• Bibliometric Research •

The 100 most influential articles in myopia: a bibliometric analysis

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Received: 2020-10-27 Accepted: 2021-03-16

Abstract

● **AIM:** To identify and characterize the 100 most influential articles in the field of myopia over the last decades.

● **METHODS:** Articles on myopia published between January 1975 and March 2020 were searched through the Web of Science Core Collection database. Two independent authors reviewed and determined the 100 most cited articles. The characteristics of each eligible article were recorded, including authors, institutions, countries, journals, publication date, total citations (TCs), annual citations (ACs), research focus and article type.

● **RESULTS:** The top 100 most influential articles were published between 1983 and 2016, with 1999 as the most prolific year. The mean number of TCs was 288 (range: 193-537) and the mean number of ACs was 19 (range: 7-109). Treatment and epidemiology of myopia were the most important research focus. These articles were published in 21 journals led by *Ophthalmology* (29%) followed by *Investigative Ophthalmology & Visual Science* (23%). The number of ACs for articles published in the last ten years was significantly higher than that for the other most-cited articles (44 *vs* 16, Mann-Whitney *U* test $P<0.01$). There is no difference in the number of TCs between original articles and review articles, while the number of ACs for review articles was significantly higher than that for original articles (22 *vs* 17, Mann-Whitney *U* test $P<0.05$).

● **CONCLUSION:** This bibliometric analysis can provide us with concise information about the development trend of research in the field of myopia in the past few decades, and provide an important reference for researchers to guide future research.

● **KEYWORDS:** bibliometric analysis; myopia; citation; therapy; refractive surgery

DOI:10.18240/ijo.2022.01.22

Citation: Wang XJ, Chen D, Jiang Y, Chou YY, Luo Y, Li Y, Ma J, Zhong Y. The 100 most influential articles in myopia: a bibliometric analysis. *Int J Ophthalmol* 2022;15(1):150-156

INTRODUCTION

Myopia (short-sightedness or near-sightedness) is becoming a major public health concern and is causing a huge economic burden[1]. The prevalence of myopia has expanded greatly over the past 50-60y and has reached epidemic levels in young adults in East and Southeast Asia[2-3]. With the increasing attention of myopia, a large volume of studies are published every year to provide new insights into the development of myopia, and treatment techniques have undergone a seismic revolution of the last decades.

In addition to the impact factor (IF) of journals, the number of citations of an article is also an important reflection of its contribution to that particular field. Bibliometric analysis can reveal the evolution of a field by objectively identifying seminal studies among a population of papers[4-5]. Since Garfield published the first bibliometric study in *JAMA* in 1987[6], this field has been developed and more and more articles have been published.

Bibliometric analysis has been widely used in several medical fields, such as asthma, obesity, diabetes, orthopedics, liver cancer, and pituitary adenoma[7-12]. A number of bibliometric studies have also been published in the field of ophthalmology, such as cataract surgery and dry eye[13-16]. However, similar bibliometric studies have not been conducted in the field of myopia. In this study, we aimed to identify and characterize the basic characteristics of the 100 most cited articles in myopia in recent few decades. We also intend to identify factors that contribute to the increase in citations, such as journals and publication time.

MATERIALS AND METHODS

Search Strategy Literature retrieval, screening and analysis follow the methods established in previously published articles[9,14]. The Web of Science (WOS) Core Collection

Table 1 The top 10 articles ranked by ACs

Rank	Articles	TCs	ACs
1	Holden BA, *et al*. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology* 2016;123(5):1036-1042.	436	109
2	Morgan IG, *et al*. Myopia. *Lancet* 2012;379(9827):1739-1748.	537	67
3	Fujiwara T, *et al*. Enhanced depth imaging optical coherence tomography of the choroid in highly myopic eyes. *Am J Ophthalmol* 2009;148(3):445-450.	493	45
4	Pan CW, *et al*. Worldwide prevalence and risk factors for myopia. *Ophthalmic Physiol Opt* 2012;32(1):3-16.	350	44
5	Rose KA, *et al*. Outdoor activity reduces the prevalence of myopia in children. *Ophthalmology* 2008;115(8):1279-1285.	519	43
6	Sekundo W, *et al*. 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. *Br J Ophthalmol* 2011;95(3):335-339.	384	43
7	He M, *et al*. Effect of time spent outdoors at school on the development of myopia among children in China: a randomized clinical trial. *JAMA* 2015;314(11):1142-1148.	209	42
8	Vitale S, *et al*. Increased prevalence of myopia in the United States between 1971-1972 and 1999-2004. *Arch Ophthalmol* 2009;127(12):1632-1639.	419	38
9	Shah R, *et al*. Results of small incision lenticule extraction: all-in-one femtosecond laser refractive surgery. *J Cataract Refract Surg* 2011;37(1):127-137.	314	35
10	Wallman J, *et al*. Homeostasis of eye growth and the question of myopia. *Neuron* 2004;43(4):447-468.	523	33

TCs: Total citations; ACs: Annual citations.

database was used for conducting a literature search on March 25, 2020. The index terms used for the search were "TOPIC: (myopia) OR TOPIC: (myopic) OR TOPIC: (nearsightedness) OR TOPIC: (shortsightedness) OR TOPIC: (near-sighted) OR TOPIC: (short-sighted) OR TOPIC: (high myopia) OR TOPIC: (pathological myopia)", a year of publication ranging from 1975 until 2020. Languages, document type and the WOS category were not restricted in the search.

Study Selection A total of 22 509 published articles were retrieved, and then these articles were sorted in descending order according to total citations (TCs). Articles conforming to the abovementioned conditions were evaluated and preliminarily analyzed by two independent readers (Wang XJ and Chou YY) to ensure its relation to myopia. The 100 most cited articles were determined by reviewing the titles and abstracts of these articles, and the full text if necessary. Articles focusing only on animals (*e.g.*, chickens and monkeys) were excluded from the screening process.

Data Extraction The 100 most cited articles that meet the screening criteria were then analyzed further. Article title, first and corresponding authors, journal, 2018 IF of Journal Citation Reports (JCR), IF of most recent 5-year, publication date, country of origin, institution, TCs, annual citations (ACs), citation number of most recent 5-year, research focus and study type were recorded for the top 100 most influential articles on myopia. The number of ACs was calculated by dividing TCs by the number of years since the manuscript was published.

Statistical Analysis The data were usually distributed in the form of mean and standard deviation, while the skewed data were presented in the form of median and range. The Shapiro-Wilk test was used to test the normality of the distribution of individual variables. Correlations among non-parametric variables were evaluated by Spearman's correlation analysis. Mann-Whitney *U* test was used to compare the difference between non-parametric variables. Analyses were performed with SPSS v.25 (IBM Corp., NY, USA). A two-sided *P*-value <0.05 was considered to be statistically significant.

RESULTS

A total of 22 509 papers related to myopia were published from the WOS Core Collection database. These papers were sorted by TCs, and the top 100 papers in the field of myopia were identified. The details of the top 100 most cited articles can be found in Supplementary Table 1.

Publication Date The 100 most influential articles were published between 1983 and 2016. Most of them were published between 2000 to 2009 (n=60), followed by 1990-1999 (n=28) and 2010-2019 (n=10), whereas only 2 articles were published between 1980 to 1989 and none before 1980. Figure 1 shows TCs for every paper in each year. Figure 2 shows the number of papers in each year. The TCs of an article was independent of its publication date (P>0.05). However, the number of ACs and citations in recent 5y are significantly correlated with publication date (r=0.774, P<0.01; r=0.597, P<0.01).

Article Type Among the top 100 most-cited articles, 85 were original articles and 15 were review articles. Three of the 15 review articles were systematic reviews and Meta-analysis. The highest TCs and ACs articles among the 100 most-cited articles were both review articles from Australia. The original articles comprised 52 observational studies and 33 experimental studies, the latter covers 10 randomized controlled trials (RCTs). Observational studies consisted of 38 cross-sectional studies, 6 cohort studies, 5 case series, and 3 case-control studies. According to the time logic classification,

the original articles included 38 cross-sectional studies, 37 prospective studies, and 10 retrospective studies. There was no difference in the number of TCs between the original articles and the review articles (Mann-Whitney *U* test *P*=0.141), while the number of ACs of review articles was significantly higher than that of original articles [Mann-Whitney *U* test *P*<0.05, median=22, range (9-109) *vs* median=17, range (7-45)].

Research Focus Treatment (*n*=27) and prevalence (*n*=27) of myopia was the most widely studied topic, accounting for more than half of the top 100 papers. Figure 3 shows the topics of articles. Among 38 studies focused on treatment and surgical complications of myopia, 25 were related to laser in situ keratomileusis (LASIK) and excimer laser photorefractive keratectomy (PRK), 3 for femtosecond laser small incision lenticule extraction (SMILE) and 3 for orthokeratology. The geographical range of epidemiological research was vast, including China, USA, India, Nepal, Singapore, Australia, Japan, South Africa, Malaysia, Chile and Western Europe. Of the 15 articles that studied the etiology of myopia, 10 articles studied children or teenagers. The most studied risk factors were parental history, near work, outdoor activities and genes.

Citations A total of 28 772 citations were obtained for the top 100 most influential articles. The number of TCs was highest at 537 for Morgan *et al*[1] and lowest at 193 for Goh *et al*[17]. The number of ACs was highest at 109 for Holden *et al*[18]. The median number of TCs and ACs were 266 and 16. Ninety-one articles were cited more than 200 times and 14 papers were cited more than 400 times. Table 1 shows the top 10 articles ranked by ACs.

Spearman correlation analyses revealed a significant positive association between the trends of TCs and ACs (*r*=0.572, *P*<0.01). Five of the top 10 articles ranked by TCs were listed in the top 10 articles ranked by ACs. The numbers of ACs of articles published in recent 10y [median=44, range (21-109)] were significantly higher than that of the other most-cited articles [median=16, range (7-45); Mann-Whitney *U* test, *P*<0.01]. Nevertheless, there was no such correlation for the average number of TCs (Mann-Whitney *U* test *P*=0.667). The recent 5-year citation number was also positively correlated with TCs (*r*=0.477, *P*<0.01). We believe that the number of citations in the last 5y can reflect the current research hotspots and trends better than TCs.

Journals The top 100 most influential papers were published in 21 journals. The journals of publication, journal IF according to the 2018 JCR and TCs for each journal are listed in Table 2. Specialized journals published most (94%) of the top 100 articles, leading with *Ophthalmology* (29 papers and 8122 citations) and *Investigative Ophthalmology & Visual Science* (23 papers and 6531 citations). None of the specialized journals listed in Table 2 had an IF of more than

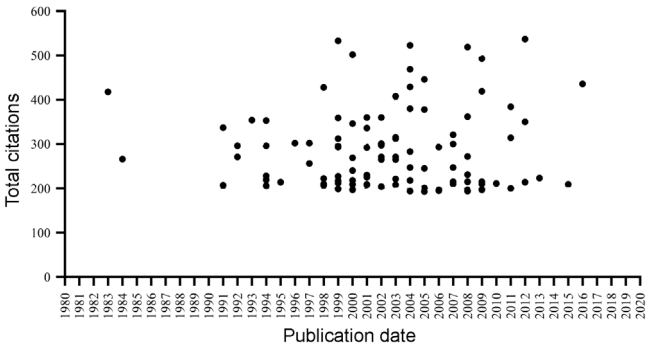

Figure 1 Overall citation rate since publication.

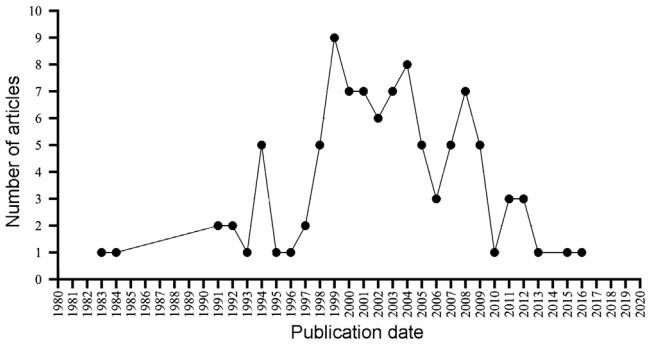

Figure 2 The number of papers in each year.

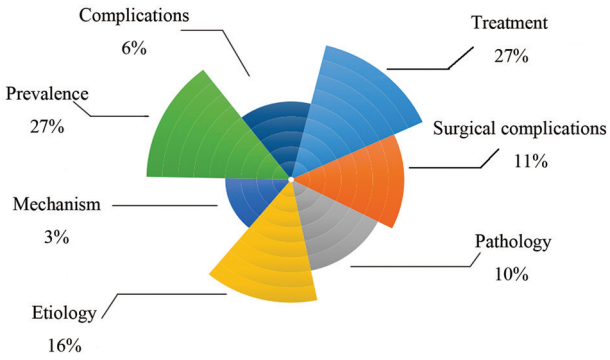

Figure 3 The topics of articles and its proportion.

12. Generalized journals published 6 papers and the IFs were all greater than 12. The *Lancet* had the highest IF of 59.1, and its only article is also the article with the most TCs. The IF is not statistically correlated with TCs (*P*>0.01).

Countries, Institutions, and Authors The top 100 most cited articles were originated from 14 countries led by the United States (*n*=43; Figure 4). The most productive institution with the highest TCs was the National Institutes of Health (NIH) of USA, which has published 12 articles and the TCs reached 3655. The top 7 institutes or academies contributing to the top 100 most-cited articles were listed in Table 3. Leon B. Ellwein's from the National Eye Institute of NIH has published the largest number of most influential articles on myopia (*n*=9) and was thus the most-cited author in this field. The authors with more than three articles were listed in Table 4.

DISCUSSION

Uncorrected or undercorrected myopia is the main cause of

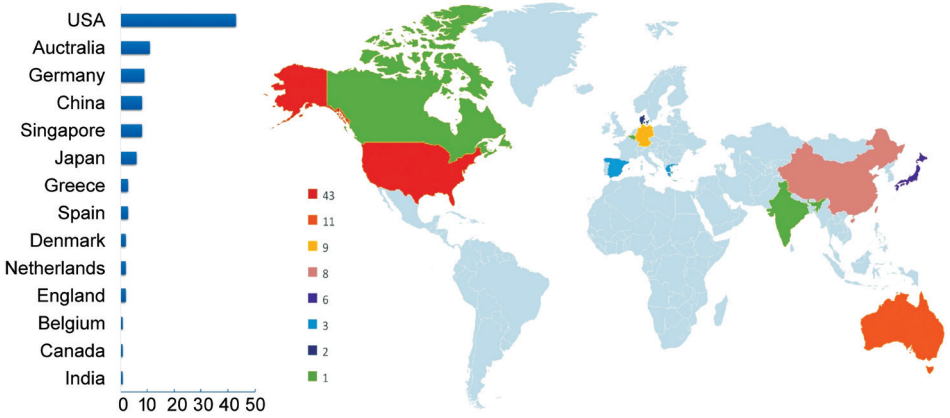

Figure 4 Geographical distribution of countries in 100 top-cited papers.

Table 2 Journals in which the 100 most-cited articles were published

Journal	No. of papers	2018 IF	IF in the past 5y	TCs
Ophthalmology	29	7.7	7.8	8122
Investigative Ophthalmology & Visual Science	23	3.8	3.7	6531
Archives of Ophthalmology (now: *JAMA Ophthalmology*)	10	4.4	4.4	2821
Journal of Cataract and Refractive Surgery	8	2.2	2.7	1891
American Journal of Ophthalmology	7	4.5	4.6	2117
British Journal of Ophthalmology	4	3.6	3.4	1004
JAMA	2	51.3	46.3	415
Progress in Retinal and Eye Research	2	11.8	12.3	690
Ophthalmic and Physiological Optics	2	2.6	2.8	796
Optometry and Vision Science	2	1.6	1.9	542
Lancet	1	59.1	54.7	537
Nature Genetics	1	25.5	31.1	223
Neuron	1	14.4	16.3	523
Retina	1	3.8	4	296
Survey of Ophthalmology	1	3.8	4	214
Epidemiology Reviews	1	6.5	10.4	302
Experimental Eye Research	1	3	3.3	293
Journal of Refractive Surgery	1	3	3.2	428
Annal Academy of Medicine Singapore	1	1.1	1.4	429
Current Eye Research	1	1.7	1.8	245
Journal of Refractive and Corneal Surgery	1			353

IF: Impact factor; TCs: Total citations.

visual impairment, and it has become an increasingly serious public health problem worldwide. Myopia brings further vision challenges since high myopia multiplies the risk of pathologic changes such as glaucoma, cataract, and myopic macular degeneration[19]. The global potential productivity loss in 2015 was estimated at $244 billion from uncorrected myopia and $6 billion from myopic macular degeneration[20].

With too many medical papers indexed in the database every day, it is difficult for clinicians and researchers to quickly find important articles in their fields of interest in the vast ocean of digital information. The bibliometric analysis can determine the most influential articles in a certain field of interest, and help clinicians and researchers grasp the changing pattern of clinical practice, current research priorities, and research trends in the future[21]. We conducted a bibliometric analysis of articles in the field of myopia and identified the 100 most influential articles, aiming to systematically determine the research trend of myopia.

The number of citations of a paper has become a valuable indicator for evaluating the efforts made by authors and journals as a measure of its impact on a particular field[22]. The TCs of the 100 most influential articles in myopia ranged from 193 to 537. This number is considerably higher than that in dry eye, for which the TCs ranged from 96 to 610, and cataract

Table 3 Institutions with more than two papers

Institution	No. of papers	No. of citations
National Institution of Health (NIH)	12	3655
National University of Singapore	8	2406
University of Sydney	6	1961
Ohio State University	5	1358
Emory University	4	1357
Johns Hopkins University	4	1280
University of Crete	3	785

Table 4 First and corresponding authors with multiple articles in the most-cited list

First author	No. of papers	No. of citations	Corresponding author	No. of papers	No. of citations
Seiler T	5	1416	Ellwein LB	9	2546
Saw SM	4	1214	Seiler T	5	1416
He MG	3	888	Saw SM	4	1262
Pallikaris IG	3	785	Mitchell P	4	1245
Morgan IG	2	915	Morgan IG	2	915
Randleman JB	2	770	Stulting RD	2	767
Lin LLK	2	741	Shih YF	2	741
Rose KA	2	716	Rose KA	2	716
Vitale S	2	691	Vitale S	2	691
Gwiazda J	2	669	Gwiazda J	2	669
Sekundo W	2	578	Bressler NM	2	631
Mutti DO	2	575	Katz J	2	604
Cho P	2	459	Sekundo W	2	578
			Mutti DO	2	575
			Pallikaris IG	2	560
			Marcos S	2	545
			Jonas JB	2	494
			Zadnik K	2	471
			Ohno-Matsui K	2	419

surgery, for which the TCs ranged from 85 to 281[14-15]. When the table is sorted in descending order according to ACs, the influence of year of publication on TCs can be reduced. The correlation between ACs and publication date indicated that the newer the literature, the more likely it is to cover the topics of the greatest concern among eye care professionals. The most-cited paper is "Myopia" by Morgan *et al*[1] published in The *Lancet* in 2012. This is a comprehensive review article of the biological basis, definition, epidemiology, pathology, risk factors of myopia, as well as interventions to control myopia.

IF can only represent the quality of the journal in a certain specialty and not enough for assessing the impact of specific articles. Spearman's correlation analysis showed the correlation between the IF and TCs is not statistically significant. This may due to that almost all of the 100 most influential papers were published by journals in the ophthalmology category, and the IF of these journals were not as high as that of comprehensive journals. Among all journal categories ranked by the number of journals in 2018 JCR (a total of 236 categories), ophthalmology ranks 126th with 60 journals, with a median IF of 1.889 and aggregate IF 2.551.

Treatment of myopia is the most studied topic, with 38 articles published after 1990. From these articles, we can discern the various intervention to control myopia and the main evolution course of refractive surgery over the past decades. Most articles published around the 1990s were about PRK and LASIK. In 1991, Seiler and Wollensak[23] proved PRK is an efficient procedure to correct or lower myopia up to -7.0 D. An RCT conducted by Pallikaris and Siganos[24] in 1994 concluded LASIK was more effective than PRK in higher myopes. In 1999, Oshika *et al*[25] found PRK and LASIK increase the wavefront aberrations of the cornea and change the relative contribution of coma- and spherical-like aberrations. This finding attributed to the smaller transition zone of the laser ablation in the LASIK. The 3 articles about SMILE were published during 2008-2011. Sekundo *et al*[26] conducted the first prospective clinical experiment in Germany to evaluate the feasibility of femtosecond lenticule extraction (FLEx) in 2008 and performed myopic FLEx through a small incision using SMILE procedure in 2011. He found SMILE was a promising new flapless minimally invasive refractive procedure to correct myopia. In 2008, Shah *et al*[27] in India carried out the first clinical study outside Germany performing SMILE with a single incision, proving all-in-one femtosecond refractive correction using a small incision technique was safe, predictable, and effective in treating myopia and myopic astigmatism. In 2004, the FDA performed a prospective clinical trial of implantable collamer lens (ICL) surgery and results supported the safety, efficacy, and predictability to treat moderate to high myopia[28]. In 2005 and 2012, Cho *et al*[29-30] published 2 studies confirming orthokeratology had both corrective and preventive/control effects in childhood myopia. In 2006, Chua *et al*[31] conducted an RCT and proved topical atropine was well tolerated and effective in slowing the progression of myopia and ocular axial elongation in Asian children.

Epidemiology is also a popular topic of myopia, with a total of 27 articles. The geographical range of epidemiological research was vast, with 8 articles from China and 5 articles from the United States, and also included India, Nepal, Singapore, Australia, Japan, South Africa, Malaysia, Chile and Western Europe. The U.S. NIH contributes 12 articles in the field of epidemiology of myopia. The article with the largest ACs, entitled "Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050", is a systematic review and Meta-analysis published in *Ophthalmology* in

2016, exerting far-reaching influences on the estimation of the prevalence trends of myopia[18]. In this article, Holden *et al*[18] included data from 145 studies covering 2.1 million participants and predicted that by 2050, myopia will show a significant increase in prevalence globally, affecting almost 5 billion people (50% of the world population), of which nearly 1 billion are high myopia (9.8% of the world population). The prevalence of myopia in high-income countries in the Asia-Pacific region is much higher than in any other region, and all regions will increase year by year over time. In 2000, the most myopic patients were between 10 and 39 years old. However, the research showed that this distribution will expand in 2050 due to the cohort effect and age effect, and most myopic patients will last between the ages of 10 and 79.

These 100 citations are landmark articles that have inspired clinical and basic research in myopia over the past decades. Our research may be worthwhile for several reasons. First of all, we found that myopia is a booming research hotspot, and the exploration on its epidemiology and treatment is in the ascendant. Second, our study offers new and old generations hints about what makes an article a most frequently cited classic. The eye care professors and their groups have to propose a surgical or medical innovation, worldwide influential clinical description, or discovery that has a long-lasting effect on clinical practice. Third, the top 100 articles reflect the major evolution of the treatment of myopia. In recent years, corrective treatment has shown a diversified trend, with treatment methods including PRK, SMILE, and ICL *etc*. Last but not least, our observations show that the authors of citation classics in myopia have produced more highly cited articles than many colleagues in other ophthalmology specialties.

Of course, some limitations of this study cannot be ignored. First, we selected the WOS database that is most commonly used in bibliometrics research, which resulted in the neglect of documents from other databases. Second, due to the use of TCs for evaluation, the importance of recently published articles may be weakened. Finally, we did not analyze self-citation, citations in textbooks, and lectures. Inappropriate self-citations might influence the results of the analysis. Some of the authors may have cited articles from the journal in which they hoped to publish their research. There may be “snowball effect” which means the previously high-cited articles may be cited more not because of their values but simply due to the tendency of complying with an established paradigm.

In conclusion, we conducted a bibliometric analysis of studies in the field of myopia, and identified the 100 most influential articles that have had the greatest impact on myopia research in the past few decades. This study emphasizes significant contributions in the field of myopia research, from which we can explore the future perspectives of myopia research.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. Bao Jin, MD., Department of Liver Surgery, Peking Union Medical College Hospital, for his kind help and advices regarding this article.

Authors’ contributions: Zhong Y, Li Y, and Luo Y conceived the study; Wang XJ and Chou YY collected the data; Wang XJ, Chen D and Jiang Y participated in data analysis and interpretation; Wang XJ wrote the first draft; Zhong Y and Ma J revised the manuscript. All authors read and approved the final manuscript.

Conflicts of Interest: Wang XJ, None; **Chen D,** None; **Jiang Y,** None; **Chou YY,** None; **Luo Y,** None; **Li Y,** None; **Ma J,** None; **Zhong Y,** None.

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