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Mathematical Models for Contraceptive Use : A Review

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Abstrak

Penelitian ini mengkaji perkembangan pendekatan kuantitatif yang digunakan untuk menganalisis penggunaan kontrasepsi, dengan penekanan khusus pada studi pemodelan matematis dan statistik yang diterbitkan antara tahun 2019 dan April 2024. Tinjauan literatur sistematis dilakukan dengan mengikuti kerangka kerja PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), yang dikombinasikan dengan analisis bibliometrik. Artikel-artikel diperoleh dari basis data Scopus dan ScienceDirect menggunakan kombinasi kata kunci yang berkaitan dengan penggunaan kontrasepsi dan pendekatan pemodelan. Pencarian awal mengidentifikasi 2.494 artikel, yang disaring berdasarkan tahun publikasi, jenis dokumen, bahasa, dan relevansi dengan topik penelitian. Setelah menyaring judul, abstrak, dan menerapkan kriteria inklusi dan eksklusi, 62 artikel dipilih untuk analisis akhir. Analisis bibliometrik menggunakan VOSviewer dilakukan untuk mengidentifikasi jaringan ko-kemunculan kata kunci dan ko-penulisan di antara para peneliti. Hasilnya menunjukkan bahwa penelitian tentang penggunaan kontrasepsi telah meningkat secara stabil selama periode studi dan bahwa berbagai pendekatan pemodelan kuantitatif telah diterapkan untuk menganalisis dinamika kontrasepsi di berbagai negara. Pendekatan kuantitatif yang digunakan dalam studi-studi yang ditinjau meliputi regresi logistik, model bertingkat, analisis spasial, metode Bayesian, model deret waktu, pembelajaran mesin, jaringan saraf tiruan, dan beberapa model populasi matematis. Pendekatan-pendekatan ini banyak digunakan untuk mengkaji faktor-faktor penentu penggunaan kontrasepsi, termasuk faktor-faktor sosiodemografis dan spasial yang memengaruhi adopsi kontrasepsi. Analisis bibliometrik menggunakan VOSviewer mengidentifikasi enam kelompok kata kunci dengan 3.636 tautan dan empat kelompok kolaborasi penulis dengan 66 tautan, yang menunjukkan hubungan tematik yang kuat dan kolaborasi penelitian yang berkembang di bidang ini. Secara keseluruhan, temuan ini menyoroti peran yang semakin penting dari pendekatan pemodelan kuantitatif dalam memahami dinamika kontrasepsi dan mengidentifikasi faktor-faktor yang memengaruhi penggunaan kontrasepsi.
Kata kunci: Penggunaan Kontrasepsi, Model Matematika, Tinjauan Literatur Sistematis

Abstract

This study reviews the development of quantitative approaches used to analyse contraceptive use, with a particular emphasis on mathematical and statistical modelling studies published between 2019 and April 2024. A systematic literature review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, combined with bibliometric analysis. Articles were retrieved from the Scopus and ScienceDirect databases using combinations of keywords related to contraceptive use and modelling approaches. The initial search identified 2,494 articles, which were filtered based on publication year, document type, language, and relevance to the research topic. After screening titles, abstracts, and applying inclusion and exclusion criteria, 62 articles were selected for final analysis. Bibliometric analysis using VOSviewer was conducted to identify

keyword co-occurrence and co-authorship networks among researchers. The results indicate that research on contraceptive use has increased steadily during the study period and that various quantitative modelling approaches have been applied to analyse contraceptive dynamics across different countries. Quantitative approaches used in the reviewed studies include logistic regression, multilevel models, spatial analysis, Bayesian methods, time-series models, machine learning, artificial neural networks, and several mathematical population models. These approaches are widely used to examine determinants of contraceptive use, including socio-demographic and spatial factors influencing contraceptive adoption. Bibliometric analysis using VOSviewer identified six keyword clusters with 3,636 links and four author collaboration clusters with 66 links, indicating strong thematic relationships and growing research collaboration in this field. Overall, the findings highlight the increasing role of quantitative modeling approaches in understanding contraceptive dynamics and identifying factors influencing contraceptive use.

***Keywords**: Contraceptive Use, Mathematical Models, Systematic Literature Review*

1 Introduction

Population growth is a global issue that seriously threatens people's quality of life, especially in countries that are developing or underdeveloped [1]. Rapid population growth can place pressure on health systems, economic resources, and social development, making population management an important global policy issue.

In many countries, population growth is closely related to reproductive health outcomes, including maternal and infant mortality. In Indonesia, population growth has an impact on public health. The maternal and newborn mortality rates remain high. In 2020, the maternal death rate was over 189 per 100,000 live births, while the infant mortality rate was roughly 18 per 1,000 live births. This rate was higher than in other ASEAN nations. The large proportion of mothers gives delivery at risk of being too young, too elderly, too close, or too numerous impacts the maternal death rate. Short birth intervals can be devastating for both mother and child.

The optimal birth spacing is connected to the practice of contraception-based family planning. Family planning is a critical component of safe motherhood programs due to its direct and indirect effect on maternal mortality [2]. It is commonly known that unwanted pregnancies contribute to maternal mortality and morbidity; research suggests that up to 44% of maternal fatalities could be prevented by using contraceptives effectively [3].

Family planning plays a crucial role in government efforts to effectively manage population growth, enhance maternal and child health, improve education and quality of life, advancing economic and social development [4], [5], [6], [7]. By promoting family planning, governments can achieve sustainable development goals and improve the quality of life of society as a whole. The manifestation of the family planning program is the use of contraception. It is essential to study the dynamics of contraceptive use to evaluate contraceptive use, trace the space of contraceptive method use, and plan for future needs. Mathematical models can play an essential role in planning and implementing effective contraceptive programs by providing

insight into the effectiveness of various methods, optimizing their use, and designing effective policies and interventions. Mathematical models and statistical analysis of contraception have increased in recent years. Statistical analyses have been used by researchers, such as multilevel modeling where observable (fixed effects) variables are included to assess the factors associated with modern contraceptive utilization [8], [9], [10]. In other studies, the researchers used logistic analysis, Bayesian approach, Data Mining, ANN to evaluated the use of contraceptive [11], [12], [13].

Despite the growing number of studies analyzing contraceptive use, the existing literature remains fragmented in terms of modeling approaches. Many studies focus on identifying determinants of contraceptive use using statistical models, while fewer studies examine broader modeling frameworks that capture contraceptive dynamics at the population level. Furthermore, there is still limited synthesis that systematically maps the types of models used, the key variables involved, and the geographical context of these studies.

Therefore, a comprehensive review is needed to provide a clearer overview of modeling approaches used in contraceptive research and to identify emerging research trends. This study integrates systematic literature review and bibliometric analysis to map modeling approaches, identify dominant research themes, and highlight potential directions for future mathematical modeling development in contraceptive studies.

Based on these issues, this study aims to:

1. Identify and classify the quantitative modeling approaches used in contraceptive use research, including both statistical and mathematical modeling frameworks;
2. Examine the geographical distribution of empirical studies and the socio-demographic factors commonly analyzed in contraceptive use research.

This study provides a systematic synthesis of modeling approaches and research trends, this study contributes to a better understanding of how quantitative models are applied in reproductive health research and highlights opportunities for the development of more advanced mathematical models for analyzing contraceptive dynamics.

2 Research Methods

This study employed a systematic literature review combined with bibliometric analysis to analyze modeling approaches used in contraceptive studies. The systematic review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure a transparent and replicable study selection process. Bibliometric analysis was used to map research trends, author collaborations, and keyword relationships in the selected studies.

The literature search was conducted in two major scientific databases, namely Scopus and Science-Direct, on April 10, 2024. The search was performed in the title, abstract, and keywords fields using Boolean operators. The search strategy included combinations of the following keywords: ("contraceptive use" OR contraception OR "family planning" OR "modern contraceptive") AND ("mathematical model" OR modeling OR "population model" OR "statistical model"). The retrieved records were exported in RIS (Research Information System) format and managed using Mendeley reference manager. Duplicate records were removed prior to the screening process.

Bibliometric analysis was then conducted using VOSviewer software to visualize relationships between keywords and authors through co-occurrence and co-authorship networks. Bibliometrics is widely used to analyze scientific publications by identifying patterns of collaboration, research themes, and publication trends [14], [15], [16].

2.1 Bibliometric Analysis

A total of 2494 records were retrieved from the two databases, consisting of 2462 records from Scopus and 32 records from Science-Direct. The records were exported in RIS format and organized using the Mendeley reference manager for data management and duplicate removal. The cleaned dataset was then imported into VOSviewer software to generate bibliometric maps based on keyword co-occurrence and author collaboration networks. Bibliometric analysis enables the identification of major research themes, collaboration patterns, and emerging topics within a scientific field [17]. In the bibliometric analysis, keyword co-occurrence was analyzed using VOSviewer with a minimum occurrence threshold of 2 keywords. Full counting was applied, and synonymous keywords were merged during the data cleaning process.

2.2 Prisma Methods

This research uses the sorting method and analyzing method or can be called the PRISMA method [18]. This method describes a systematic review and is a well-defined review with systematic tools prepared to identify, select, and analyze and provide relevant assessments to collect relevant data.

The Prisma method analyzes and provides relevant assessments to collect relevant data. In this method, 4 stages are carried out (identification, screening, eligibility and inclusion). In the identification stage, 2494 records were obtained from the database search (Scopus = 2462; Science Direct = 32). After filtering the records based on the publication period (2019–2024), 1061 records remained for further screening. During the screening stage, titles and abstracts were evaluated based on predefined criteria, including document type, language, and relevance to the research topic. The screening process was conducted independently by two authors through title

and abstract evaluation to ensure the relevance of the selected studies. Only English-language research articles were considered. After this stage, 88 articles were retained for full-text assessment.

In the eligibility stage, the full texts of the 88 articles were carefully reviewed to determine their relevance to contraceptive use research and quantitative modeling approaches. Articles that did not meet the inclusion criteria were excluded. Finally, 62 articles were included in the final analysis of this systematic literature review. The overall study selection process is illustrated in Figure 1 (PRISMA flowchart).

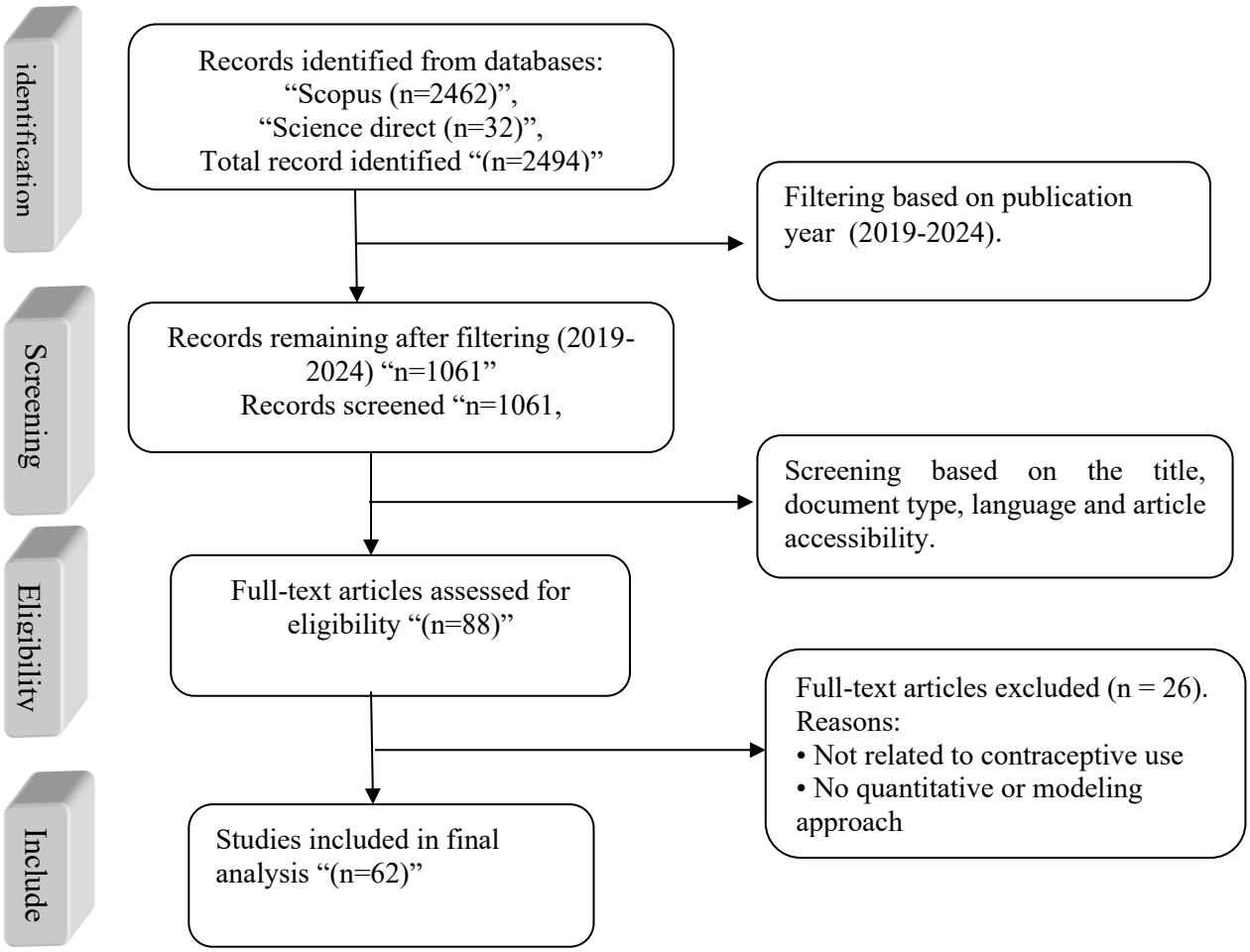

Figure 1. PRISMA flowchart

In the next step, the selected articles were carefully examined to determine their suitability for inclusion in this study. Articles that did not meet the predefined inclusion and exclusion criteria were excluded. The inclusion and exclusion criteria applied in this study are presented in Table 1. Ultimately, 62 studies were identified as relevant to the aims of this review.

Table 1. Inclusion and Exclusion criteria

Inclusion Criteria	Exclusion Criteria
Articles focusing on contraceptive use or family planning	Article not related to contraception
Quantitative research methods	Qualitative studies
Studies using statistical or mathematical modeling	Studies without modeling approaches
Articles published between 2019-2024	Articles outside the selected period

3 Result and Discussion

Search results from the two databases produced 62 relevant articles, which were then analyzed. The results are presented in two subsections: (1) distribution of the research by publication year and geographical location, and (2) bibliometric analysis.

3.1 Distribution of the Research

3.1.1. Distribution by publication year

The first analysis examines the distribution of studies on contraceptive use published between 2019 and April 2024. A total of 62 articles were identified and analysed. The distribution of these studies by publication year is presented in Table 2.

Table 2. Distribution of the Research by Publication Year

Year	Number of Document	Percentage
2019	6	9.6%
2020	10	16%
2021	10	16%
2022	14	22.6%
2023	17	27.4%
2024	5	8%

Table 2 shows that research on contraceptive use has generally increased over the last five years. In 2019, there were 6 articles (9.6%), followed by 10 articles (16%) in 2020 and 10 articles (16%) in 2021. The number increased to 14 articles (22.6%) in 2022 and reached its highest level in 2023 with 17 articles (27.4**%)**. In 2024**,** there were 5 articles (8%) published up to April 2024.

These results indicate that research on contraceptive use and family planning continues to attract increasing attention, reflecting the growing importance of reproductive health issues and population management in many countries.

3.1.2. Distribution by Country

Next, the geographical distribution of studies on contraceptive use was analysed based on the countries where the research was conducted. The results are presented in Table 3.

Table 3. Distribution of Sample Country

Sample (Country)	Number of Article	Percentage (%)	Sample research
India	6	9.68	Sharma et al. [19]
United States	2	3.23	Anglewicz et al. [20]
Sub-Saharan Africa	10	16.13	Odwe et al. [21]
Ethiopia	21	33.87	Asresie et al [22]
Malawi	4	6.45	Thindwa et al. [23]
Tanzania	1	1.61	Munuo & Moshi [24]
Kenya	5	8.06	Lahiri et al. [24]
Senegal	2	3.23	Krug et al. [25]
Cameroon	1	1.61	Akoku et al. [26]
Congo	3	4.84	Gage et al. [27]
Indonesia	1	1.61	Zaen N.A [28]
China	1	1.61	Pan & Liu [29]
Bangladesh	3	4.84	Roy et al. [30]
Nigeria	2	3.23	Guilkey & Speizer [31]

The analysis of the literature found that studies on contraceptive use are relevant in developing and densely populated countries including Bangladesh, Indonesia, China, India, and the United States. In research analyzing the use of contraceptives, Ethiopia came in first place with 33.87%. One of the nation having a low rate of contraception use is Ethiopia [32][33]. Furthermore, the research that discusses quite a lot of contraceptive use is Africa (16.13%). Geographical conditions also influence contraceptive use and access to family planning services. Studies conducted in sub-Saharan Africa, Ethiopia, Europe, Ghana, and South and Southeast Asia highlight the importance of spatial factors such as distance to health facilities, regional disparities in service coverage, and accessibility of contraceptive services [34], [35], [36]. These findings emphasize the importance of considering geographic context when designing effective family planning programs.

In addition, the reviewed literature shows that the study population was not limited to married women of reproductive age, but also included adolescents [24], [37], [38], [39], [40]. Factors such as education, religion, economic conditions, and non-use of contraceptives have been identified as significant predictors of adolescent pregnancy. Adolescent pregnancy rates are considerably higher in low-income countries compared to high-income countries [41].

3.1.3. Analytical Methods Used in Contraceptive Studies.

Various statistical analyses and mathematical modelling approaches have been used by researchers to analyse contraceptive use. The analytical methods identified in the reviewed studies are summarised in Table 4.

Table 4. Analytical Methods Use in Contraceptive Use Studies

Category of Method	Mathematical models/ statistics analysis	Number of Articles	Sample Research
Regression-based models	Logistic Regression	23	Michael et al [42]
	Multivariate Regression	3	Anglewicz et al [20]
	Multilevel model	5	Habte et al. [43][44]
	Poisson regression	1	Akoku et al. [26]
	Negative binomial regression	1	Krug et al. [25]
	Weilbull regression	1	Emiru et al. [45]
Spatial and Bayesian models	Spatial analysis	7	Ejigu et al, Medina G.N [35]
	Bayesian analysis	4	Pattnaik et al, Kantorova[46] [40]
Survival / event-time models	Hazard Model	2	Guilkey & Speizer [31]
	Survival statistic	1	Biswas et al. [47]
	Kaplan-Meier survival Statistics	1	Biswas & Banerjee [47]
Machine Learning Approaches	Machine Learning	1	Kabede et al. [48]
	Artificial Neural Network	1	Elnagar et al.
Mathematical population Models	Sharpe-Lotka Model	1	Karim et al. [49]
	Thanzi La Onse Model	1	Colburn et al.[50]
Other analytical methods	Time Series	1	Fuseini et al.
	Generalized estimating equation	1	Bayene et al. [32]
	Correlation analysis, Compare mean	2	Gedfie et al, Zaen N.A [51]

Table 4 provides information from which numerous statistical analyses and mathematical models are derived to examine the dynamics of contraceptive use across different nations. Most studies applied statistical modeling approaches to analyze factors influencing contraceptive use, including socio-demographic determinants and behavioral factors [28], [30], [31], [35], [42], [44], [46], [49], [52].

Several statistical approaches have been widely used to analyze contraceptive use, including logistic regression, multilevel models, and multivariate regression. These regression-based models are commonly applied to identify socio-demographic determinants associated with contraceptive use [32], [38], [47], [48], [53], [54], [55], [56]. Overall, logistic regression appears to be the most frequently used analytical method in the reviewed studies.

It should be noted that some studies applied more than one analytical method; therefore, the total number of methods reported may exceed the total number of articles analyzed.

The reviewed studies show that quantitative approaches used in contraceptive research can generally be classified into three main categories. First, regression-based statistical models, such as logistic regression, multilevel models, and multivariate regression, are widely used to identify socio-demographic determinants associated with contraceptive use. These models are particularly useful for analyzing survey-based datasets and identifying factors influencing contraceptive adoption. Second, survival and time-to-event models, including hazard models and survival analysis, are applied to examine the timing of contraceptive adoption or discontinuation. These approaches allow researchers to analyze behavioral changes over time and understand the dynamics of contraceptive use across different population groups. Third, population-based mathematical models, such as the Sharpe–Lotka model and other demographic modeling frameworks, are used to simulate population dynamics related to fertility, contraceptive adoption, and reproductive behavior. These models provide insights into long-term population trends and the potential impact of family planning policies.

The results indicate that most studies focus on identifying determinants of contraceptive use using statistical models, while relatively fewer studies employ mathematical models to describe the dynamic behavior of contraceptive adoption at the population level. This suggests that there is still considerable potential for developing more comprehensive mathematical modeling frameworks to better understand contraceptive dynamics and support evidence-based family planning policies.

3.2 Bibliometric Analysis

A bibliometric analysis was conducted using VOSviewer software to examine collaboration patterns among authors and relationships between research keywords focused on two main aspects: co-authorship networks and keyword co-occurrence.

3.2.1. Co-Authorship

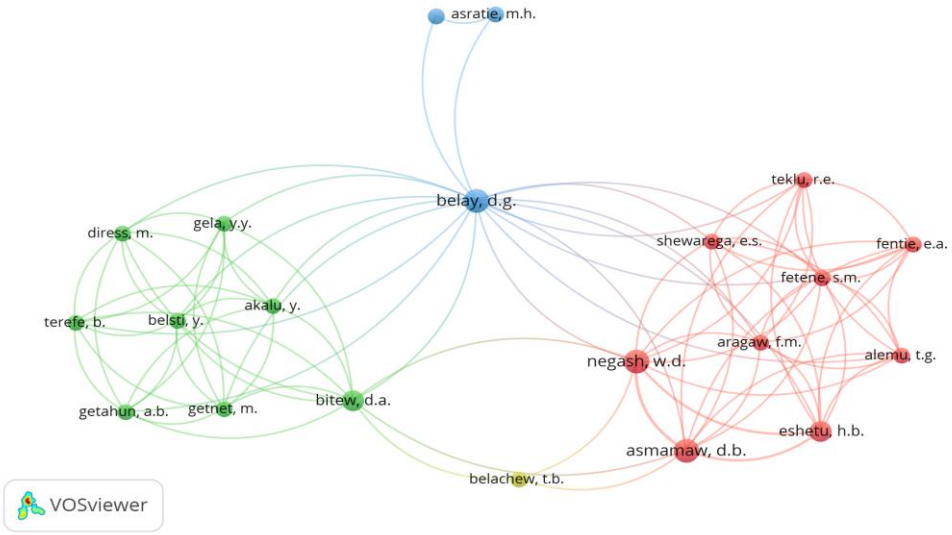

Figure 2. Co-Authorship (Overlay Visualization)

Figure 2 shows the co-authorship network among researchers working on contraceptive use studies. Different colors in the network represent clusters of authors who frequently collaborate with each other. The analysis identified 4 clusters with 66 collaboration links, indicating the presence of several collaborative research groups in this field.

3.2.2. Co-Occurrence

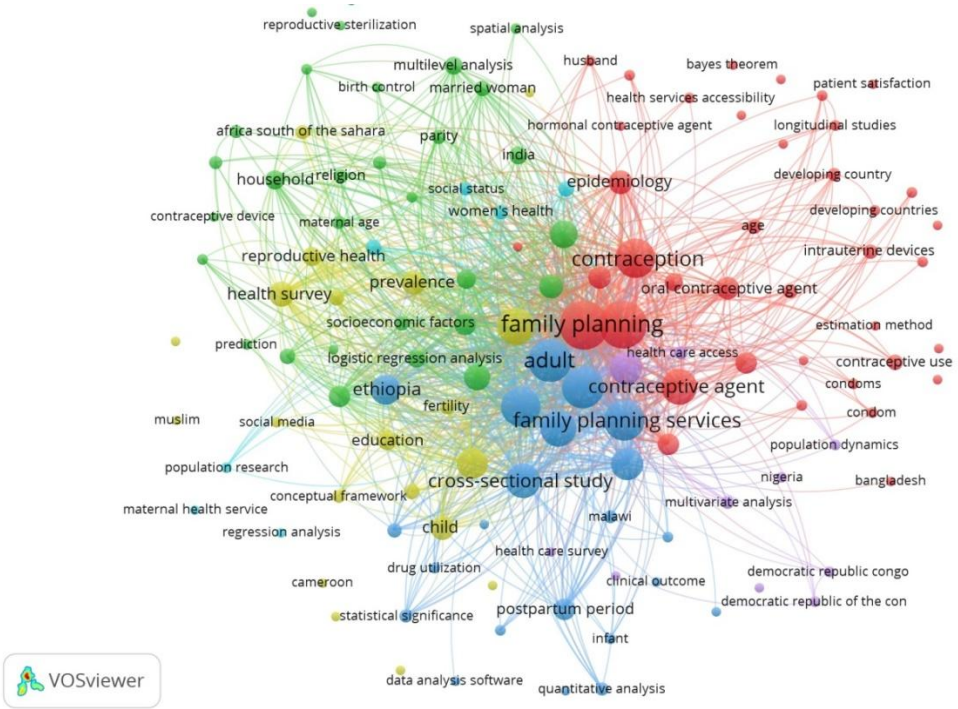

Figure 3. Co-Occurence (Network Visualization)

Figure 3 presents the keyword co-occurrence network, which illustrates the relationships between frequently used keywords in contraceptive research. The VOSviewer analysis identified 6 clusters with 3636 links, indicating several interconnected research themes related to contraceptive use, family planning, epidemiology, and demographic factors. These interconnected keywords suggest potential directions for future research, particularly in exploring the relationships between family planning behavior, contraceptive use, epidemiological factors, and demographic dynamics. The figure also shows some statistical analysis that are related to research on family planning and contraceptive use such as logistic regression, multivariate analysis, spatial analysis. Quantitative analysis has a great opportunity to analyze the problems and dynamics of contraceptive use in the future.

3.2.3. Research Trends

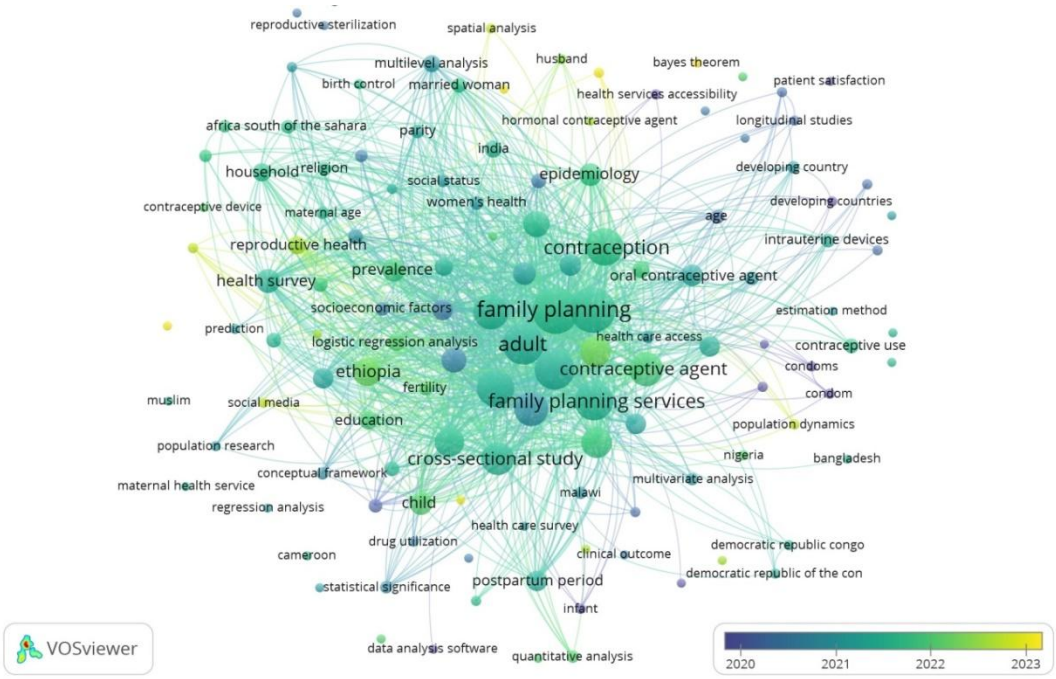

Figure 4. Co-Occurrence (Overlay Visualization)

Figure 4 shows the overlay visualization of keywords, where colours represent the average publication year of the keywords. The results indicate that topics such as quantitative analysis, spatial analysis, Bayesian methods, and population dynamics have emerged as recent research trends in contraceptive studies.

These findings suggest that recent studies increasingly integrate quantitative modeling approaches, including spatial analysis, Bayesian modeling, and machine learning techniques. This trend highlights the growing importance of interdisciplinary approaches in reproductive

health research, combining demographic analysis, statistical modeling, and mathematical modeling to better understand contraceptive dynamics.

Overall, the findings highlight that while statistical approaches dominate current contraceptive research, the development of mathematical modeling frameworks remains limited and represents an important direction for future studies.

4 Conclusions

This study presents a systematic literature review of quantitative modeling approaches used to analyze contraceptive use. Based on the analysis of 62 research articles published between 2019 and 2024, several key findings can be highlighted.

First, the reviewed studies indicate that contraceptive research is dominated by regression-based statistical models, particularly logistic regression, which are widely used to identify socio-demographic determinants associated with contraceptive use. Other approaches such as multilevel models, spatial analysis, Bayesian methods, survival analysis, and machine learning have also been applied to analyze behavioral patterns and regional variations in contraceptive adoption. Second, the geographical distribution of studies shows that research on contraceptive use is largely concentrated in developing and densely populated regions**,** particularly in sub-Saharan Africa and South Asia. These studies highlight the significant influence of socio-economic conditions, education levels, and geographic accessibility on contraceptive utilization. Third, the bibliometric analysis reveals that key research themes in contraceptive studies are strongly associated with contraceptive behavior, demographic characteristics, and quantitative analytical methods. The results also indicate increasing interest in integrating advanced quantitative techniques such as spatial modeling, Bayesian approaches, and machine learning to analyze contraceptive dynamics

Despite the increasing number of studies, the findings show that most research focuses on identifying determinants of contraceptive use using statistical models, while relatively limited attention has been given to the development of dynamic mathematical models that describe contraceptive behavior at the population level. This gap suggests an opportunity for future research to develop more comprehensive mathematical modeling frameworks that integrate demographic, behavioral, and spatial factors to better understand contraceptive dynamics.

This study has several limitations. The literature search was limited to two databases (Scopus and ScienceDirect) and included only English-language articles, which may introduce potential selection bias. In addition, the review did not include a formal quality assessment of the

selected studies. Future research should therefore expand the scope of databases and incorporate methodological quality appraisal to improve the robustness of systematic reviews in this field. Overall, the development of integrated mathematical models for contraceptive use remains an important research direction. Such models can provide valuable insights for policymakers and health practitioners in designing more effective family planning strategies and improving reproductive health outcomes. Future research should focus on developing integrated mathematical models that combine demographic, behavioural, and spatial variables to better explain contraceptive dynamics and support evidence-based family planning policies.

5 References

[1] S. Kumar *et al.*, "Chenopodium album seed extract: a potent sperm-immobilizing agent both in vitro and in vivo," *Contraception*, vol. 75, no. 1, pp. 71–78, 2007, doi: 10.1016/j.contraception.2006.07.015.

[2] S. Ontiri, V. Were, M. Kabue, R. Biesma-Blanco, and J. Stekelenburg, "Patterns and determinants of modern contraceptive discontinuation among women of reproductive age: Analysis of Kenya Demographic Health Surveys, 2003-2014," *PLoS One*, vol. 15, no. 11 November, pp. 1–14, 2020, doi: 10.1371/journal.pone.0241605.

[3] S. Ahmed, Q. Li, L. Liu, and A. O. Tsui, "Maternal deaths averted by contraceptive use: An analysis of 172 countries," *Lancet*, vol. 380, no. 9837, pp. 111–125, 2012, doi: 10.1016/S0140-6736(12)60478-4.

[4] S. Sangar, "Bringing a women's perspective to family planning," *Curr. Sci.*, vol. 115, no. 4, pp. 633–637, 2018, doi: 10.18520/cs/v115/i4/633-637.

[5] G. H. Djatmika and A. Hendriyana, "Penerapan Sistem Informasi Manajemen Keluarga Berencana Pada Badan Kependudukan Keluarga Berencana Daerah," *Ilmu Ekon. Manaj. dan Akunt.*, vol. 1, no. 1, pp. 82–93, 2020, doi: 10.37012/ileka.v1i1.400.

[6] T. Petruney, L. C. Wilson, J. Stanback, and W. Cates, "Family planning and the post-2015 development agenda," *Bull. World Health Organ.*, vol. 92, no. 8, pp. 359–360, 2014, doi: 10.2471/BLT.14.142893.

[7] J. Jaiswal, S. Naik, R. Rangari, and A. Sinha, "Awareness and acceptance of various contraceptive methods among postpartum women in a tertiary care center," *Int. J. Reprod. Contraception, Obstet. Gynecol.*, vol. 10, no. 4, p. 1352, 2021, doi: 10.18203/2320-1770.ijrcog20210996.

[8] S. N. Dwivedi and K. R. Sundaram, “Epidemiological models and related simulation results for understanding of contraceptive adoption in India,” *Int. J. Epidemiol.*, vol. 29, no. 2, pp. 300–307, 2000, doi: 10.1093/ije/29.2.300.

[9] T. Ferede, “Multilevel modelling of modern contraceptive use among rural and urban population of Ethiopia,” *Am J Math Stat*, vol. 3, no. 1, pp. 1–16, 2013.

[10] D. J. Makupe, S. Kumwenda, and L. Kazembe, “An application of mixed-effect models to analyse contraceptive use in Malawian women,” *Contracept. Reprod. Med.*, vol. 4, no. 1, pp. 1–11, 2019, doi: 10.1186/s40834-019-0088-y.

[11] N. A. Samat, N. A. M. Sapri, N. C. Him, A. Mahmud, and N. W. M. Junus, “Socio Demographic Determinants of Contraceptive Use Among Women in Malaysia: Logistic Regression Model,” in *Springer Proceedings in Physics*, 2022, pp. 279–288. doi: 10.1007/978-981-16-8903-1_26.

[12] D. K. Irawaty and H. Pratomo, “Socio-demographic characteristics of male contraceptive use in Indonesia,” *Malaysian J. Public Heal. Med.*, vol. 19, no. 1, pp. 152–157, 2019.

[13] M. M. Azanaw, D. T. Fentie, Y. A. Bukayaw, A. M. Lakew, and M. M. Sisay, “Spatial distribution and determinant factors of unmet need for family planning among all reproductive-age women in Ethiopia: a multi-level logistic regression modelling approach,” *Contracept. Reprod. Med.*, vol. 7, no. 1, pp. 1–14, 2022, doi: 10.1186/s40834-022-00178-9.

[14] B. H. Lange, “Sustainability in Media,” *SMPTE Motion Imaging J.*, vol. 132, no. 7, pp. 7–9, 2023, doi: 10.5594/JMI.2023.3285270.

[15] P. Hallinger and V. T. Nguyen, “Mapping the landscape and structure of research on education for sustainable development: A bibliometric review,” *Sustain.*, vol. 12, no. 5, pp. 1–16, 2020, doi: 10.3390/su12051947.

[16] M. Tang, H. Liao, Z. Wan, E. Herrera-Viedma, and M. A. Rosen, “Ten years of Sustainability (2009 to 2018): A bibliometric overview,” *Sustain.*, vol. 10, no. 5, pp. 1–21, 2018, doi: 10.3390/su10051655.

[17] A. Ninkov, J. R. Frank, and L. A. Maggio, “Bibliometrics: Methods for studying academic publishing,” *Perspect. Med. Educ.*, vol. 11, no. 3, pp. 173–176, 2022, doi: 10.1007/s40037-021-00695-4.

[18] R. G. Roni, H. Tsipi, B. A. Ofir, S. Nir, and K. Robert, “Disease evolution and risk-based disease trajectories in congestive heart failure patients,” *J. Biomed. Inform.*, vol. 125, no. November 2021, p. 103949, 2022, doi: 10.1016/j.jbi.2021.103949.

[19] H. Sharma, S. K. Singh, and S. Srivastava, “Spatial heterogeneity and major correlates of

Unmet Need of family planning among young married women aged 15-24 in India: An Exploratory Study," *SAGE Open*, vol. 11, no. 2, 2021, doi: 10.1177/21582440211024615.

[20] P. Anglewicz, D. Sarnak, A. Gemmill, and S. Becker, "Characteristics Associated with Reliability in Reporting of Contraceptive Use: Assessing the Reliability of the Contraceptive Calendar in Seven Countries," *Stud. Fam. Plann.*, vol. 54, no. 1, pp. 17–38, 2023, doi: 10.1111/sifp.12226.

[21] G. Odwe, Y. D. Wado, F. Obare, K. Machiyama, and J. Cleland, "Method-specific beliefs and subsequent contraceptive method choice: Results from a longitudinal study in urban and rural Kenya," *PLoS One*, vol. 16, no. 6 June, pp. 1–15, 2021, doi: 10.1371/journal.pone.0252977.

[22] M. B. Asresie, G. A. Fekadu, and G. W. Dagnew, "Contraceptive use among women with no fertility intention in Ethiopia," *PLoS One*, vol. 15, no. 6 June, pp. 1–13, 2020, doi: 10.1371/journal.pone.0234474.

[23] D. Thindwa *et al.*, "Correction: Pregnancy intention and contraceptive use among HIV-positive Malawian women at 4-26 weeks post-partum: A nested cross-sectional study (PLoS ONE (2019) 14: 4 (e0215947) DOI: 10.1371/journal.pone.0215947)," *PLoS One*, vol. 14, no. 5, pp. 23–32, 2019, doi: 10.1371/journal.pone.0217330.

[24] U. Munuo and F. V. Moshi, "Assessing motivators for utilizing family planning services among youth students in higher learning institutions in Dodoma, Tanzania: Protocol for analytical cross sectional study," *PLoS One*, vol. 18, no. 3 March, pp. 1–10, 2023, doi: 10.1371/journal.pone.0282249.

[25] C. Krug, F. L. Cavallar, K. L. M. Wong, A. Gasparrini, A. Faye, and C. A. Lync, "Evaluation of Senegal supply chain intervention on contraceptive stockouts using routine stock data," *PLoS One*, vol. 15, no. 8 August, pp. 1–16, 2020, doi: 10.1371/journal.pone.0236659.

[26] D. A. Akoku, T. A. Vukugah, M. A. Tihnje, and I. B. Nzubepie, "Childbearing intentions, fertility awareness knowledge and contraceptive use among female university students in Cameroon," *PLoS One*, vol. 17, no. 10 October, pp. 1–14, 2022, doi: 10.1371/journal.pone.0276270.

[27] A. J. Gage, F. E. Wood, and P. Z. Akilimali, "Perceived norms, personal agency, and postpartum family planning intentions among first-time mothers age 15–24 years in Kinshasa: A cross-sectional analysis," *PLoS One*, vol. 16, no. 7 July, pp. 1–24, 2021, doi: 10.1371/journal.pone.0254085.

[28] N. A. Zaen, "The Relationship Between Age, Education Level, and Residential Area

Towards Contraceptive Use in Married Woman in Indonesia," *J. BIOMETRIKA DAN Kependud. (J. Biometrics Popul.) Relatsh. BETWEEN AGE , Educ. Lev. , Resid. AREA Towar. Contracept. USE MARRIED*, vol. 11, no. July, pp. 1–10, 2022.

[29] Y. Pan and Y. Liu, "Economics of Education Review Birth control , family size and educational stratification : Evidence from the Han and ethnic minorities in China ☆," vol. 81, no. March 2020, pp. 1–10, 2021.

[30] N. Roy *et al.*, "Prevalence and factors associated with family planning during COVID-19 pandemic in Bangladesh: A cross-sectional study," *PLoS One*, vol. 16, no. 9 September, pp. 1–14, 2021, doi: 10.1371/journal.pone.0257634.

[31] D. K. Guilkey and I. S. Speizer, "The direct and indirect effects of community beliefs and attitudes on postpartum contraceptive method choice among young women ages 15-24 in Nigeria," *PLoS One*, vol. 17, no. 1 January, pp. 1–20, 2022, doi: 10.1371/journal.pone.0261701.

[32] K. M. Beyene, S. A. Bekele, and M. K. Abu, "Factors affecting utilization of modern contraceptive methods among women of reproductive age in Ethiopia," *PLoS One*, vol. 18, no. 11 November, pp. 1–12, 2023, doi: 10.1371/journal.pone.0294444.

[33] M. A. Kibret and L. T. Gebremedhin, "Two decades of family planning in Ethiopia and the way forward to sustain hard - fought gains !," *Reprod. Health*, vol. 19, no. 1, pp. 1–4, 2022, doi: 10.1186/s12978-022-01435-5.

[34] S. H. Nyarko, "Spatial variations and socioeconomic determinants of modern contraceptive use in Ghana: A Bayesian multilevel analysis," *PLoS One*, vol. 15, no. 3, pp. 1–12, 2020, doi: 10.1371/journal.pone.0230139.

[35] B. A. Ejigu *et al.*, "Spatial analysis of modern contraceptive use among women who need it in Ethiopia: Using geo-referenced data from performance monitoring for action," *PLoS One*, vol. 19, no. 4 April, pp. 1–20, 2024, doi: 10.1371/journal.pone.0297818.

[36] L. A. Zimmerman, S. O. Bell, Q. Li, A. Morzenti, P. Anglewicz, and A. O. Tsui, "Individual, community and service environment factors associated with modern contraceptive use in five Sub-Saharan African countries: A multilevel, multinomial analysis using geographically linked data from PMA2020," *PLoS One*, vol. 14, no. 6, pp. 1–21, 2019, doi: 10.1371/journal.pone.0218157.

[37] E. Arlotti-Parish, C. Ajema, L. Mutea, and S. Ontiri, "Determinants of Contraceptive Use among Unmarried Young Women in Kakamega County, Kenya," *Adolescents*, vol. 3, no. 3, pp. 382–393, 2023, doi: 10.3390/adolescents3030026.

[38] S. Lahiri, J. Bingenheimer, E. Sedlander, W. Munar, and R. Rimal, "The role of social

norms on adolescent family planning in rural Kilifi county, Kenya," *PLoS One*, vol. 18, no. 2 February, pp. 1–15, 2023, doi: 10.1371/journal.pone.0275824.

[39] G. O. Babore and A. Z. Heliso, "Contraceptive utilization and associated factors among youths in Hossana town administrative, Hadiya zone, Southern Ethiopia," *PLoS One*, vol. 17, no. 11 November, pp. 1–15, 2022, doi: 10.1371/journal.pone.0275124.

[40] V. Kantorova, "Contraceptive use and needs among adolescent women aged 15-19: Regional and global estimates and projections from 1990 to 2030 from a Bayesian hierarchical modelling study," *PLoS One*, vol. 16, no. 3 March, pp. 1–28, 2021, doi: 10.1371/journal.pone.0247479.

[41] D. A. Bitew, "Predictors of underage pregnancy among women aged 15–19 in highly prevalent regions of Ethiopia: a multilevel analysis based on EDHS, 2016," *Sci. Rep.*, vol. 13, no. 1, 2023, doi: 10.1038/s41598-023-27805-y.

[42] T. O. Michael, T. F. Ojo, O. A. Ijabadeniyi, M. A. Ibikunle, J. O. Oni, and A. A. Agboola, "Prevalence and factors associated with contraceptive use among sexually active adolescent girls in 25 sub-Saharan African countries," *PLoS One*, vol. 19, no. 2 February, pp. 1–15, 2024, doi: 10.1371/journal.pone.0297411.

[43] A. Habte, A. Tamene, and B. Bogale, "Women empowerment domains and unmet need for contraception among married and cohabiting fecund women in Sub-Saharan Africa: A multilevel analysis based on gender role framework," *PLoS One*, vol. 18, no. 9 September, pp. 1–26, 2023, doi: 10.1371/journal.pone.0291110.

[44] A. B. Teshale, "Factors associated with unmet need for family planning in sub-Saharan Africa: A multilevel multinomial logistic regression analysis," *PLoS One*, vol. 17, no. 2, 2022, doi: 10.1371/journal.pone.0263885.

[45] A. A. Emiru, G. D. Alene, and G. T. Debelew, "The role of maternal health care services as predictors of time to modern contraceptive use after childbirth in Northwest Ethiopia: Application of the shared frailty survival analysis," *PLoS One*, vol. 15, no. 2, pp. 1–15, 2020, doi: 10.1371/journal.pone.0228678.

[46] A. Pattnaik *et al.*, "The aggregate effect of implementation strength of family planning programs on modern contraceptive use at the health systems level in rural Malawi," *PLoS One*, vol. 16, no. 11 November, pp. 1–16, 2021, doi: 10.1371/journal.pone.0232504.

[47] M. Biswas and A. Banerjee, "Examining the linkages between maternity services and postpartum modern contraceptive adoption among young women in India: Insights from the 2015-16 and 2019-21 National Family Health Survey," *PLoS One*, vol. 18, no. 8 August, 2023, doi: 10.1371/journal.pone.0289701.

[48] N. Kebede, "A multivariate decomposition analysis of modern contraceptive utilization among married women in the emerging region of Ethiopia (2000–2019)," *Sci. Rep.*, vol. 13, no. 1, 2023, doi: 10.1038/s41598-023-48176-4.

[49] R. Karim, M. A. Bkar Pk, M. Asaduzzaman, P. Dey, and M. A. Akbar, "Investigation on Predicting Family Planning and Women'S and Children'S Health Effects on Bangladesh By Conducting Age Structure Population Model," *J. Mech. Contin. Math. Sci.*, vol. 19, no. 3, pp. 65–86, 2024, doi: 10.26782/jmcms.2024.03.00005.

[50] T. Colbourn *et al.*, "Modeling Contraception and Pregnancy in Malawi: A Thanzi La Onse Mathematical Modeling Study," *Stud. Fam. Plann.*, vol. 54, no. 4, pp. 585–607, 2023, doi: 10.1111/sifp.12255.

[51] S. Gedfie, S. Getawa, W. Kassahun, K. T. Gashaye, and M. Melku, "Hematological parameters of reproductiveage women using hormonal contraceptives at University of Gondar Comprehensive Specialized Referral Hospital, Northwest Ethiopia: A comparative cross-sectional study," *PLoS One*, vol. 17, no. 11 November, pp. 1–13, 2022, doi: 10.1371/journal.pone.0277254.

[52] P. Singh, "Factors explaining the dominion status of female sterilization in India over the past two decades (1992-2016): A multilevel study," *PLoS One*, vol. 16, no. 3, 2021, doi: 10.1371/journal.pone.0246530.

[53] N. G. Gejo, A. A. Anshebo, and L. H. Dinsa, "Postpartum modern contraceptive use and associated factors in Hossana town," *PLoS One*, vol. 14, no. 5, pp. 1–10, 2019, doi: 10.1371/journal.pone.0217167.

[54] P. Anglewicz *et al.*, "Service delivery point and individual characteristics associated with the adoption of modern contraceptive: A multi-country longitudinal analysis," *PLoS One*, vol. 16, no. 8 August, pp. 1–17, 2021, doi: 10.1371/journal.pone.0254775.

[55] F. T. Fantaye and S. A. Damtew, "Women decision making on use of modern family planning methods and associated factors, evidence from PMA Ethiopia," *PLoS One*, vol. 19, no. 2 Febuary, pp. 1–24, 2024, doi: 10.1371/journal.pone.0298516.

[56] S. Babazadeh, P. Anglewicz, J. M. Wisniewsk, P. K. Kayemb, J. Hernandez, and J. T. Bertran, "The influence of health facility-level access measures on modern contraceptive use in Kinshasa, DRC," *PLoS One*, vol. 15, no. 7 July, pp. 1–20, 2020, doi: 10.1371/journal.pone.0236018.