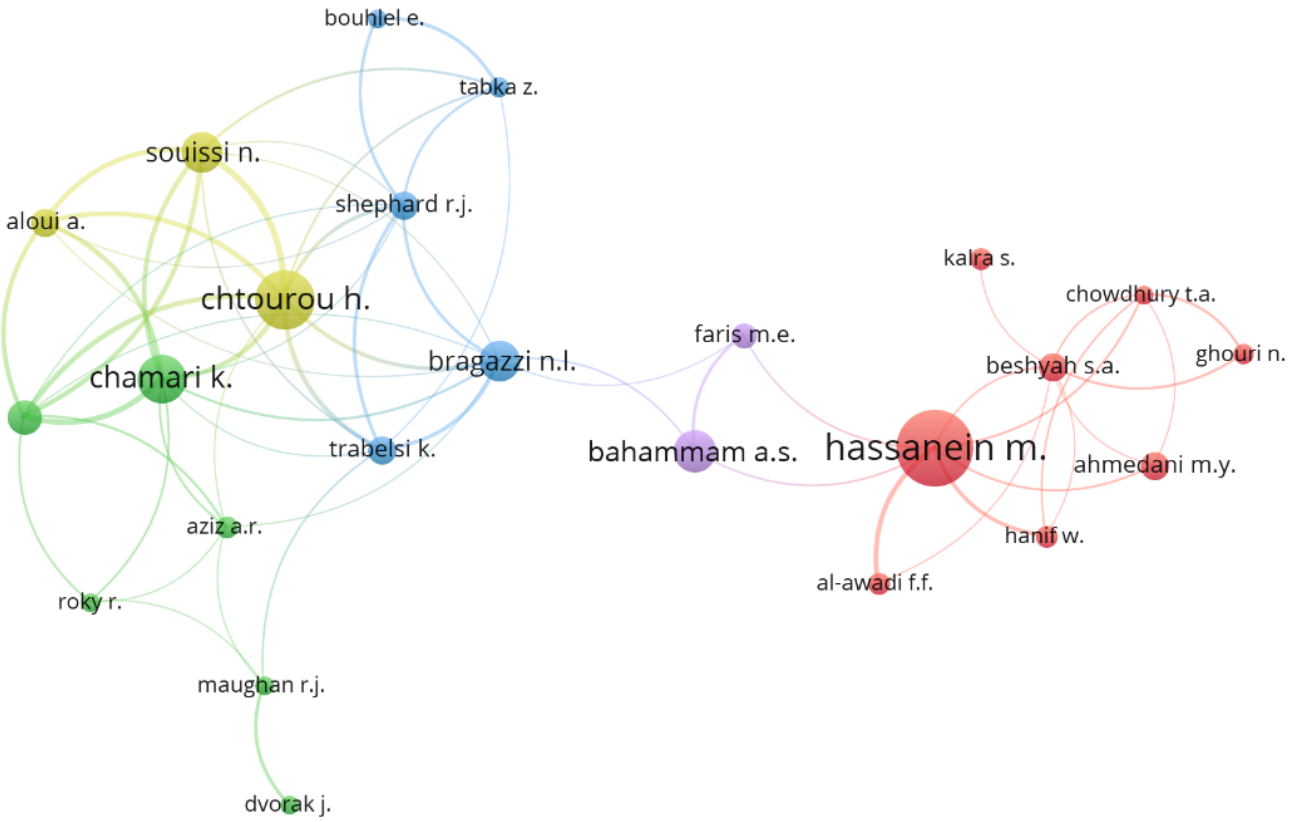

Figure 10

Collaboration networks of the 25 most prolific authors with at least 13 publications. The authors with the same color belong to the same collaboration cluster, which reflects their frequent collaboration on the same publications.

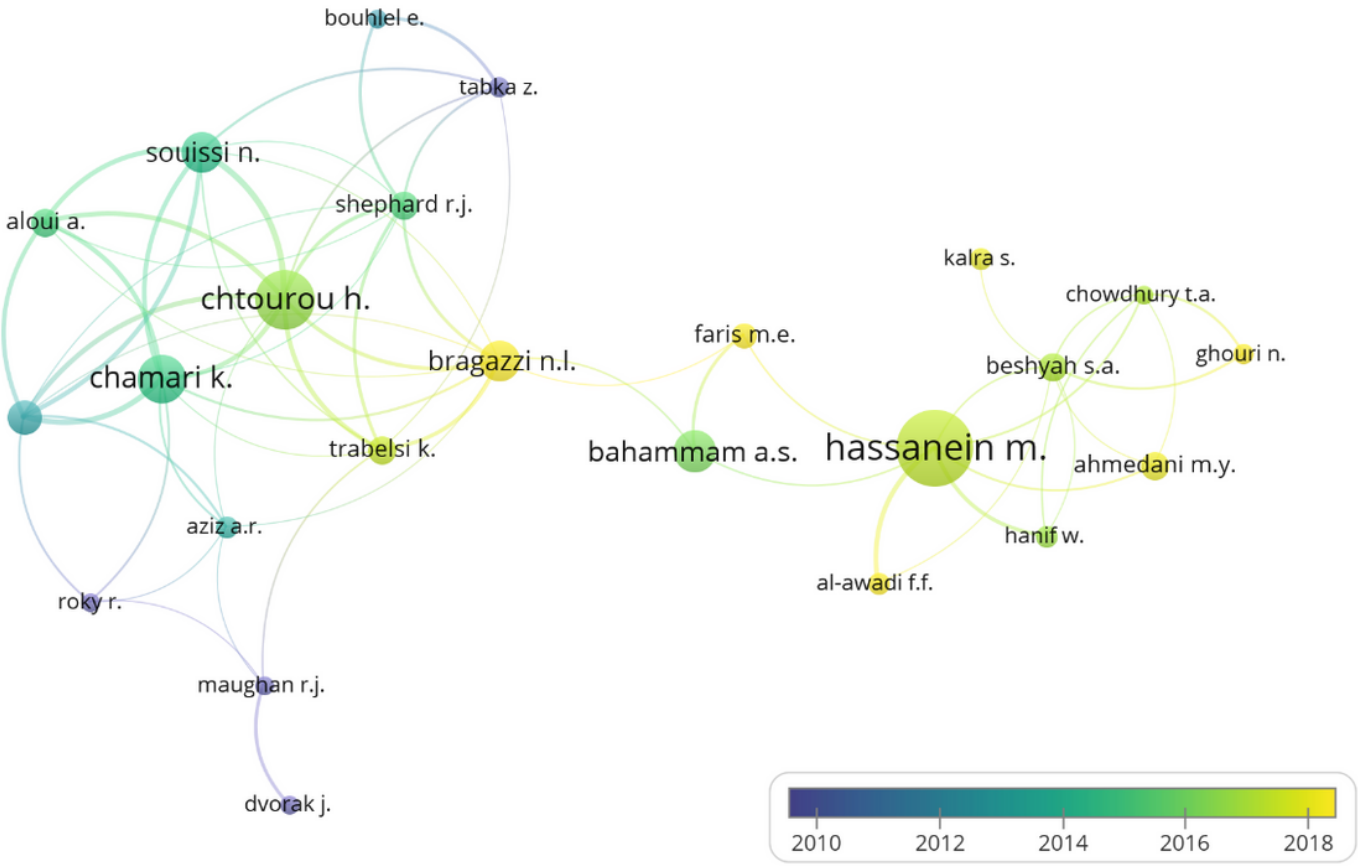

Figure 11

Average publication year of the 25 most prolific authors with at least 13 publications (2010–2018 scale). The circles of the presented authors are color-coded on a spectrum from dark blue = near 2010 to yellow = near 2018, according to their average year of publication.

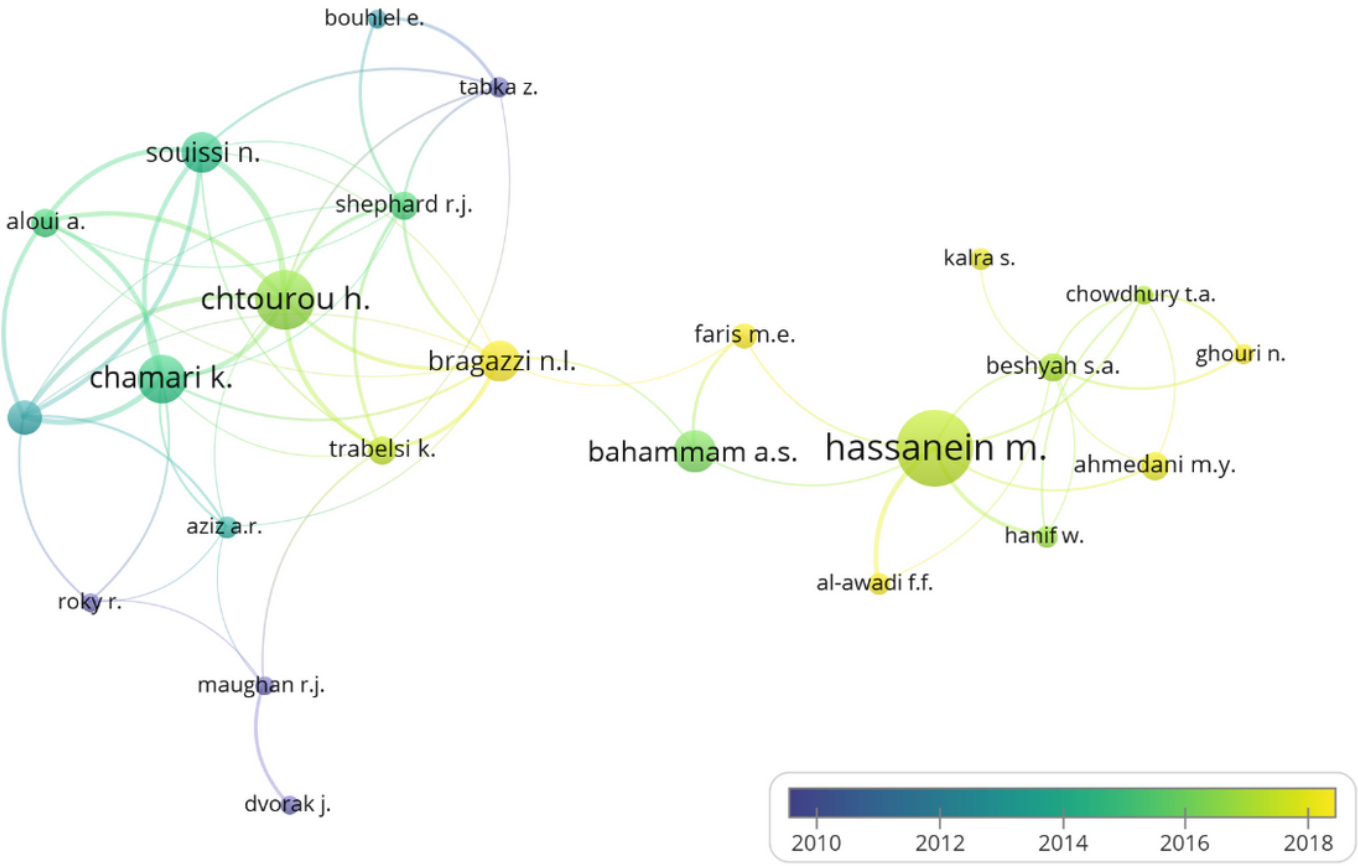

Figure 11

Average publication year of the 25 most prolific authors with at least 13 publications (2010–2018 scale). The circles of the presented authors are color-coded on a spectrum from dark blue = near 2010 to yellow = near 2018, according to their average year of publication.

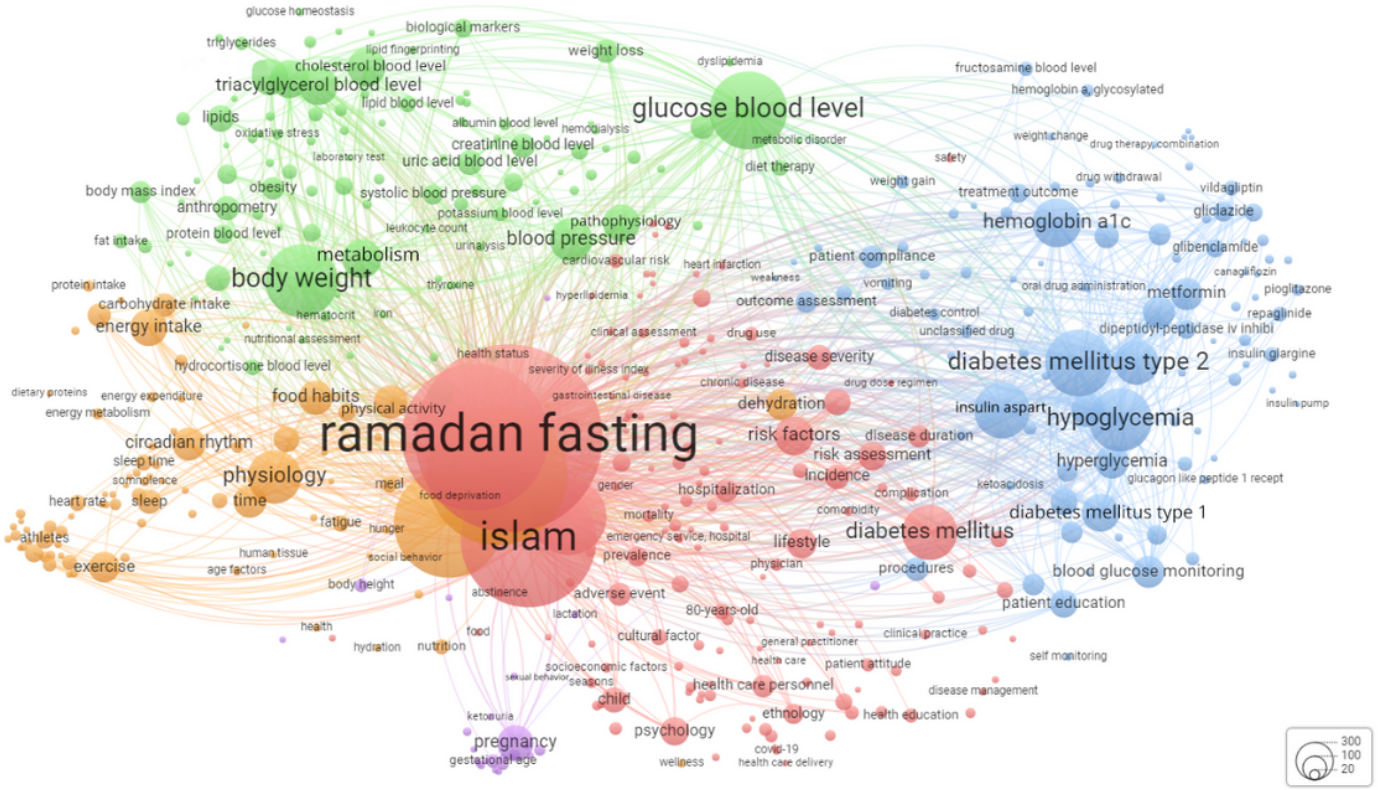

Figure 12

Thematic clusters of the top index words in Ramadan medical research over the last seven decades. The size of the circles and their links reflect the frequency and strength of the connections, respectively. Index words with the same color belong to the same thematic cluster, which reflects their co-occurrences in the same publications.

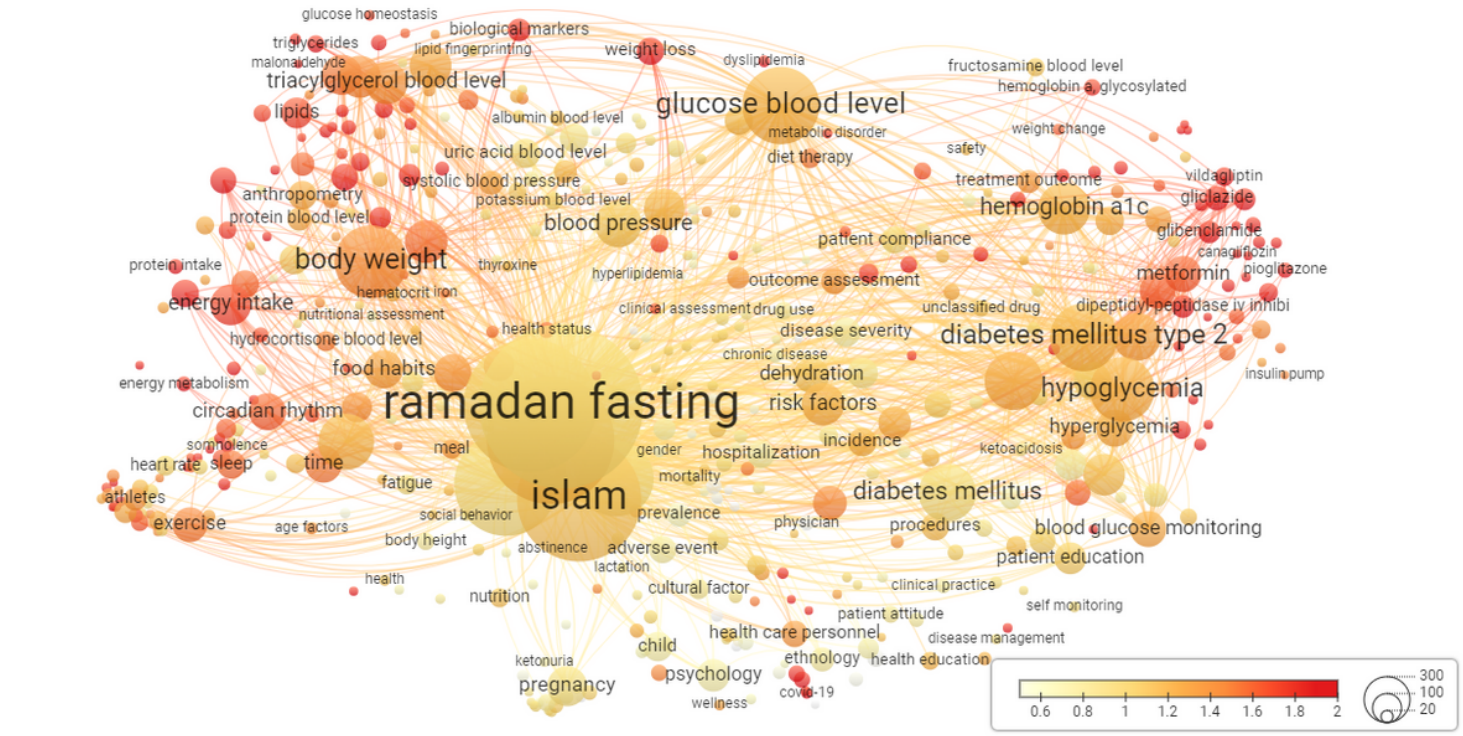

Figure 13

Average normalized citation number for the top index words (0.6–2.0 normalized citations scale). The circles of the index words are color-coded on a spectrum from white = near 0.6 normalized citations to red-orange = near 2 normalized citations, according to the average normalized citations received.

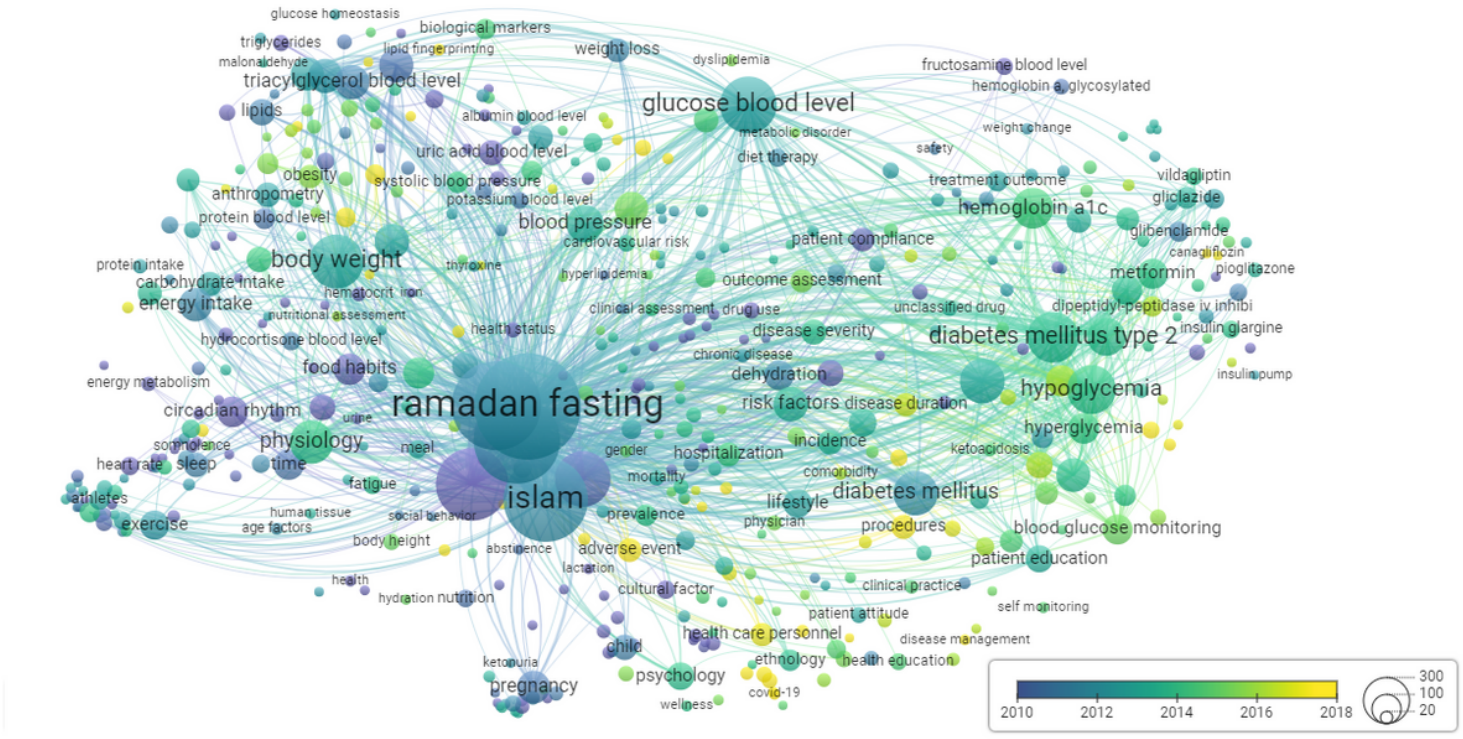

Figure 14

Average publication year of the top index words (2010–2018 scale). The circles of the words are color-coded on a spectrum from dark blue = near 2010 to yellow = near 2018, according to the average year of publication.