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Global trends and performances of Mediterranean diet

A bibliometric analysis in CiteSpace

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Abstract

Background: The Mediterranean diet (MD) is an ancient eating habit that is believed to contribute to a healthy lifestyle. Unsurprisingly, research on the MD is growing rapidly as people pay more attention to health preservation and prevention, treatment and rehabilitation of chronic diseases. Previous reviews focused more on the effects of MD on a particular disease which has enhanced its significance in the medicine field. However, few studies have attempted to provide a comprehensive summary and analysis of this topic. This study evaluates the global research trends of scientific outputs related to MD from multiple perspectives, using a bibliometric analysis and visualization tool (CiteSpace software) to scientifically analyze the knowledge from the literature.

Methods: The core collection database of Web of Science was used to retrieve the bibliographic records related to MD from 1984 to March 30, 2021. CiteSpace was used to generate and analyze visual representations of the complex data input, including number of publications, research performances in journals, authors, institutions, countries and co-occurrence networks of keywords and co-citation references.

Results: Overall, the number of MD publications has shown a significant upward trend since 2012. *Nutrients* and *American Journal of Clinical Nutrition* contained the most articles related to MD, indicating that they were important platforms for related research. Martinez-gonzalez Ma and Estruch Ramon are the authors with the highest number of publications related to MD, and it is noteworthy that these 2 authors have close cooperation in this field. The countries with the most publications are Spain and the United States, and the institutions with the most publications are Univ Navarra, Inst Salud Carlos III. The main research disciplines are "Mediterranean diet," "risk," "cardiovascular disease," "adherence," "obesity," "coronary heart disease," "diet," "health," "physical activity" and "risk factor". Estruch R's 2013 study on cerebrovascular disease and Tricopoulou A's 2003 mortality study were cited 881 cases for 437 times, respectively, showing the importance of these 2 articles in this field.

Conclusion: The current global trends of MD research as well as people's increasing awareness of healthcare and healthy lifestyle imply that MD research is expected to become increasingly popular with further breakthroughs.

Abbreviation: MD = Mediterranean diet.

Keywords: bibliometric analysis, co-citation analysis, mediterranean diet, web of science

1. Introduction

At present, the occurrence of diseases is gradually showing an upward trend. Most people are in a sub-optimal health state. Acute diseases increase the economic burden on families, society, and the country. Chronic diseases also seriously affect people's quality of life. All of this seems to point to a key point, that is people's lifestyle.[1] The World Health Organization puts forward many recommendations on a healthy lifestyle, hoping

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Our research without directly relates to individual patients and therefore the issue of ethical review does not exist. Our research is a bibliographic analysis, mainly involving literature review and analysis.

The authors have no conflicts of interests to disclose.

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

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to promote healthy living.[2,3] Diet is one of the most important aspects of lifestyle. Studies have shown that combined factors such as physical environment and diet have led to at least 18.2 percent of cancer cases and 15.8 percent of cancer deaths in the United States.[4] The meta-analysis shows that diet is closely related to diseases such as cardiovascular disease, diabetes and fatty liver.[5–7]

Launched in 1993, the Mediterranean diet (MD) emphasizes the locality, diversity, and seasonality of food. The pyramid approach of MD promotes people's health, which is highly acknowledged by the worldwide users. It is also listed by United Nations Educational Scientific and Cultural Organization as a world cultural heritage.[8] The MD is beneficial to almost all groups of people, including the elderly, children and women. For example, a cohort study has shown that MD improves cognitive status and reduces depression in the elderly. Cross-sectional studies have shown that MD can prevent memory decline and atrophy of the middle temporal lobe.[9,10] The healthy growth of children depends on a reasonable diet. Children who adhere to the MD diet can reduce the occurrence of obesity, insulin resistance and metabolic syndrome.[11,12] A recent meta-analysis shows that MD can prevent gestational diabetes, which could be regarded as a promising approach.[13] Menopause is a critical period for women's health. Clinical practice guidelines point out that combining MD with regular physical exercise can reduce the risk of cardiometabolic health.[14] However, the benefits of MD on people's health is not adequately analyzed in a comprehensive way. To address this gap, this study explores the global performance and development of MD research and maps the research patterns and trends by using a visualization tool. The analysis and results will help researchers to have an in-depth understanding of the research status and frontier trends in MD field, hoping to provide useful information and references for future publication interest and further investigation on this topic.

2. Methods

2.1. Data sources

The research data was retrieved from the core set of Web of Science database, which is the premier and the world's most reliable global research database. Selected data covers all authoritative English articles. The search term was set to TS = ("MD"). The time interval was set from January 1, 1984 to March 30, 2021. 10380 records were obtained. There were 18 types of literature with 7126 articles and 1872 reviews, accounting for 64.76% and 17.01% respectively. The top 10 literature types are shown in Table 1.

Table 1

Document types for documents on MD.

No.	Type	Counts	(%)
1	Article	7126	64.76%
2	Review	1872	17.01%
3	Meeting abstract	630	5.73%
4	Editorial material	391	3.55%
5	Proceedings paper	335	3.04%
6	Book Chapter	274	2.49%
7	Letter	176	1.60%
8	Early access	106	0.96%
9	Correction	36	0.33%
10	News item	35	0.32%

2.2. Data processing and methodology

CiteSpace (version: 5.6. R5) is a visual analysis software based on the Java platform developed by Drexel University Professor Chen Chaomei's team, a combination of information visualization, graphics, metrology, and other disciplines can visually demonstrate the knowledge structure of a research field.

CiteSpace uses the Web of Science textual data format, therefore, the data was preprocessed and then imported into Excel for analysis and column mapping. Then the literature data was imported into CiteSpace (version 5.6. R2) and analyzed visually, including journal co-citation analysis, author co-citation analysis, country co-citation analysis and keyword co-citation analysis. Parameters of CiteSpace were set as follows: time interval was set as 1984 to 2021 and the data was examined in 1 year per slice as the trend of development in this field can be grasped through each year's research. The "title, abstract, Keyword Plus, author keywords" were key parameters to be examined to identify research trends.

3. Results

3.1. Research performance

The fist MD article was published in 1984. At the initial stage, less than 100 articles were published between 1984 and 2003 annually. This field increasingly attracted more attention from international scholars since 2003, articles published were more than 1000 articles per year between 2003 and 2012. The publication volume increased rapidly from 2012 to 2020, which exceeded 1000 articles per year in 2018, and continued to grow for the next 2 years. Until May 30, 2021, 376 articles have been published this year. We predict that there will be about 1,300 articles published in 2021(Fig. 1).

3.2. Publication performance by Journals

The MD research was covered by hundreds of journals, with top 3 journals are Nutrients (649 articles), American Journal of Clinical Nutrition. The top 10 publications were shown in Figure 2 and Table 2. One possible reason contributes to these 3 journals as top ones is that these 3 journals focus on the effects of eating habits on human health, therefore, they are influential in the topic of MD.

3.3. Analysis of authors and author collaboration

In Figure 3, each dot pints represents an author. The larger the size of the dot, the more published articles of the authors. The line between the dots represents the connection or cooperation between authors, and the thicker the line, the closer the cooperation between authors. CiteSpace statistics show that Martinez-Gonzalez Ma was the most prolific author in this field with 276 articles published, followed by Estruch Ramon and Salas-Salvado with 267 and 143 articles respectively. It shows that these 3 authors have made outstanding contributions to this field. The top 10 authors are shown in Table 3. On the one hand, Demosthenes b pangiotakos and Christos pitsavos work closely with Christing chrysohoou and Cgristodoulos stefanadis, on the other hand, other more prolific authors are all related, as presented in Figure 3.

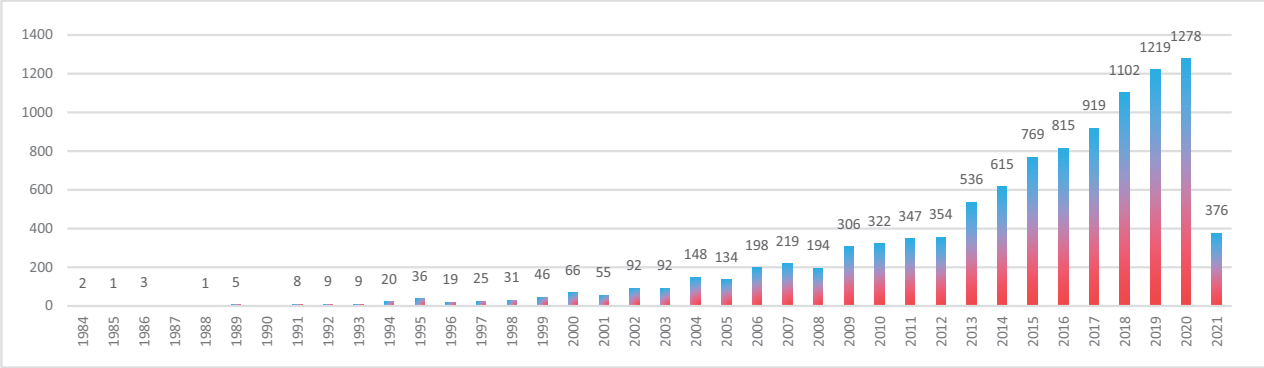

Figure 1. Time sequence of relevant papers on MD published from 1984 to 2021 in Web of Science.

Figure 2. Top 10 Journals related to MD.

3.4. Research performance by institutions

According to Figure 4 found that the MD research institutions are relatively concentrated and interrelated with no obvious independent team. The Univ Navarra, Inst Salud Carlos III, and Univ Barcelona are 3 institutions with highest publication records (Fig. 4 and Table 4). It indicates that these 3 institutions have conducted in-depth and comprehensive studies on the MD and they have big impact in the field.

Table 2

Top 10 most productive journals.

No.	Journals	Counts	IF
1	*Nutrients*	649	4.564
2	*American Journal of Clinical Nutrition*	233	6.766
3	*Public health nutrition*	206	3.182
4	*British Journal of Nutrition*	200	3.334
5	*Nutrition and Metabolism Yearbook*	196	2.848
6	*Nutrition Hospital*	165	0.888
7	*European Journal of Nutrition*	163	4.664
8	*Nutritional metabolism and cardiovascular disease*	161	3.700
9	*European Journal of Clinical Nutrition*	149	3.291
10	*Journal of Nutrtion*	132	4.067

3.5. Research performance by countries

CiteSpace found that Spain, the United States and Italy are countries with the largest number of MD publications. In the Figure 5, each dot represents a country. The larger the dot radius, the more articles published in that country. Lines between the dots indicate links or cooperation between countries, with thicker lines indicating closer cooperation between authors. MD studies are conducted with a small number of countries, with close cooperation between countries, (Fig. 5 and Table 5).

3.6. Co-occurrence of keywords

Keywords indicate the gist of an academic paper. Through the analysis of high-frequency keywords, the development process, research focus, and direction of this field could be delineated. The top 10 keywords for the MD are: "MD, risk, cardiovascular disease, adherence, obesity, coronary artery disease, diet, health, physical activity, risk factors". The main disciplines are "cardiovascular disease, coronary artery disease, and obesity" (Fig. 6 and Table 6). We further categorized keywords into clusters. Six categories were obtained, which are "children, polyphenols, mortality, metabolic syndrome, older adults, non-alcoholic fatty liver disease". The variance in diseases, pop-

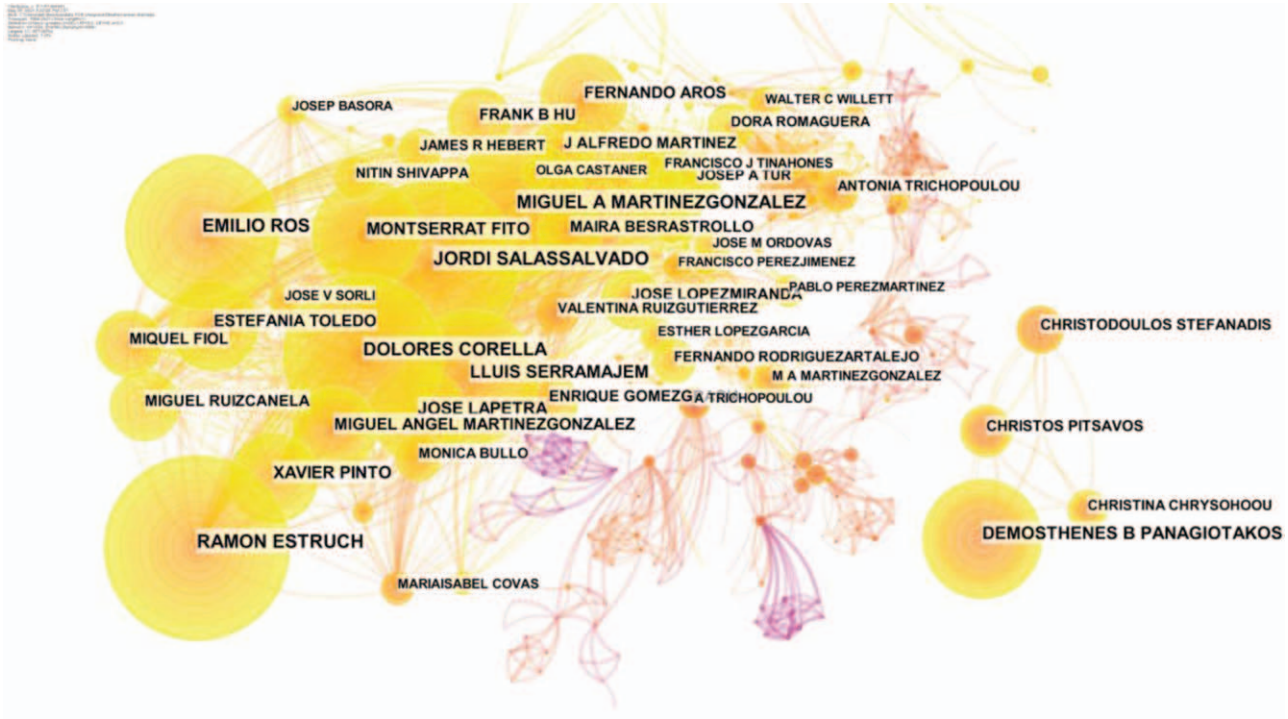

Figure 3. Map of authors' collaborations related to MD research.

ulations and deaths are the main focuses of studies (Fig. 7 and Table 7). Based on the clustering results, a timeline diagram is drawn to show the temporal change of these topics. In Figure 8, the horizontal line represents the year which the paper was published, and the vertical line shows different clusters. Each node represents keywords, and the larger the node, the higher the frequency of their occurrence. It shows that cluster "mortality" has the longest research period, followed by "children," "polyphenols," "metabolic syndrome," "older adults," and "non-alcoholic fatty liver disease" is the latest study.

3.7. Co-citation of reference

The co-citation literature shows the authoritativeness of the research in this field and the great contribution made by authors. Statistics from CiteSpace found that Estruch R et al had the highest citations of 881 articles published in 2013 in the Primary prevention of cardiovascular disease with a MD at New England Journal of Medicine, the main findings of the study illustrates an inverse association between adherence to the MD and cardiovascular risk.[15] It is well known that cardiovascular risk imposes a serious impact on human health, so it is necessary to study the MD and cardiovascular risk at same time. The second most cited article, by Trichopoulou et al, was published in 2003, in the Journal New Engl J Med, titled *Adherence to a MD and survival in a Greek population,* with 437 citations. It indicates that a higher degree of adherence to the MD was associated with a reduction in total mortality[16] (Fig. 9, Table 8).

3.8. Identification of research hotspots

Research hotspot can be detected from the burst of keywords. In Table 9, the timeline is depicted as the blue line. The burst period is shown as the red segment on the blue timeline, indicating the time duration of the burstness, that is the period that the occurrence of a particular keyword increased rapidly.[17]

According to the visual result of CiteSpace the hot topics in this field are: "coronary heart disease, olive oil and lipoprotein".

There are a total of 257 frontier keywords detected in this review. We selected the most popular 50 keywords in recent 3 years, hoping to guide further research direction through the research trends. In general, there are many diseases studied, such as rheumatoid arthritis, disability, prediabetes, depression, older age, and so on. The research hotspots in the past 3 years are

Table 3

Top 10 most productive journals.

No.	Authors	Counts	No.	Authors	Counts
1	Martinez-gonzalez ma	37	6	Corella do	222
2	Estruch ramon	267	7	Serra-majem l	211
3	Salas-salvado j	243	8	Fito m	188
4	Panagiotakos db	226	9	Pitsavos c	151
5	Ros e	224	10	Stefanads c	141

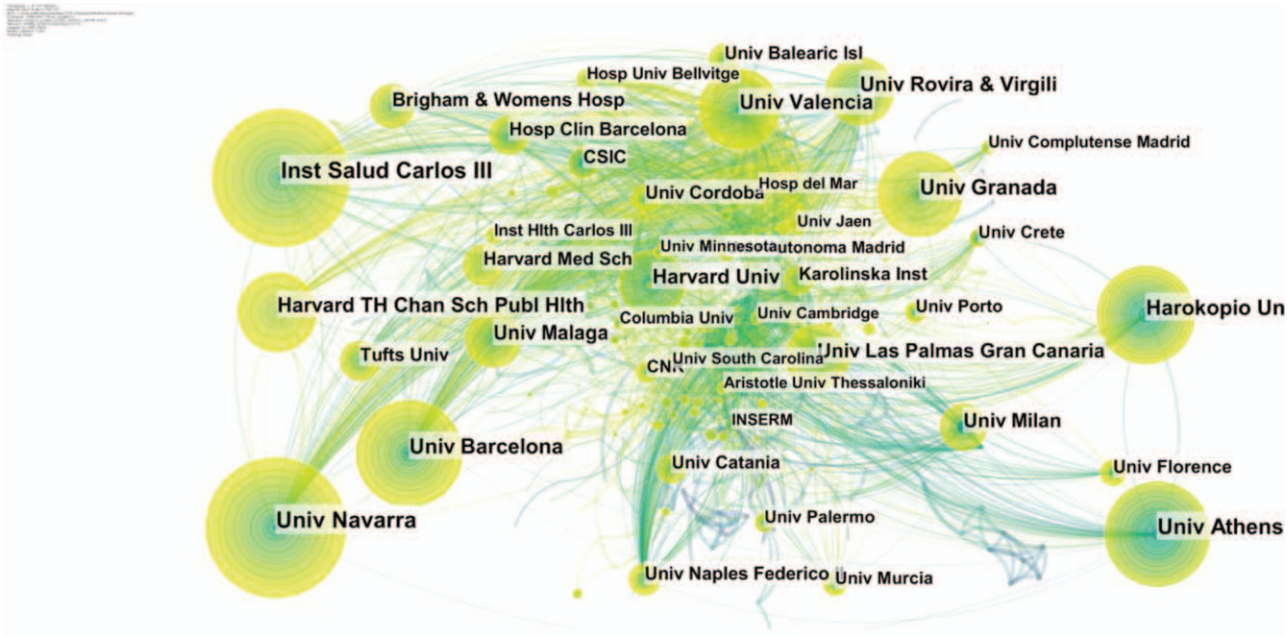

Figure 4. Map of institutions' collaborations related to MD research.

Table 4

The ten most productive and influential institutions sorted by total publication record.

No.	Institutions	Freq	Year	Half-life
1	Univ Navarra	398	2002	13.5
2	Inst Salud Carlos III	373	2007	9.5
3	Univ Barcelona	298	1999	11.5
4	Univ Athens	297	2000	17.5
5	Harokopio Univ	281	2004	13.5
6	Univ Granada	243	2000	19.5
7	Univ Valencia	225	2007	10.5
8	Harvard TH Chan Sch Publ Hlth	211	2016	3.5
9	Univ Rovira & Virgili	202	2004	11.5
10	Harvard Univ	198	2002	14.5

covering 50 keywords, indicating that the scope of research centered on the MD is expanding and affecting many fields. Further research into the MD will potentially lead to cross-disciplinary studies (Table 10).

4. Conclusion

In conclusion, this study provides an overview of the evolution and current global research directions of the MD. The occurrence and development of diseases are closely related to diet, so in the

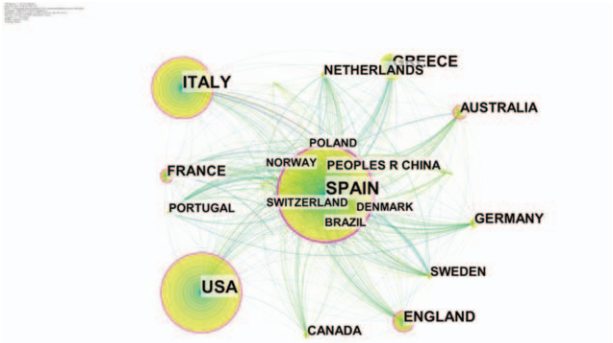

Figure 5. Map of Country' collaborations related to MD research.

Table 5

The ten most productive and Country countries.

No.	Freq	Centrality	Year	Country
1	1989	0.37	1992	SPAIN
2	1641	0.17	1984	USA
3	1366	0.19	1984	ITALY
4	677	0.04	1995	GREECE
5	506	0.1	1998	ENGLAND
6	392	0.16	1994	FRANCE
7	357	0.13	1995	AUSTRALIA
8	329	0.04	1998	GERMANY
9	258	0.06	1997	NETHERLANDS
10	219	0.07	1996	SWEDEN

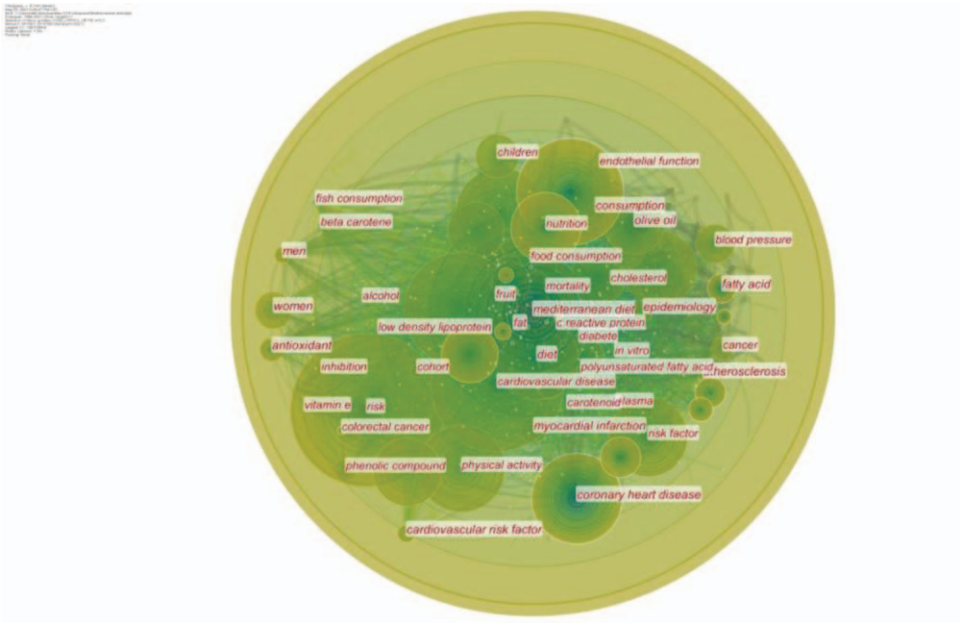

Figure 6. Map of co-occurring keywords related to MD research.

Table 6

Top 10 keywords related to MD.

No.	Freq	Degree	Keyword	No.	Freq	Degree	Keyword
1	4845	95	MD	6	830	104	Coronary heart disease
2	1332	79	risk	7	794	91	diet
3	1140	86	cardiovascular disease	8	791	57	health
4	974	61	adherence	9	789	77	Physical activity
5	913	73	obesity	10	752	82	Risk factor

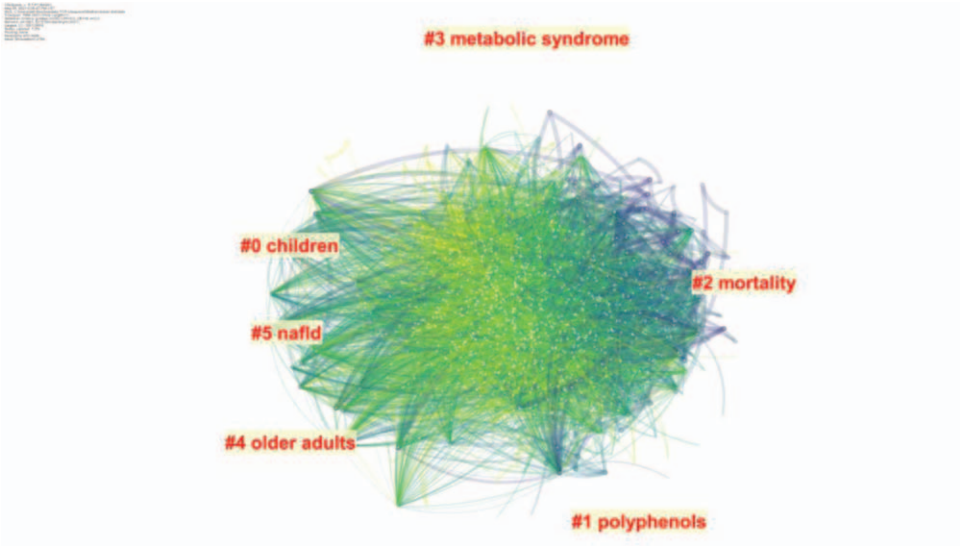

Figure 7. Recurring MD research after Figure 6 data are sorted into chronological order.

modern era, people are not only concerned about the treatment of diseases, but also about lifestyle changes, such as a healthy diet and moderate exercise, so as to improve health status. What is more important is the change in people's awareness of the importance of health preservation. It is crucial to pay attention to the rationality and scientific nature of the diet.

From the perspective of literature research, the number of countries that have studied the MD is limited. More diverse

Table 7

Top 7 subjects of cluster analysis.

Cluster ID	Size	Centrality	Year	Cluster label (LLR)
#0	264	0.64	2011	MD; sustainability; conviviality; commensality; machine learning; nutrition disorders; feature selection; carbohydrate; support vector machines; indirect calorimetry | physical activity; gut microbiota; dietary factors; sedentary behaviors; dietary change; childbearing age; maternal diet; feeding patterns; healthy diet; qualitative research
#1	228	0.674	2006	MD; oxidative stress; metabolic syndrome; f2-isoprostanes; disease activity; proliferation; disease impact; functional disability; vascular endothelial cells; controlled trial | polyphenols; arterial stiffness; high resolution mass spectrometry; immune status; endothelial dysfunction; antioxidant activity; nonalcoholic steatohepatitis; sunflower oil; experimental autoimmune encephalomyelitis; urinary excretion
#2	188	0.77	1999	MD; metabolic syndrome; oxidative stress; f2-isoprostanes; arterial stiffness; ethnic density; atherogenesis; atherothrombosis; exposure assessment; cause mortality | cardiovascular disease; coronary heart disease; risk factor; weight gain; walnut consumption; inflammatory marker; cognitive function; meat intake; brain morphometry; womens health
#3	165	0.618	2008	MD; metabolic syndrome; blood pressure; waist circumference; meta-analysis; cardiometabolic profile; mediterranean lifestyle; nonalcoholic liver disease; liver disease; liver cirrhosis | type; diabetes; adolescents; diabetes technology; children; arterial stiffness; hepatic lipase gene; regression analysis; endothelial dysfunction; leukotrienes
#4	131	0.718	2012	MD; dietary pattern; healthy diet indicator; calcium supplements; social contacts; cortical thickness; handgrip strength; sleep dysfunction; dietary patterns; acute pancreatiti | adults; healthy eating index; nurses' health study; fatty acid; monounsaturated fatty acid; calcium supplements; social contacts; cortical thickness; handgrip strength; sleep dysfunction
#5	75	0.762	2009	MD; bone fractures; bone turnover; bone density; red meat intake; fish intake; sugar-sweetened beverages; dietary quality; risk-factors; consumption | colorectal cancer; case-control study; breast cancer; head; systematic review; mediterranean; neck cancer; dietary inflammatory index; retrospective studies; glomerular filtration rate

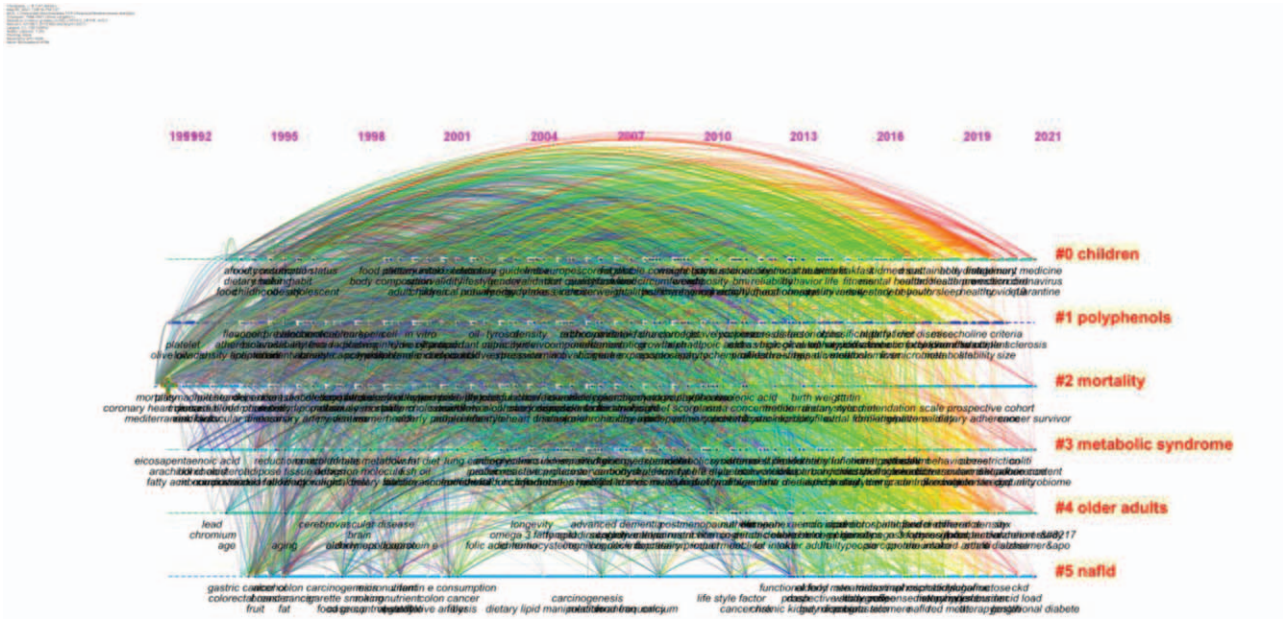

Figure 8. Recurring MD research after Figure 6 data are sorted into chronological order.

Figure 9. Document co-citation analysis in MD research.

Table 8

Top 10 document co-citation related to MD.

No.	Freq	Year	Reference	Half-Life
1	881	2013	Estruch R, 2013, NEW ENGL J MED, V368, P1279, DOI 10.1056/NEJMoa1200303	3.5
2	437	2003	Trichopoulou A, 2003, NEW ENGL J MED, V348, P2599, DOI 10.1056/NEJMoa025039	4.5
3	358	2010	Sofi F, 2010, AM J CLIN NUTR, V92, P1189, DOI 10.3945/ajcn.2010.29673	4.5
4	277	2008	Sofi F, 2008, BMJ-BRIT MED J, V337, P0, DOI 10.1136/bmj.a1344	4.5
5	255	2011	Schroder H, 2011, J NUTR, V141, P1140, DOI 10.3945/jn.110.135566	6.5
6	249	2011	Kastorini CM, 2011, J AM COLL CARDIOL, V57, P1299, DOI 10.1016/j.jacc.2010.09.073	4.5
7	248	2006	Estruch R, 2006, ANN INTERN MED, V145, P1, DOI 10.7326/0003-4819-145-1-200607040-00004	5.5
8	237	2011	Bach-Faig A, 2011, PUBLIC HEALTH NUTR, V14, P2274, DOI 10.1017/S1368980011002515	5.5
9	234	2014	Sofi F, 2014, PUBLIC HEALTH NUTR, V17, P2769, DOI 10.1017/S1368980013003169	3.5
10	177	2004	Knoops KTB, 2004, JAMA-J AM MED ASSOC, V292, P1433, DOI 10.1001/jama.292.12.1433	4.5

Table 9

Top 20 keywords with the strongest citation bursts.

Keywords	Year	Strength	Begin	End	1984 - 2021
coronary heart disease	1984	75.0938	1991	2010	
olive oil	1984	59.3852	1991	2009	
lipoprotein	1984	50.7395	1991	1999	
antioxidant	1984	43.7383	1994	2005	
oxidation	1984	43.1233	1998	2002	
wine	1984	30.792	2000	2004	
low density lipoprotein	1984	30.3387	1996	1998	
elderly people	1984	29.7683	2000	2006	
survival	1984	27.9001	2004	2012	
plasma lipid	1984	27.5021	1992	1999	
red wine	1984	27.1382	2000	2009	
atherosclerosis	1984	26.4243	1994	2002	
myocardial infarction	1984	24.0494	2004	2006	
monounsaturated fatty acid	1984	22.1532	1991	2000	
lipid peroxidation	1984	21.8612	1994	2007	
cholesterol	1984	21.6725	1993	2000	
serum lipid	1984	21.4339	1991	2002	
beta carotene	1984	20.6139	1996	2006	
risk factor	1984	20.5909	2006	2009	
greece	1984	20.438	2004	2009	

Table 10

The top 20 keywords cited most in recent 3 years.

Keywords	Year	Strength	Begin	End	2018 - 2021
body composition	1984	4.2727	2018	2021	
steatosis	1984	3.8455	2018	2021	
aged	1984	3.6733	2018	2019	
sex difference	1984	4.904	2018	2021	
rheumatoid arthriti	1984	6.6196	2018	2021	
sustainable diet	1984	5.2951	2018	2021	
gender difference	1984	5.0512	2018	2019	
eating index	1984	4.5919	2018	2019	
healthy diet	1984	6.2122	2018	2021	
reliability	1984	7.7319	2018	2021	
performance	1984	7.4137	2018	2021	
time	1984	4.9831	2018	2021	
older	1984	4.115	2018	2019	
metabolite	1984	5.2951	2018	2021	
strength	1984	4.1326	2018	2019	
disability	1984	5.4845	2018	2019	
prediabete	1984	4.6059	2018	2021	
fitness	1984	5.7384	2018	2021	
frailty	1984	5.6404	2018	2021	
oleocanthal	1984	4.3019	2018	2021	
impact	1984	14.157	2018	2021	
sport	1984	4.633	2018	2021	
adolescence	1984	6.6196	2018	2021	
depression	1984	6.9557	2018	2021	
mass index	1984	4.633	2018	2021	
behavior	1984	8.9229	2019	2021	
muscle strength	1984	4.0315	2019	2021	
obese	1984	4.0315	2019	2021	
MD adherence	1984	4.4796	2019	2021	
sedentary behavior	1984	4.715	2019	2021	
product	1984	3.8615	2019	2021	
attitude	1984	4.5551	2019	2021	

Table 10 (Continued).

scale	1984	6.2721	2019	2021
health promotion	1984	4.4796	2019	2021
people	1984	4.791	2019	2021
therapy	1984	4.9277	2019	2021
management	1984	4.1604	2019	2021
healthy	1984	8.065	2019	2021
perception	1984	6.1875	2019	2021
vegetarian diet	1984	4.9277	2019	2021
greenhouse gas emission	1984	4.5126	2019	2021
mind diet	1984	4.4796	2019	2021
mineral density	1984	4.4796	2019	2021
kidmed	1984	4.2673	2019	2021
global burden	1984	4.4796	2019	2021
diet quality	1984	3.8059	2019	2021
dash	1984	4.5551	2019	2021
ma	1984	4.1494	2019	2021
all cause	1984	5.9249	2019	2021
sustainability	1984	7.1484	2019	2021

groups of people should be involved in this field to improve the reliability of findings that MD is good for people's health. Moreover, it is necessary to carry out relevant research, such as prevention, treatment, rehabilitation and other comprehensive assessments at different stages of the disease. For the same type of disease, whether the intervention of the MD imposes same effect in different countries requires further research. Large testing samples, multi-center clinical trials might help to understand the pros and cons of the MD, so that MD can play a better role in protecting human health.

Author contributions

Conceptualization: Ci Ming Pan, Changwu Dong.
Data curation: Ci Ming Pan.
Investigation: Beiling Cao.
Methodology: Nan Jiang.

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