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RESEARCH ARTICLE

The Development Status and Countermeasures of Biomedical OA Journals in China: A Study Based on Statistical Analysis of the Journal Indexed Data in PubMed Central and DOAJ

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Abstract: This study aimed to analyze the characteristics of biomedical journals included in PubMed Central (PMC) and DOAJ, summarize the OA countermeasures of biomedical journals in China and provide a reference for the development of OA in biomedical journals in China. Firstly, this study retrieved and analyzed the features of biomedical journals indexed in PMC and DOAJ, including languages, OA types, CC licenses, peer review strategies, publishers, and APCs. Statistical processing was performed by SPSS 22.0 on the data of each feature, and a normal distribution test was performed on APC. By Dec. 31, 2023, DOAJ had included 92 (vs. PMC 103) of China's biomedical OA journals, of which 29 do not charge APC (diamond OA journal) and 63 charge APC (gold OA journal). China's biomedical journals included in PMC and DOAJ showed significant statistical differences in various characteristics, including language($P<0.05$), OA model ($P<0.05$), and CC license ($P<0.05$). APCs all exhibit a positively skewed distribution either in DOAJ or in PMC. The peer review method for China's biomedical journals is mainly single-blind peer review, followed by double-blind peer review, with a relatively evenly distribution, and no statistically significant differences are shown between groups ($P>0.05$). CC BY-NC-ND is the most commonly adopted license by China's biomedical journals, both in DOAJ and PMC, but there are significant differences between them (75.00% vs 47.57%). In terms of publishers, among the journals included in DOAJ, non-corporate editorial offices have the highest proportion (40.22%), followed by KeAi (26.09%) and Elsevier (8.70%). Among them, non-corporate editorial office owned journals are mainly Chinese journals. Among the journals included in the PMC, AME is the largest publisher (17.48%), followed by Elsevier (12.62%) and Springer Nature (8.74%). Among the 46 biomedical journals included in both DOAJ and PMC, English journals account for the vast majority (97.82%); gold OA, CC BY-NC-ND, and single-blind peer review are the main features of the journals mainly included in the list. The APCs of Chinese journals are significantly lower than those of English journals, with an average APC of $2065 ($400-4500) for English journals, and exhibit a normal distribution but far below the APC standards reported by internationally renowned journals in the literature. Currently, Bronze OA is the main OA type for biomedical journals in China. Compared to gold OA, diamond OA, or hybrid, bronze OA journals are short of clear OA statements, along with unclear copyright announcements. By referring to the journal indexing criteria of PMC and DOAJ, along with the OA characteristics of the included journals, it is helpful for the development of biomedical journals in China.

Keywords: DOAJ; PMC; Open Access; Gold OA; Diamond OA; Bronze OA; Hybrid Publishing

1. Introduction

The 41st Session of the UNESCO General Conference held in November 2021 reviewed and approved the "Open Science Recommendation", marking a new stage of global consensus on open science [1]. Open science includes open access (OA), open research data, and open peer review [2]. OA is an important component of open science [3]. OA breaks down barriers to access and promotes the rapid dissemination of academic achievements, which has a positive impact on the influence of science, technology, and medical journals (STM journals). In addition, OA has also made the journals change the business model, from the traditional subscription-based model to the author-paid model.

OA journals could be classified mainly into gold OA, diamond OA, bronze OA, hybrid, green OA, and delayed OA. Which, the differences between gold and diamond OA depend on whether journals charge Article Processing Charges (APCs), and as for the bronze OA journals, they bear the characteristics of unclear copyright issues [4]. According to the percentage of OA articles published in a certain journal, OA journals can be divided into Full OA journals and hybrid journals [5]. Different types of OA journals implement different OA strategies, among which golden OA and Diamond OA journals have clear provisions on the author's retention, transfer, and licensing of copyright. The main difference between gold OA and diamond OA is whether the journals charge APCs.

PubMed Central (PMC) is a biomedical full-text OA database created by The National Library of Medicine (NLM) in the United States in 2000[6]. PMC is one of the most important English evidence-based medicine databases that are also recommended as retrieving mandatory databases by many international regulatory agencies. The Directory of Open Access Journals (DOAJ) database was established by Lund University in Sweden in May 2003 and includes peer-reviewed Full OA (gold OA and Diamond OA) journals [7]. DOAJ is an OA database that includes all disciplines and languages and can truly reflect the publishing situation of global OA journals. The inclusion criteria of the DOAJ have also become the gold standard for unofficially evaluating OA journals [8-9]. At present, PMC does not have requirements for the journals with OA types, peer review, APC, etc., but has strict requirements for the language, editorial and writing standards, and transparency of the journal policies; The DOAJ only includes gold OA and diamond OA journals, and does not include journals with other types: Bronze OA, hybrid, Green OA, or subscription-based models with OA options. In addition, DOAJ has clear requirements for the Creative Commons (CC) license and peer review policy adopted by journals [10].

The former study discussed the inclusion strategy for biomedical journals in DOAJ and PMC [11], but the current status and features of China's biomedical journals included in PMC and DOAJ, as well as the significance of their selection criteria for OA development, remains unclear. Besides, no research on comparing the OA features of journals indexed by PMC and DOAJ was retrieved by us. This study retrieved and analyzed the current status of Chinese biomedical journals included in PMC and DOAJ, used statistical methods to analyze and compare the distribution of journals in PMC and DOAJ under different characteristics, and then summarized the publishing strategies of OA journals in order to provide a reference for the OA development of biomedical journals in China.

2. Research methods and data sources

2.1 PMC and DOAJ inclusion analysis

This study took the biomedical journals in China that are included in PMC and DOAJ as research objects and grouped the journals according to different types of characteristics (OA type, language, CC license, peer review strategy, APC, etc.) to investigate the current situation, similarities and differences of OA journals included in PMC and DOAJ under different groups. SPSS 22.0 statistical software was used to process the data, the Pearson x^2 test was used to test the grouped data, and the histogram model and normal distribution test were used to analyze the inter group differences of APC.

2.1.1 Grouping criteria and research content

Due to the fact that the DOAJ only includes Full OA journals, it is required that the indexed journals have clear copyright agreements and OA statements. Therefore, DOAJ only includes gold OA and diamond OA journals. PMC has no restrictions on OA types. In view of this, the analysis of OA types in PMC and DOAJ is divided into three categories: gold OA, diamond OA, and others (including hybrid, bronze OA, etc.). In addition, subgroup grouping is performed based on various parameters. Subgroup grouping criteria: 1) Inclusion time; 2) Language; 3) OA type; 4) CC license; 5) Peer review; 6) Publisher.

The research indicators include: 1) Statistical analysis of the differences in subgroup data between PMC and DOAJ. 2) Analysis of APC distribution characteristics of the journals indexed in PMC and DOAJ. 3) Feature analysis of journals that are included in both PMC and DOAJ.

2.1.2 Exclusion criteria

Due to the classification options in DOAJ, many journals are allocated into two categories. For example, if a Chinese journal has an English abstract, it will be listed as a Chinese journal or a Chinese-English journal. Therefore, it should be considered as the

Chinese journal and counted for one time. Other types of OA journals indexed in PMC include hybrid, Green OA, Bronze OA, etc. In terms of the CC licenses, such as CC BY-NC, CC BY-NC-ND, CC BY-SA, and CC BY-NC-SA all include the principle of attribution (CC BY), journals that execute the CC BY license should be excluded from duplicate labeling; but as for those with optional CC license up to the author, should be excluded.

2.2 Retrieval strategy

2.2.1 PMC retrieval strategy

PMC provides classification retrieval and MeSH keyword retrieval. Chinese journal retrieval strategy in this study: China [Country of Publication] AND Chinese[Language] AND (currently indexed[All]) Sort by: PubDate Filters: journals currently indexed in PMC; English journal retrieval strategy: China[Country of Publication] AND English[Language] AND (currently indexed[All]) Sort by: PubDate Filters: Journals currently indexed in PMC. Other search strategies: Journals PMC [All Fields] AND China[country]; Journals PMC[All Fields] AND Chinese[Language]. Then merge the data and eliminate duplicate bilingual journals.

Statistics analyses were carried out on the language, publisher, and other details such as CC licenses, APC, peer review policy, and others which were collected from PMC retrieval results and surfing on the journals' websites.

2.2.2 DOAJ retrieval strategy

The DOAJ retrieval strategy includes classification retrieval and keyword retrieval. This process used the DOAJ classification retrieval function. The specific classification function parameters included: publishing location, indexed time, subject classification, language, CC license, peer review types, publisher, APC, etc.

The retrieval process of DOAJ: 1) Selecting China as the publication location of the journal (including the option Taiwan Province of China); 2) The language is English AND/OR Chinese; 3) According to the type of discipline, select biology-related sub-specialties under the conditions of Medicine and other discipline options, such as Human Anatomy in the Science option; 4) Other parameters such as inclusion year, OA type, CC license, publisher information, APC, etc. 5) Duplicate information removal according to the exclusion criteria in 2.1.2.

2.3 Statistical processing

SPSS 22.0 statistical software was used in this study to conduct inter group comparative analysis of data from journals included in PMC and DOAJ under different classification categories. The inter group comparison of qualitative variable data (such as language, OA types, CC licenses, peer review types) was conducted using Pearson chi square test (component data $n \geqslant 40$, and $T \geqslant 5$), corrected chi square test (component data $n \geqslant 40$, and $1<T<5$) or Fisher's exact probability method (component data satisfying $n<40$ or $T<5$). $P<0.05$ indicated a statistically significant difference.

A normal distribution test was performed on quantitative variable data (APC). When the mean is greater than the mode, it would be positive skewness; When the mean is less than the mode, it would be negative skewness. As for the grouping of the group distance, the calculation of mode should consider the distribution of adjacent groups in the group where the maximum frequency ($M0$) is located. The calculation formula is as follows:

$$M0 = L + d \times \Delta 1/(\Delta 1 + \Delta 2)$$

In the formula above, L is the lower limit value of the group where the maximum frequency is located, d is the group distance, $\Delta 1$ is the difference between the frequency of the group where the maximum frequency is located and the frequency of the upper group.

3 Results and analysis

3.1 Analysis of Global Journal Inclusion in DOAJ and PMC

By December 31, 2023, DOAJ had included 20218 OA journals, of which 13326 do not charge APC (diamond OA), accounting for 65.91%; There is a total number of 6892 Gold OA journals, which accounts for 34.09% of the total number. In terms of language, DOAJ has no restrictions on the language of journals. As for the journal language category, the top 5 languages (including bilingual and multilingual journals) were English (16289, 80.57%), Spanish (3830, 18.94%), Portuguese (2450, 12.12%), Indonesian (1807, 8.94%), and French (1557, 7.70%). Since 2007, DOAJ has shown an upward trend in the inclusion of global OA journals. Since 2014, it has entered a period of rapid development, especially from 2015 to 2022, with DOAJ including over 1000 Diamond OA journals annually.

By December 31, 2023, PMC had included 4167 journals. The main language is English (3990, 95.75%). Journals in non-English languages (including bilingual) included in MEDLINE are rare (55 in French, 45 in Portuguese, 36 in Spanish, 29 in German, 12 in Chinese, etc.). Non-English journals before applying for PMC must firstly apply for MEDLINE. Starting from

2023, PMC will directly include Spanish language journals. The slow growth rate of journals indexed by PMC in recent years is mainly due to PMC's increasingly stringent Scientific and Editorial Quality Assessment. The main manifestation is that PMC strictly adheres to biomedical international guidelines for the writing and editing of the articles.

3.2 Analysis of the inclusion of Chinese biomedical OA journals in DOAJ and PMC

3.2.1 Inclusion status and trend analysis

By December 31, 2023, DOAJ had included 92 Chinese biomedical OA journals, in which, 29 are Diamond OA and 63 are Gold OA. The growth rate of the Chinese biomedical OA journals included in DOAJ from 2007 to 2013 was not relatively low. Since 2014, the growth rate increased obviously year-on-year, and since and since 2019, owning the strong promotion from DOAJ to China's scholarly journals, the growth rate was rocketing. The inclusion of Chinese biomedical journals by PMC was quite different from that of DOAJ. Before 2009, the growth rate of inclusion was relatively slow, but from 2009 to 2020, the growth rate was significantly fast year-on-year, mainly because the former MEDLINE included China's Chinese biomedical journals and newly launched English biomedical journals successfully applied for PMC. However, since then, the growth rate slowed down sharply. The annual growth and trend of biomedical journals in China included by DOAJ and PMC are shown in Figure 1.

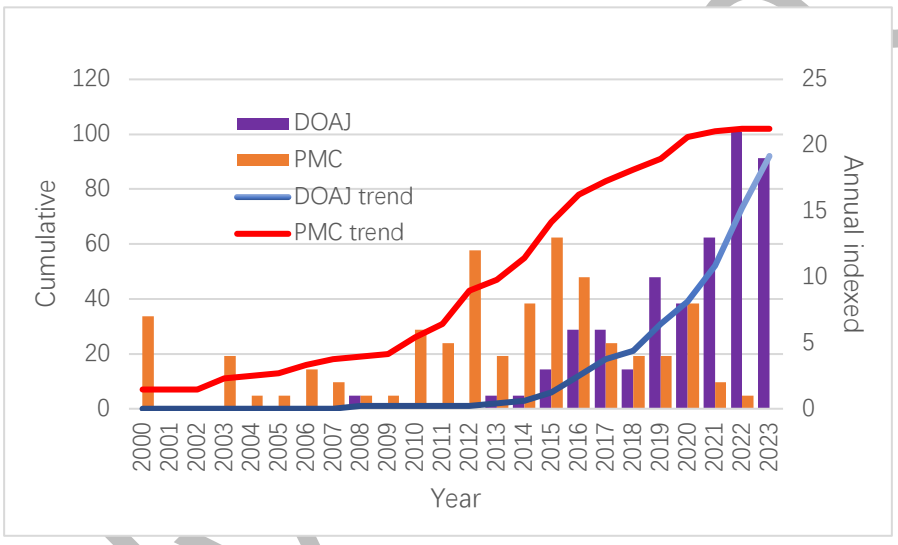

Figure 1. Analysis of the inclusion and trend of Chinese journals in DOAJ and PMC

3.2.2 Comparative analysis of the characteristics of journals indexed by DOAJ and PMC

In terms of language, English journals account for 59.78% of the Chinese journals included in DOAJ. Unlike DOAJ, PMC has a higher proportion of included English journals (88.35%). There is a significant statistical difference in language between DOAJ and PMC in the inclusion of Chinese biomedical journals (P<0.01).

In terms of OA classification, the inclusion of DOAJ and PMC is significantly different: DOAJ only includes Gold OA and Diamond OA journals; In addition to the Gold OA and Diamond OA journals, PMC also includes journals such as Bronze OA, Green OA, and hybrid journals. The proportion of Gold OA journals included in PMC and DOAJ has no statistical difference (68.48% *vs* 61.17%), but in terms of overall classification, there is a statistically significant difference in the OA types of Chinese biomedical journals included in the two databases (P<0.01).

In terms of CC license, CC BY-NC-ND is the most commonly adopted license by China's biomedical journals, indicating that China's OA journals tend to adopt stricter CC licenses. Meanwhile, the proportion of DOAJ indexed journals adopting this CC license is significantly higher than PMC (75.00% *vs* 47.57%), mainly because Chinese journals account for a higher proportion in DOAJ indexed journals, and Chinese journals mostly adopt CC BY-NC-ND license; In PMC, CC BY-NC and CC BY also account for a relatively high proportion (38.83% and 26.21%) of the included journals. Overall, there is a statistically significant difference (P<0.05) in the CC license adopted by biomedical journals in China which were included in the two databases.

In terms of peer review, there is no statistically significant difference between the China's biomedical journals included in the two databases (P>0.05). The peer review types for China's biomedical journals are mainly single-blind peer review, followed by double-blind peer review, with a relatively evenly distribution and no statistically significant differences are shown between

groups (P>0.05). The main feature analysis of China's OA journals, Gold OA journals, and Diamond OA journals included in DOAJ is shown in Table 1.

TABLE 1 MAIN CHARACTERISTICS ANALYSIS OF CHINESE BIOMEDICAL OA JOURNALS RECORDED IN DOAJ AND PMC

OA journals	DOAJ		PMC		Pearson χ^2	P value
	Number of journals (n=92)	Percentage/ %	Number of journals (n=103)	Percentage /%		
Language					21.078	0.000▲
English	55	59.78%	91	88.35%		
Chinese	37	40.22%	12	11.65%		
OA model					18.399	0.003▲
Gold OA	63	68.48%	63	61.17%		
Diamond OA	29	31.52%	22	21.36%		
Others*	0	0.00%	18	17.48%		
CC license					9.008	0.018▲
CC BY	16	17.39%	27	26.21%		
CC BY-NC	6	6.52%	4	38.83%		
CC BY-NC-ND	69	75.00%	49	47.57%		
CC BY-NC-SA	1	1.09%	5	4.85%		
CC BY-ND	0	0.00%	0	0.00%		
CC BY-SA	0	0.00%	0	0.00%		
Peer review					0.482	0.074
Single-blind	48	52.17%	52	50.48%		
Double-blind	38	41.30%	50	48.54%		
Others#	6	6.52%	8	7.77%		

*: Including Bronze OA, hybrid and Delayed OA. ▲: P<0.05; #: Include open peer commentary and open peer review, as well as a small amount of post publication use peer review and editorial board review.

Through the normal distribution test, it was found that the APCs of journals from China included in PMC and DOAJ exhibited a skewed distribution, and the distribution was positively skewed (Figure 2). Among them, in the journals included in PMC, the APCs distribution follows a normal distribution with $1963 (US dollars) as the axis of symmetry (M0=1963), ranging from 400 to 3500 US dollars. However, as the APC increases over $1963, the number of journals gradually decreases, showing a lightly skewed distribution trend (Figure 2). The average APC is $1943 and the standard deviation is $1108.

As for the journals included in DOAJ, the APCs distribution follows a normal distribution with $1027 as the axis of symmetry (M0=1027), ranging from $160 to $1893. However, as the APC increases, the number of journals gradually decreases, showing a lightly skewed distribution trend, either. The average APC is $1007 and the standard deviation is $625 (Figure 3).

Without considering the policy of reducing page fees, among the journals included in DOAJ, 37 Chinese journals and 26 Chinese-English journals explicitly stated that they charge fees. Among them, Chinese journals charge lower fees than English journals. The main charging methods are page-based charging and article-based charging. The situation of journals included in PMC is similar to that of DOAJ, with Chinese journals charging lower fees than English journals. The main charging methods are page-based charging and article-based charging. Among the journals included in PMC, there are 7 Chinese journals with unclear APC information on the websites (Bronze OA journals), 4 of which charge for 500 RMB/page, and 1 charges for 5000 RMB/article. In terms of English journals, except for Diamond OA and 7 OA journals with unclear fees, the APCs range from $1000 to $5000 per article.

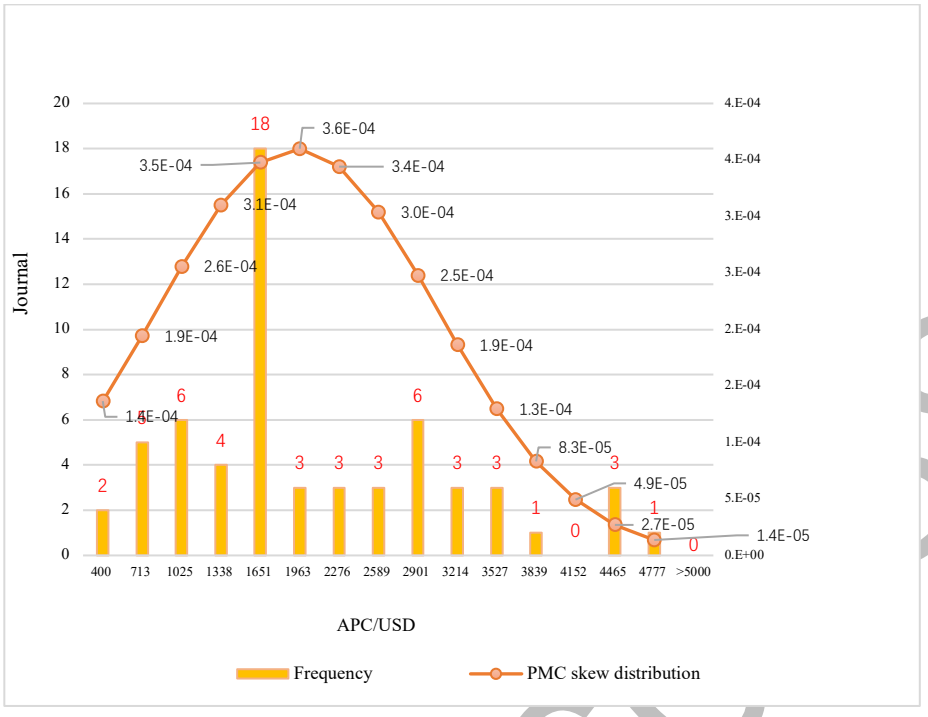

Figure 2. Skew distribution of the APC of China's biomedical journals indexed in PMC

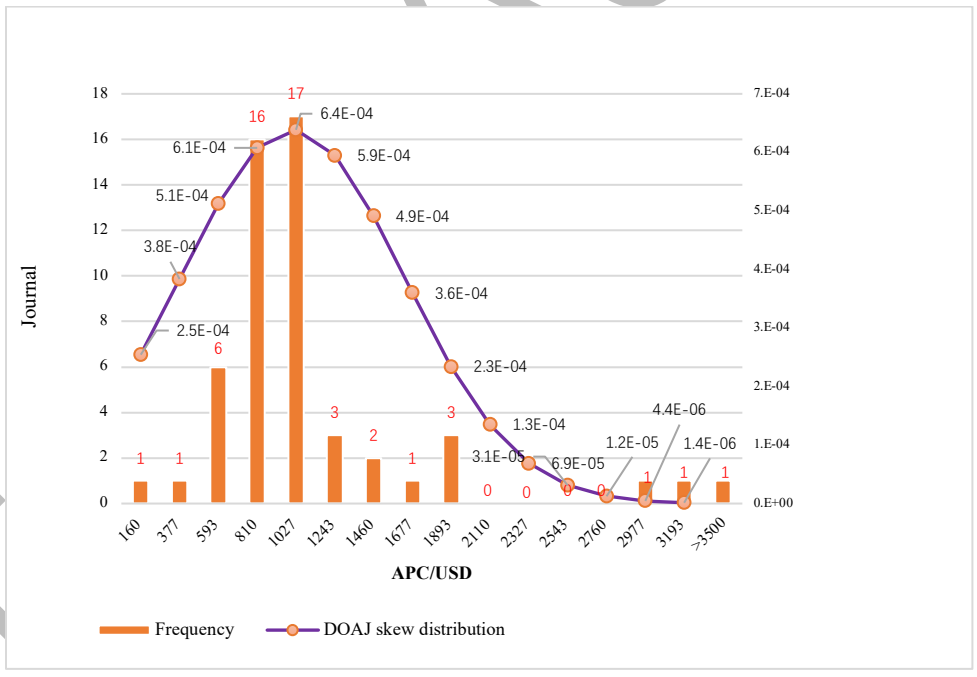

Figure 3. Skew distribution of the APC of China's biomedical journals indexed in DOAJ

In terms of publishers, among the journals included in DOAJ, non-corporate editorial offices have the highest proportion (40.22%), followed by KeAi (26.09%) and Elsevier (8.70%). Among them, non-corporate editorial offices owned journals are mainly Chinese journals; Among the journals included in the PMC, AME is the largest publisher (17.48%), followed by Elsevier (12.62%) and Springer Nature (8.74%). In addition, the results of this study also found that: 1) Among the China's biomedical journals included in the two databases, KeAi Publishing Group is the largest OA journal publisher; 2) None of the AME journals

included in PMC have been included in DOAJ, possibly because DOAJ is not the target database for AME's application. 3) Many journals belong to Springer Nature and other publishers adopt a hybrid model and are therefore not included in DOAJ. The distribution and comparison of publishers of Chinese biomedical journals included in the DOAJ and PMC are shown in Table 2 and Figure 4.

TABLE 2. THE PUBLISHERS DISTRIBUTION OF THE OA BIOMEDICAL JOURNALS PUBLISHED IN CHINA BOTH INDEXED IN DOAJ AND PMC

Publisher	DOAJ		Publisher	PMC	
	Number of journals (n=92)	Percentage/%		Number of journals (n=103)	Percentage /%
Non-corporate editorial office	37	40.22%	AME	18	17.48%
KeAi	24	26.09%	Elsevier	13	12.62%
Elsevier	8	8.70%	Springer-Nature	9	8.74%
Science Press	6	6.52%	KeAi	7	6.80%
Open Exploration Publishing Inc.	6	6.52%	Chinese Medical journal Publish House Co. Ltd	6	5.83%
Others	11	11.96%	Others	50	48.54%

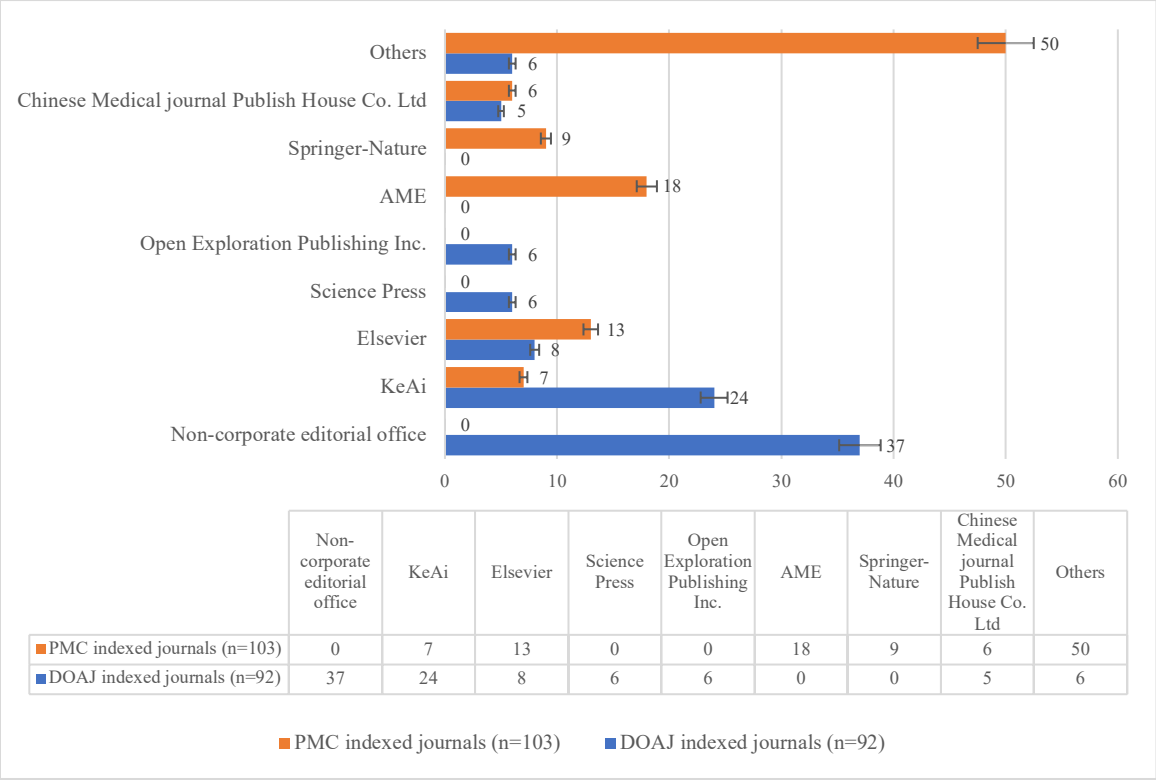

Figure 4 The publisher distribution status of China biomedical journals that both indexed by DOAJ and PMC

3.2.3 Characteristic analysis of journals indexed by both DOAJ and PMC simultaneously

A total of 46 Chinese biomedical journals were simultaneously included in DOAJ and PMC (Table 3). In terms of language, English journals account for the vast majority, reaching 97.82%. There is only one Chinese journal included. In terms of OA types,

the proportion of Gold OA is significantly higher than that of Diamond OA (63.04% *vs* 36.96%). There are no other types of OA journals. As far as CC license is concerned, CC BY-NC-ND has the highest proportion (45.64%), indicating that OA journals tend to adopt stricter CC licenses, followed by CC BY (39.13%), CC BY-NC-SA (10.87%), and CC BY-NC (4.35%), with no other types of CC journals. As for peer review, single-blind peer review is the main peer review method (63.04%), followed by double-blind peer review (34.78%), and one journal adopts open peer review (2.18%).

Regarding the APC, 29 journals charge APC. The APC distribution is between $400 and $4500 per article (Figure 5). By conducting a normal distribution test on APCs, it was found that the APCs of journals included in DOAJ and PMC exhibit an approximate normal distribution, with an average of $2065 per article and a standard deviation of $1086 per article. The normal distribution diagram of APC is shown in Figure 6.

TABLE 3. THE CHARACTERISTICS OF THE OA BIOMEDICAL JOURNALS PUBLISHED IN CHINA BOTH INDEXED IN DOAJ AND PMC

OA journals	Number of journals (*n*=46)	Percentage
Language		
English	45	97.82%
Chinese	1	2.18%
OA model		
Gold OA	29	63.04%
Diamond OA	17	36.96%
Bronze OA	0	0.00%
CC license		
CC BY	18	39.13%
CC BY-NC	2	4.35%
CC BY-NC-ND	21	45.64%
CC BY-NC-SA	5	10.87%
CC BY-ND	0	0.00%
CC BY-SA	0	0.00%
Peer review		
Single-blind	29	63.04%
Double-blind	16	34.78%
Open peer review	1	2.18%
Publisher		
Elsevier	10	21.74%
BMC	4	8.70%
Springer-Nature	4	8.70%
Wiley	3	6.52%
KeAi	3	6.52%
Others	25	54.35%

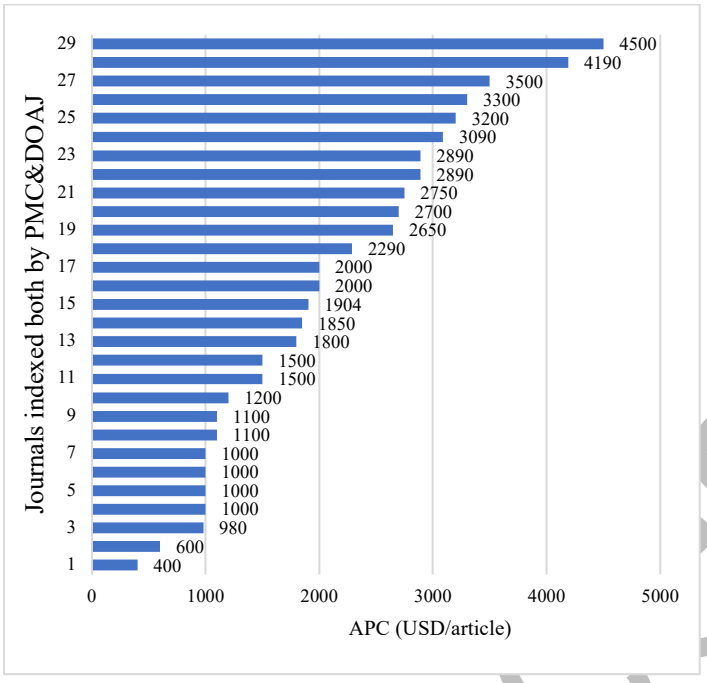

Figure 5 The distribution status of APC charged by China biomedical journals that both indexed by DOAJ and PMC

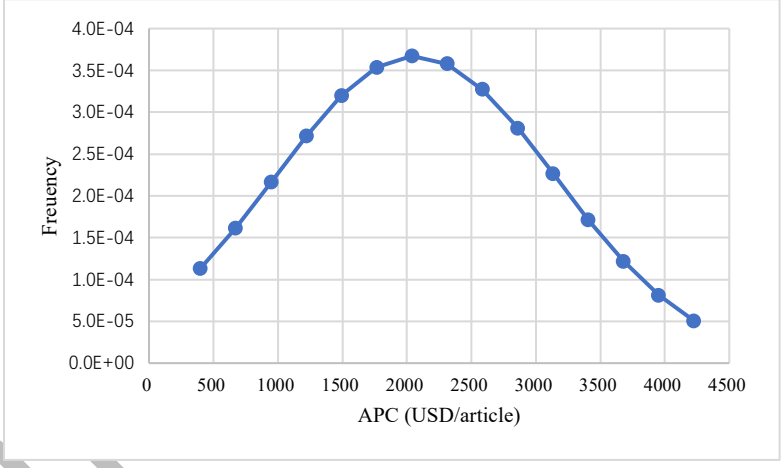

Figure 6 Normal distribution of the APC of China biomedical journals both indexed by DOAJ and PMC

DOAJ is the world's largest OA database, and PMC is one of the most important biomedical evidence-based databases. The OA standards of DOAJ and PMC for journals are of great significance for a journal to carry out OA publishing model, as well as for transparency policy. In recent years, although DOAJ has increased its publicity efforts and the number of journals included in DOAJ is booming, the overall number of China's biomedical journals included in PMC and DOAJ is still very small, which cannot fully reflect the OA status of domestic biomedical journals in China[12]. This is mainly because DOAJ and PMC have strict including standards for journal. In addition, PMC has strict requirements for the writing and editing standards[13-14] of a journal by adopting the guidelines released by Enhancing the QUAlity and Transparency Of health Research (EQUATOR) Network[15]. Therefore, the China's journals newly included in PMC have dropped to freezing point in recent years.

In terms of publishers, Elsevier has the highest proportion of journals (21.74%), followed by BMC (8.70%), Springer Nature (8.70%), and Wiley (6.52%). KeAi's journals account for only 6.52%, significantly lower than KeAi's in DOAJ (6.52% *vs* 26.09%), which may result from the different publishers has its own target databases, therefore leading to different statistical results. Anyway, cooperating with international publishers is important for the development of China's OA biomedical journals[16].

4. Countermeasures for OA in Biomedical Journals in China

At present, there are over 8400 STM journals in China. Biomedical journals are an important component of China's STM journals. According to the *"Blue Book on the Development of China's Science and Technology Journals (2023)"* [17]. At the end of 2022, the total number of STM journals in China was 5163, including 1251 in the fields of biology and medicine and health care (90 *vs* 1161). The research results of the *"Report on the Development of Open Access Publishing in China (2022)"*[18] showed that by May 2022, OA STM journals in China accounted for 36.47%, in which, bronze OA journals have the highest proportion (29.40%), followed by Gold OA and Diamond OA journals, and 63.53% STM journals are subscription-based model. In addition, a study reported that China's OA journals currently were mainly Bronze OA, which means the copyright details of the journals are unclear [19]. In January 2022, cOAlition S, an organization promoting the Golden OA Plan S, released its annual report "Accelerating Open Access"[20], which summarized the overall development and future trends of Plan S. The report points out that the gold OA model is an important OA model for the future. Liu reported the trends and policy perspectives in Singapore [21]. While it is quite different from China. The results of this study revealed that among China's biomedical journals included in PMC, bronze OA, and delayed OA journals account for 17.48%, and more than 60% are gold OA journals either in DOAJ or PMC. We could see that the proportion of China's biomedical journals included in PMC and DOAJ is still lying on the floor. Therefore, there is still a long way for the OA development of biomedical journals in China to go.

4.1 Formulate OA strategies in line with China's biomedical journals

CC license should be adopted and clarified in the OA statement. OA statement is the media for displaying the OA model and copyright agreement of the journal. The CC license is an important component of the journal OA statement [10], which includes four basic claims: creator (BY), non-commercial use (NC), no derivatives (ND), and share alike (SA).

The current CC 4.0 version includes 7 CC licenses (CC BY, CC BY-NC, CC BY-NC-ND, CC BY-NC-SA, CC-BY-ND, CC BY-SA and CC0). In this study, the CC license type most commonly used by China's biomedical journals included in PMC and DOAJ is CC BY-NC-ND, but it accounts for a higher proportion in DOAJ than in PMC (75.00% *vs* 47.57%), and the difference is statistically significant. CC BY-NC-ND is the strictest type, and there are significant differences in the use of other types of CC licenses between DOAJ and PMC-indexed journals. DOAJ has more journals using CC BY and CC BY-NC, while PMC has more journals that prefer CC BY-NC to CC BY. In addition, PMC includes hybrid journals, and authors can choose whether to publish their articles through OA or not totally based on whether they would pay APC. If the journal is a hybrid publication, the impact of adopting an OA strategy on PMC is reflected in the delayed opening of literature, usually for 12 months. The journal restricts commercial use and prohibits authors or any other one from interpreting works before publishing them (adaptation, translation, annotation, organization).

Among the journals either indexed by DOAJ or PMC, CC BY-NC-ND still has the highest proportion (45.64%), indicating that OA journals tend to adopt stricter CC licenses. CC BY-NC-ND prohibits commercial use and derivatives. According to the current Copyright Law of the People's Republic of China, derivative works are created by adaptation, translation, annotation or arrangement of a pre-existing work. Therefore, restrictions can be imposed through CC BY-NC-ND on the re-publication of derivative works by authors or other persons after interpretation. It is worth learning about China's Bronze OA biomedical journals. The journal that uses a CC BY license has the maximum open permission under the premise of author authorship. There are no restrictions on the interpretation or commercial use of published works. CC BY-NC-SA and CC BY-SA are applicable to journals prioritized for online publication or those prioritized for publication on preprint platforms. Therefore, for most bronze OA journals and those unindexed journals under the subscription-based model in China, the OA model is worth trying.

4.2 Fast display of academic achievements

DOAJ is an instant OA database, and PMC has a great flexibility attitude to the OA types of journals. Although PMC includes Delayed OA, it requires that a journal should open its full text no longer than 12 months after the publication of the article. The half-life of biomedical literature is short, OA is beneficial for the rapid dissemination of academic results, thereby improving the visibility of journals [2-3]. By drawing on the requirements of DOAJ and PMC, as well as the characteristics of OA journals included in both databases, journals can help biomedical journals develop OA strategies and related policies.

4.3 Practice Academic Publishing Transparency and Best Practices Standards

The DOAJ first released the *Principles of Transparency and Best Practice in Scholarly Publishing* in December 2013[12], and another three revised versions have been published since then, aiming to ensure the quality and credibility of academic research by improving the transparency of academic publishing behaviors and processes [22]. Subsequently, PMC also uses it to evaluate the applying journals.

Principles of Transparency and Best Practices in Scholarly Publishing would be helpful for the improvement of the transparency of China's scholarly journals. According to it, the basic information of the journal, CC license, OA statement, peer review policy, APC, etc. should be exposed and carried out. As for the OA statement, it should demonstrate that the journal should

comply with its own CC license and clarify the scope of users' rights and obligations. Implementing a peer review policy is one of the important means to achieve open science, furthermore, it is an important guarantee for the content quality of biomedical journals and an important means to prevent the predatory development of journals [12]. Strictly implementing OA strategies in journals can help to prevent the occurrence of predatory publishing and to improve the transparency of OA journals.

4.4 Strengthening the scientific and editorial quality

PMC has very strict evaluation criteria for article quality. PMC set a standard named "Scientific and Editorial Quality Assessment Principles"[6] for evaluating the articles of journals applying for inclusion, which requires that the writing and editing of articles should strictly comply with international standards (all from the EQUATOR Network's Biomedical Research Reporting Guidelines) [15] and disclose specific elements of the research according to the guidelines. For example, clinical research needs to strictly follow the Helsinki Declaration and CONSORT (Consolidated Standards of Reporting Trials) guidelines for information disclosure and writing, and the author needs to expose the registration numbers; Systematic reviews and meta-analyses need to be written according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, flow chart, forest plot and bias analysis should be exhibited in the article. Therefore, referring to PMC's "Principles for Scientific and Editorial Quality Assessment" can help standardize the writing standards of the articles and improve the quality of journal content.

In short, Strengthening the scientific and editorial quality will contribute to the quality of biomedical journals in China.

4.5 Selection of journal publishing model and APC strategy

At present, many biomedical journals in China have transformed from traditional subscription-based models to Bronze OA or Gold OA, and have formed their own characteristics. APC is the main source of revenue for gold OA journals. In the development process of OA, Bronze OA journals can be transformed into Gold OA and Diamond OA journals by clarifying copyright agreements through transparency and policy standardization [22-23].

The DOAJ requires journals to disclose APC and other fee information. The charges by gold OA journals should be within a reasonable range. When the charge is too high, the submitting number will decrease, moreover, OA journals with large publication volumes and high APC fees may be considered as predatory journals [24]. The results of this study showed that the APCs for Chinese biomedical journals indexed by PMC and DOAJ in China are significantly lower than those for English journals; In journals indexed by both PMC and DOAJ, the APC distribution ranges from $400 to $4500 per article, with an average of $2065 per article, following a normal distribution pattern. However, the average APC is much lower than the that of the journals published by internationally renowned publishers [25].

Most Chinese Bronze OA journals and subscription-based journals in China still use the traditional layout fee charging model, and the fees are generally not high compared with those owned by international publishers. As for the Gold OA Chinses journals, the APC charges in this study are relatively as low as the former study reported [26]. Some English OA journals have established preliminary APC charging policies. Therefore, it is necessary to establish a charging system framework suitable for the development of OA journals in China. In short, whether to charge APC or not, biomedical journals should clearly display relevant information about APC, and the waving of APC should be clearly announced either.

5. Discussion

5.1 The challenge of OA transformation for China's biomedical journals

The Blue Book on the Development of China's Scientific and Technological Journals (2023)[17] points out that China's STM journals have their own characteristics, forming a self-operated journal website, free access to full-text, and a paid model that relies on external platform dissemination channels to provide full-text, opening up a parallelled publishing model of OA and subscription for the same journal. PMC also included a large number of hybrid journals. However, the difference between hybrid and Gold OA is that the hybrid journals included in PMC are based on the author's choice, and authors may choose whether their papers will be published in OA or not. Nevertheless, regardless of whether the OA model is adopted or not, the publishing style of hybrid journals is worth learning from. However, it should be pointed out that although the development of OA in China's journals has its own characteristics, we should also recognize that bronze OA journals in China are still short of OA statements and CC licenses, as well as clarified copyright agreements. In addition, in terms of copyright transference agreements, many journals do not clarify the transference of information network dissemination rights and other transfer contents, which can also lead to disputes in subsequent database payment, downloads, and derivatives [27]. Therefore, improving and publicizing copyright agreements is beneficial for journals, authors, and readers.

Through the analysis of China's biomedical journals included in DOAJ and PMC, we may find that the majority of biomedical journals in China have not yet been indexed in the PMC and DOAJ, which shows enormous potential for inclusion. The existing inclusion data is insufficient to reflect the situation and characteristics of OA circumstances in China, but their inclusion standards and requirements for OA journals are worth learning from. Since the implementation of the "Action Plan for the Excellence of China's STM Journals" in 2019, dozens of new journals categorized as "High Starting Point Journals" have been selected each

year [27-28]. We are looking forward to new launched OA journals in China would break the ice, be included by world renowned databases, and do favor to the progress of biomedical research.

5.2 To collaborate with international publishers

The results of this study showed that DOAJ included 37 journals published by non-corporate editorial offices in China, accounting for 40.22% of the total number of journals included in China, and most of them are Chinese journals. For English publications, they are mostly jointly organized by domestic units and international publishers. In essence, for Chinese hosting units, their model is also a single-journal publication model, rather than a publisher clustering model. *The Blue Book on the Development of China's Science and Technology Journals (2023)* [17] points out that by the end of 2022, the total number of China's 5163 STM journals belonging to 3218 sponsoring units, and 77.13% of sponsoring units only sponsored one scholarly journal. In the development trend of OA journal clustering, disciplinary or regional clusters of OA journals may be the future developmental style.

5.3 The differences of OA characteristics of the journals indexed in DOAJ and PMC

DOAJ and PMC are both OA full-text databases, with the difference being that DOAJ only includes Gold OA and Diamond OA journals (with full disciplines and languages)[27], while PMC only includes biomedical journals but with no requirements for OA types[7, 29-30]. PMC has great flexibility on the OA types and CC licenses implemented for indexed journals, especially for hybrid and Delayed OA, among which, Delayed OA journals need to specify how long after publication they can switch from subscription to OA [6]. For China's OA journals, bronze OA accounts for the vast majority. Clarifying copyright agreements, OA statements, and CC licenses can help bronze OA journals regulate the scope of users' rights and obligation.

Given the current development status of OA in China's STM journals, this study analyzed the inclusion of China's biomedical journals in PMC and DOAJ and analyzed the number and characteristics of the included journals (including discipline classification, language, CC license, peer review, publication status, etc.). The results of this study showed that there were statistically significant differences in languages, OA types, and CC licenses between China's biomedical journals indexed by DOAJ and PMC (P<0.001, P<0.01, and P<0.05), while there was no statistically significant difference in peer review type (P>0.05). In all, regardless of the OA model adopted by biomedical journals, CC licenses (or clear copyright agreements), OA statements, CC licenses, clear APC charges, and peer review strategies are necessary conditions for OA journals. Moreover, APC and the OA model should depend on the journal's own condition.

6. Limitations of this study

This study still faces the following shortcomings: 1) The number of China's biomedical journals included in DOAJ and PMC is definitely small, larger sample analysis is needed in the future. 2) China's biomedical journals are divided into two categories based on copyright ownership: journals sponsored by China's authorities and journals published in collaboration with foreign publishers, some data might be ignored.

7. Conclusion

In recent years, the quantity of China's biomedical OA journals has been booming, but we should also be aware of the existence of bronze OA journals, which are characterized by unclear copyright details and a shortage of OA statements. OA journals, especially gold OA and diamond OA indexed by PMC and DOAJ, are still unsatisfied. Therefore, studying the OA characteristics and including policy from PMC and DOAJ would be helpful to the bronze OA journals to clarify the copyright and CC licenses in China. To publish under the Gold, Diamond, or hybrid OA model and clarify the copyright and transparency of the journal's information would be beneficial for China's biomedical journals.

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Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Author Contribution Statement

Linhui Wang: Conceptualization, Methodology, Funding, Database Retrieving of DOAJ, Writing-Original Draft and Editing the Final Draft. Ming Ni: Formal Analysis, Review & Editing. Xiaowen Li: Database Retrieving of PubMed, Writing-Original Draft, Review.

Data Availability Statement

Not applicable.

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