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How to cite:

Earle, Sarah; Marston, Hannah; Hadley, Robin and Banks, Duncan (2020). The use of menstruation and fertility app trackers: a scoping review of the evidence. *BMJ Sexual & Reproductive Health* (Early Access).

For guidance on citations see [FAQs](#).

© [not recorded]

Version: Accepted Manuscript

Link(s) to article on publisher's website:
<http://dx.doi.org/doi:10.1136/bmjsex-2019-200488>

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The use of menstruation and fertility app trackers: A scoping review of the evidence

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Abstract

Introduction: There has been a phenomenal worldwide increase in the development and use of mobile health applications (mHealth apps) that monitor menstruation and fertility. Critics argue that many of the apps are inaccurate and lack evidence from either clinical trials or user experience. The aim of this scoping review is to provide an overview of the research literature on mHealth apps that track menstruation and fertility.

Method: This project followed the PRISMA Extension for Scoping Reviews. The ACM, CINAHL, Google Scholar, PubMed, and Scopus databases were searched for material published between 1st January 2010 and 30th April 2019. Data summary and synthesis were used to chart and analyse the data.

Results: In total 654 records were reviewed. Subsequently, 135 duplicate records and 501 records that did not meet the inclusion criteria were removed. Eighteen (n=18) records from 13 countries form this review. The papers reviewed cover a variety of disciplinary and methodological frameworks. Three main themes were identified: fertility and reproductive health tracking; pregnancy planning; and, pregnancy prevention.

Discussion & conclusions: Motivations for fertility app use are varied, overlap and change over time although women want apps that are accurate and evidence-based regardless of whether they are tracking their fertility, planning a pregnancy or using the app as a form of contraception. There is a lack of critical debate and engagement in the development, evaluation, usage, and regulation of fertility and menstruation apps. The paucity of evidence-based research and absence of fertility, health professionals and users in studies is raised.

Keywords: Mobile apps, pregnancy, fertility, menstruation, self-tracking.

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KEY MESSAGES

- Although the use of fertility apps is growing, evidence-based research on the development and use of menstruation and fertility apps is limited.
- Women use fertility apps for a number of purposes that can change over time or overlap but regardless of how apps are used, women value apps that are accurate and based on scientific evidence.
- With some notable exceptions, app developers seldom involve health professionals or users in the design, development or deployment of menstruation and fertility apps.
- There is limited regulation of menstruation and fertility apps.

INTRODUCTION

The use of personal digital health informatics, including self-tracking, is becoming increasingly important to the way in which people manage their own health. It has even been argued that apps are changing the way that medicine is practised.¹ There has been a significant increase in the development of mobile health applications (mHealth apps) including those that monitor menstruation and fertility.² Self-tracking of menstruation and fertility is not new, and the development of apps is the latest in a long line of approaches.^{2 3} Self-tracking is thought to promote personal choice and self-knowledge¹ through their affordability,³ privacy and ubiquity.⁴ Consequently, user-app-interaction can take place at any time or place. Fertility awareness-based methods, including digital ones, are also seen as an increasingly viable alternative for women who reject hormonal methods of contraception.^{5 6} Worldwide, the use of ‘period tracking’ apps has been increasing, with at least 200 million downloads by 2016.⁷ Despite their growing popularity, two major concerns have been raised over menstruation and fertility apps. First, how apps have been marketed, including the use of social media influencers⁸ and, second, questions surrounding their evidence base and efficacy, particularly in relation to the risk of unintended pregnancy.^{9–11} For these reasons it is important to review what is known about the use of menstruation and fertility tracking apps.

Methods

A scoping review strategy was selected to provide an overview of this expanding and complex subject. The aims of this project fit the scoping review method¹² and followed the PRISMA Extension for Scoping Reviews (PRISMA-ScR).¹³

Selection criteria

This study sought to review apps designed to track women's menstruation or fertility with a specific focus on the evidence. In this review each article was subject to the inclusion and exclusion criteria (table 1).

Search strategy

A desktop search was conducted of the following databases: ACM, CINAHL, Google Scholar, PubMed and Scopus for material published between 1 January 2010 and 30 April 2019. Limiters were 'English' and 'humans'. However, each database required tailored strategies in order to access the appropriate material and there was some variation in search terms and/or limitations (table 2). Consequently, some databases involved several searches to extract the full range of material. The references of each paper selected for inclusion were also searched manually for additional citations. The search was conducted in May 2019. Titles of papers and abstracts were initially screened for suitability and, if necessary, the full paper was reviewed. Abstracts and full texts were retrieved to determine if they met the inclusion criteria. The reviewers HM, SE and DB assessed all records from each database using data extraction forms. Any discrepancies were discussed by HM, DB and SE before a final decision was made.

Quality summary

The papers selected for review are methodologically very diverse. The purpose of this scoping review is to provide an overview of the existing evidence on menstruation and fertility tracking apps, in spite of methodological quality or risk of bias and without excluding papers on this basis. Indeed, this is a key difference between scoping reviews and systematic reviews.¹³ In table 3 we include a brief quality summary of each paper indicating main limitations and potential indications of bias (including commercial interests) for information. We have also used the Mixed Methods Assessment Tool (MMAT) checklist to enable comparison of methodological quality between different papers.¹⁴ The reviewers HM and DB assessed all papers using the MMAT checklist. SE reviewed the papers where there was a discrepancy in quality assessment scoring in order to agree a final score for each paper.

Charting the data: summary and synthesis

Two approaches were used to chart the data: summary and synthesis. First, each paper was summarised by extracting data on research aims, participants, study design, method/assessment and role of technology (table 3). Second, using QSR NVivo 12 for Mac, a data analysis software package, thematic data analysis¹⁵ was carried out to determine descriptive categories (according to focus) and themes (according to specific issues) to produce a synthesis of the use of menstruation and fertility tracking apps. A line-by-Line coding of the findings/results and discussion/conclusion sections of each paper was carried out by SE and HM who discussed and compared initial codes, categories and themes.

Results

The database search identified 654 records. Following the removal of 135 duplicate records, the reviewers (HM, SE and DB) independently assessed 519 records for inclusion. Five hundred (n=500) records did not meet the inclusion criteria. Nineteen papers were initially identified for inclusion, but one was rejected since it reported interim data from a study which was then published in full 2 months later.¹⁶ Eighteen (n=18) records met the criteria for inclusion and are examined in this scoping review (figure 1).

Process of the database search

Of the 18 papers selected for review, 15 were published in peer-reviewed journals and the remainder (n=3) as peer-reviewed conference proceedings. The majority of studies were conducted in the USA (n=7) and the remainder in Germany (n=4), Sweden (n=3), Egypt (n=1), Ghana (n=1), India (n=1), Jordan (n=1), Kenya (n=1), Nigeria (n=1), Portugal (n=1), Rwanda (n=1), South Korea (n=1) and the UK (n=1). Three papers report data from their respective studies on the NaturalCycles app.^{17–19} Similarly, two papers report their individual studies on the Dot app.^{16 20} Summaries of all the selected papers are given in table 3. Following analysis of the selected papers, the results are organised in relation to the three different functions that menstrual and fertility app trackers serve: fertility and reproductive health tracking, pregnancy planning, and pregnancy prevention.

Fertility and reproductive health tracking

One-third of the papers in this review address fertility and reproductive health tracking.^{21–26} These papers are very diverse, but they all address the opportunities afforded by apps that

support women to track their reproductive health. Three papers focus specifically on women's motivations for tracking. In the first of these, Gambier-Ross *et al*²¹ argue that although there is increased use of digital health information, and some health professionals are recommending health apps to patients, we do not know nearly enough about how people interact with and use their own digital health data. Their survey data highlight four main motivations for the use of fertility tracking apps: (1) observing cycle, (2) to conceive, (3) to inform fertility treatment and (4) as a method of contraception. Some 72% of app users were observing their cycle only and follow-up interviews indicated that menstrual cycle prediction was especially important for the majority of interviewees.

Epstein *et al*²² also explored how and why women track their menstrual cycles and found that women self-track for five main reasons: (1) to be aware of their body, (2) to understand their body in different phases of the menstrual cycle, (3) to be prepared, (4) to become pregnant and (5) to inform conversations with healthcare providers. They note that women's motivations and the means they use to track change over time, suggesting that apps should be designed to accommodate this but that "existing apps also generally fail to consider life stages that women experience, including young adulthood, pregnancy, and menopause" (p. 6876).

The laboratory-based study conducted by Bretschneider *et al*²³ – based on the development of the app NetMoms Cycle Calendar – suggests that women who self-track can be categorised as either 'trying to conceive' or 'not trying to conceive' but that the motivations of the latter group were complex. This included women who were using apps as contraception, for medical reasons, to learn about their cycle, or to understand their body. The study explored the functionality of menstruation trackers and suggest that if apps enable women to track too many symptoms (eg, date of menstruation, basal body temperature, cervical mucus, mood, and so on) then users could experience 'tracker fatigue'. Although this could be said of fertility-based awareness methods in general, the respective authors argue that this could negatively influence accuracy since all apps rely on women inputting their data accurately, consistently and regularly. Accuracy is especially important when women are relying on the predictive potential of their digital data (eg, to prevent pregnancy) but this review highlights that women self-track for a variety of reasons, that their motivations for tracking change over time, and that accuracy can be important even when apps are being used observationally.²²

The paper by Haile *et al*²⁴ focuses on the CycleBeads app, which incorporates a digital algorithm based on the Standard Days Method (SDM), using first date of menstruation only. The app enables women to track their cycle, prevent or plan pregnancy. The paper examined the social marketing campaigns of the CycleBeads app in seven developing countries. This is the only study that draws on data from low- or middle-income countries and highlights that app use differed significantly by country and age of user. The majority of app users were aged between 20 and 29 years, 39.9% of users were using the app to prevent pregnancy, 38.5% to plan a pregnancy, and 21.6% were tracking their cycles. One-third of the women who were using the app to track their cycles were not using any form of contraception in the 3 months prior to using the app. The authors conclude by arguing that the CycleBeads app can be easily distributed at low cost, has the potential to expand access to fertility-based awareness methods, and can address multiple reproductive intentions. Two studies focus on the potential of apps to improve women's reproductive health and well-being. ^{23 24}

The paper by Blödt *et al*²⁵ evaluated the effectiveness of an app-based self-acupressure intervention – AKUD – to alleviate menstrual pain. Lee *et al*²⁶ focused on women's experiences of the menopause in order to develop guidelines for an mHealth app designed to support women's well-being. This review indicates that women self-track for a variety of reasons and that – over time – motivations for tracking can change or can overlap. The studies highlight the significance of personal digital health information in developing knowledge and understanding of the body, as well as its use in informing treatment or for predictive purposes. The next two sections of this article focus on the latter and on the use of apps to either plan or prevent pregnancy.

Pregnancy planning

Four papers focused on apps that could be used to support pregnancy planning.^{27–30} Two of these address specific mHealth apps,^{27 31} whereas the others seek to evaluate apps that either support pregnancy planning or support both pregnancy planning and prevention. The study by Sodha *et al*²⁷ focused on the Luna Luna app, which is part of a commercial women's health service in Japan. The app requires that women only enter their first day of menstruation and it then predicts ovulation dates and fertility. Using data from 7043 women, this study explored how the app's dataset could be used to improve the accuracy of ovulation date prediction. The authors argue it compares favourably to more traditional calendar methods that do not make use of such large aggregate data. The authors highlight the importance of user consistency in

relation to how women record their data, but the paper focuses, in particular, on the potential of large datasets to improve accuracy of prediction. The authors conclude that the Luna Luna app is an especially good option for couples in the early stages of pregnancy planning since it requires data only on the first day of menstruation.

Of the three papers that evaluate a range of apps, the study by Freis *et al*²⁸ is the only one focused specifically on the evaluation of apps marketed to support conception. Twelve apps were scored including calendar-based, calculothermal and symptothermal apps. The authors conclude that apps which base fertility predictions on data from previous cycles only are unsuitable. They identified apps that would be suitable for good-quality prospective studies but did not comment on the efficacy of the apps themselves. They highlight the importance of precision in being able to determine the fertile window and the significance of this for the sexual behaviour of couples trying to conceive. Setton *et al*²⁹ evaluated the top free 33 fertility apps downloadable to mobile phones from free websites and apps, replicating the likely behaviour of the general public when downloading fertility apps to use. For the purposes of analysis, a 28-day cycle length with 4 days of menstruation was used. The predicted dates of ovulation were compared with an assumed actual date of ovulation. Only three apps (9%) predicted the precise fertile window or did not give false-negative results (ie, there were no fertile days classed as infertile).

The evaluation by Moglia *et al*³⁰ assessed 108 free menstrual cycle tracking apps, using a modified version of the APPLICATIONS scoring system.³² Only 20 (19%) of the apps were found to be accurate; accuracy was based on the ability to predict the next menstrual cycle based on averages of past cycles and not on a default cycle length, allowing input of at least three full menstrual cycles. This study concluded that most freely available menstrual cycle tracking apps are “inaccurate, containing misleading health information, or do not function” (p. 1157). We report this study here because 80% of the apps contained information that supported conception and 50% for contraception. There is limited research on apps that support women or couples to have a baby. The ability to accurately predict the fertile window is important but the limited research that exists seems to indicate that many of the most popular apps are not accurate even though they might contain information that supports pregnancy planning or are marketed specifically for this purpose.

Pregnancy prevention

More than half of the papers in the review address the issue of pregnancy prevention,^{16–20} although some of these apps address both prevention and planning and these have been discussed above.^{24 29 30} Six papers focus on apps that can be used to prevent pregnancy. Three of these are focused on the paid-for app NaturalCycles.^{17–19} NaturalCycles has CE certification and US Food and Drug Administration (FDA) approval as a contraceptive. This app requires women to enter basal body temperatures and date of menstruation and, then, using a proprietary algorithm, calculates ovulation and fertility. Women are also encouraged to purchase luteinising hormone tests that predict ovulation.

Drawing on two retrospective studies^{17 18} and one prospective observational study,¹⁹ these studies argue that the app is effective at identifying ovulation day and fertile window although there are differences depending on perfect- and typical-use. There has been discussion of NaturalCycles within the press, particularly following complaints made by women who became pregnant while using the app. However, the Swedish Medical Products Agency concluded in 2018 that the pregnancies were in line with the product's failure rate but that the company should make clearer in their instructions and advertising the risk of unwanted pregnancies. In the UK, a complaint was also upheld by the Advertising Standards Authority with respect to the way that the company marketed NaturalCycles on Facebook in 2017.⁹

Two further papers are based on research of the Dot app which estimates fertile days only using date of menstruation.^{16 21} Using modern Bayesian statistical methods and an analysis of three large datasets, the app uses Dynamic Optimal Timing (DOT) to flag the days with the highest estimated probabilities of pregnancy. Li *et al*²¹ describe several simulation studies using this method to estimate its efficacy in preventing pregnancy. Jennings *et al*¹⁶ presents the findings from a prospective 13-cycle contraceptive effectiveness trial. At the time of writing, the Dot app has not received either European certification or FDA approval and some concerns have been expressed within the press about the marketing of the app to prevent pregnancies.³³

Koch *et al*³¹ presented the results of a retrospective efficacy study of the free DaysyView app. The DaysyView app was designed to improve the usability and pregnancy rates of a companion fertility monitor (a biosensor-embedded device used to measure basal body temperature) called 'Daysy'. Daysy is classified (in Europe) as a class I medical device used to 'facilitate conception' and based on the principle that the use of apps can increase a person's focus on their health behaviour(s). However, this particular paper focuses on the efficacy of Daysy and

DaisyView as a form of female contraception. The study indicates that the combination of the fertility monitor (Daisy) with the DaisyView app leads to higher user engagement and, therefore, higher overall usability. A commentary published by Polis¹⁰ in the journal *Reproductive Health* has, however, criticised the findings of this study, arguing that the analysis “was flawed in multiple ways”. Subsequently the Koch *et al* paper has been retracted due to “flaws in the methodology which mean that the conclusions are unreliable”³⁴ although the authors do not agree with this retraction.

The two remaining papers that focus specifically on pregnancy prevention include the paper by Starling,³⁵ which reports on a user survey exploring women’s preferences in fertility apps, and the paper by Duane,³⁶ which evaluated 40 fertility awareness-based method apps specifically marketed to avoid pregnancy using an established rating system.³⁷ Starling *et al*³⁵ conclude that since there is evidence of increasing interest and demand for fertility apps that prevent pregnancy, there should be enhanced collaboration between app developers, women’s health experts, and consumer groups to ensure that women are able to make informed choices about fertility apps. Duane *et al*³⁶ concluded that the majority of fertility apps marketed to avoid pregnancy are not designed for this, nor do they use evidence-based fertility-based awareness methods.

There is considerable interest in the use of fertility apps to prevent pregnancy and a number of studies indicate that some apps are effective. However, there is some evidence to suggest that not all apps marketed to prevent pregnancy have been designed for this purpose and that women may be using a range of apps for pregnancy prevention that are not intended to be used in this way.

Discussion and conclusions

This scoping review explored what is known about the use of menstruation and fertility tracking apps. The number of such apps is large, they are growing, and they are increasingly popular. There is enormous variation in the types of apps³⁸ available, ranging from very simple diaries through to apps that use complex, sometimes proprietary, algorithms to determine ovulation and fertility windows. A survey of 1000 women indicates that nearly 80% of women intend to use a fertility tracker app in the future.³⁵ The review has a number of limitations that may reduce its usefulness. For example, given our resources, it was only possible to include

studies published in the English language. Our particular search terms and other delimiters may also have inadvertently excluded other materials that may otherwise have been included.

The disciplinary and methodological heterogeneity of papers means that comparing the different studies is complex and it is challenging to apply quality assessment criteria to studies that are so varied.

This review highlighted how women are motivated to use menstruation and fertility tracking apps for a range of reasons but that their motivations and goals shift over time and can overlap. Previous research highlighted the complexities of both defining pregnancy intention and women's experiences of reproduction.³⁹ Existing apps do not necessarily take into account the way in which women use such apps and human–computer interaction researchers highlight the importance of involving users in their design and development.^{40 41} This is especially important because the user is considered to be the single greatest 'risk factor' in the accuracy of apps, and this is particularly significant if women are seeking to prevent, or plan, a pregnancy.³⁷

The evidence suggests that women value apps that are accurate and based on scientific evidence regardless of whether they are relying on the app to predict their fertile window or not.²¹ There is limited research on apps that specifically support pregnancy planning but the evidence that does exist suggests that popular apps which contain information on planning a pregnancy are not always accurate, which could be very misleading for women and couples that are trying for a baby.²⁹

The review highlights a growing evidence base on apps marketed to prevent pregnancy with evidence suggesting that some apps are useful for women who do not want to rely on hormonal methods of contraception or do not want to use condoms.^{16–19 31} However, not all apps accurately predict the fertile window and women may be using apps for pregnancy prevention that have not been designed for this purpose.³⁶ Given this issue and the fact that fertility apps are used fluidly over time, this poses the potential risk of unintended pregnancy.

While there are many apps available for download there is little discussion surrounding the regulation of

fertility and menstruation apps. Guidance is available for both app developers and individuals seeking to receive approval via the FDA^{42 43} for Mobile Medical Application (MMA). The FDA have approved many different types of MMAs for use across different health disciplines^{42 43} but, as noted earlier, NaturalCycles^{17–19} is the only app to have been granted approval as a contraceptive,^{44 45} and the DaysyView app supports the class I medical device Daysy.³¹ The recently published *Joint BASHH/FSRH Standard for Online and Remote Providers of Sexual and Reproductive Health Services* may be useful going forward.⁴⁶

The limited evidence base that exists within this field means there is considerable scope for future research. As demonstrated across the various studies, there is a need for further prospective independent research free from commercial interests and risk. Consequently, it is important that future research involve users that reflect ethnic, cultural and geographical diversity, as well as differences across the life course. The role of menstruation and fertility tracker apps in developing countries is also significantly under-researched. The involvement of fertility specialists and other health professionals should also be an important aspect of future research and development in this field.

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Author Disclosure Statement

There are no competing interests.

Author Contributions

SE and HM drafted the paper and revisions, All authors proofread. All authors conducted the MMAT checklist to assess the quality of papers. HM and DB decided on search criteria. All authors agreed upon in/exclusion criteria. RH conducted database searches, HM DB and SE conducted decision making of papers after database searched.

Funding Funding [£3,000.00] was received by DB, HRM and SE via the Synergy Programme in the School of Life, Health and Chemical Sciences, Faculty of STEM, The Open University. Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Table 1 Inclusion and exclusion criteria

Inclusion	Exclusion
Apps	Animals/non-human
Basal body temperature	Baby information
Birth control	Book chapters
Commercial technologies	Editorials
Commercial technologies	Editorials
Conference proceedings	Foetal information
Contraception	Health and fitness
Contraceptive efficacy	Implant
Dysmenorrhea	Letters to the editors
e-Health	Master's and PhD theses
Family planning methods	Modelling
Female	Motherhood
Fertility	Newsletters
Fertility awareness	Parenting
Human	Preconception care
Menopause	Pregnancy
Menstrual Apps	Pregnancy rate
Menstrual cycle	Pregnancy risk factors
Menstrual tracking	Purpose built technologies
Menstruation	Reports
Mobile application (apps)	Reviews
Mobile Health (mHealth) Apps	Security/Privacy
Natural Family Planning	Sexual health
Ovulation detection	Simulation
Paid and free apps	Smart Fabric/textiles
Pearl Index	STIs
Period	Theoretical papers
Purpose built technologies	Website
Quantified Self (QS)	
Self-tracking	
Smartphone access	
Study designs: (RCT, Exploratory, Cohort, Prospective, Feasibility)	
Wearables	
Women's health	

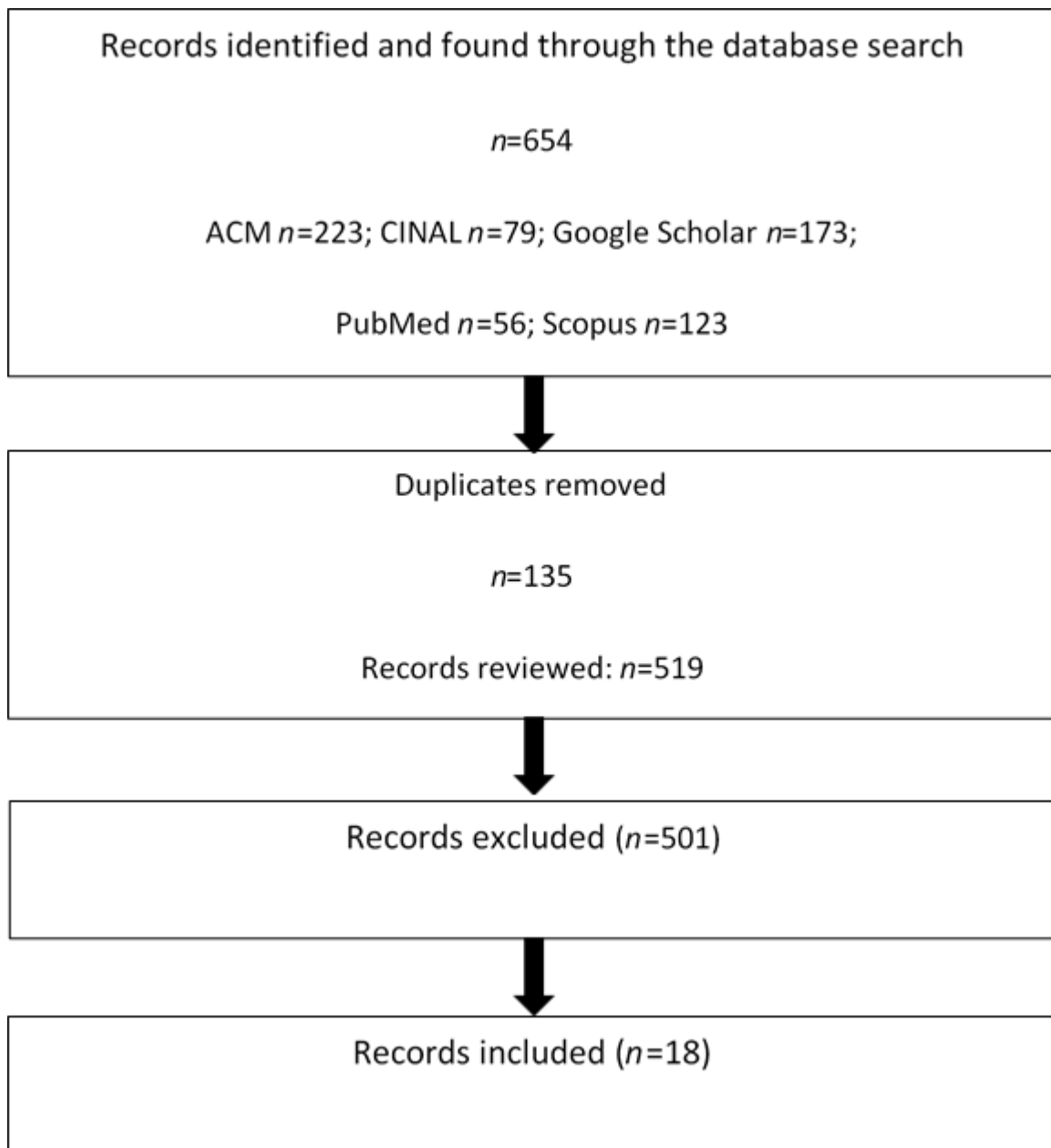


Figure 1 Process of the database search

Table 2 Databases searched, search terms used, reasons for adaptations

Database	Search term used	Adaptions/Notes
ACM	Searched for (+Fertility +awareness-based +planning +methods +ovulation +menstrual +cycle +mobile +applications +self +tracking +mhealth +ovulation +infertility +menstrual +cycle +mobile +applications +self +tracking +menses +pregnancy + menstrual-calendar diary +birth + self-tracking surveillance fertility +control +contraception +menstruation + self-tracking menstruation fertility)	2010 Excluded: soil, fertiliser
CINHAL	<i>self-tracking AND fertility awareness based methods AND (mobile apps or mobile applications or apps) AND (mhealth or mobile health or m-health or mobile app or mobile application) AND fertility awareness AND <u>mobile apps AND fertility</u> AND (menstruation or menstrual cycle or menarche) AND ovulation OR (mobile applications or apps or mobile apps) AND ovulation</i>	
PubMed	<i>mhealth AND menstruation OR ovulation OR reproductive health OR fertility-awareness smart phone applications OR fertility-awareness cell phone applications OR ((fertility-awareness) AND menstru*) AND mobile apps OR menstru* AND self tracking OR mhealth AND reproductive health</i>	
Scopus	<i>fertility-awareness applications AND Fertility monitoring applications OR Tracking women's periods OR mhealth AND menstru* OR fertili* OR ovulation OR menstru* AND mhealth AND OR reproductive health OR period AND tracking</i>	<i>TITLE-ABS-KEY(fertility AND monitoring AND applications) Adjusted criteria: AND (EXCLUDE (SUBJ AREA,"AGRI")) AND (EXCLUDE (SUBJ AREA,"EART")) AND (EXCLUDE (SUBJ AREA,"ENVI")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (EXACT KEYWORD, "Humans"))</i>
Google scholar	<i>fertility OR menstru* AND self-tracking OR mobile apps self-tracking OR mobile apps and menstruation or ovulation OR Fertility awareness-based mobile app for contraception OR Fertility awareness-based mobile apps OR Fertility mobile apps OR Fertility monitoring mobile apps</i>	

Table 3. Summary of papers (n=18) included in scoping review

Author (date)	Country	Study aims	Participants	Study Design	Method of assessment	Technology/ approach	Quality summary
Fertility and reproductive health tracking							
Gambier-Ross et al. (2018) [24]	UK	To explore women's uses of and relationships with fertility tracking apps	N=240 (survey); n=11 interviews; women aged 18+ years	Mixed methods exploratory study	Online survey using SurveyMonkey distributed via social media including Facebook and Twitter; participants for follow-up interviews derived from survey	Fertility tracking apps	Survey was only live for 5 days; convenience sample therefore not necessarily generalisable to whole population; only 37% of sample had used a fertility tracking app
Epstein et al. (2017) [20]	USA	To understand menstrual cycle tracking practices and to examine users' experiences to explore potential design opportunities for apps	N=687 (survey completion), n=12 (interviews)	Experimental study	3 sources were used for data collection: online app reviews, a survey of women's tracking practices, and a follow-up interviews with some survey participants.	01/2016 the term period tracker was searched across the Apple and Android App stores. 12 most reviewed apps, 2000 most recent app reviews were downloaded. Review scores were ignored, and focus was on open-ended review text.	Results likely to exaggerate technology use due to HCI focus; demographic bias in favour of women who identified as White or Asian and from Western, industrialised, rich and democratic countries
Bretschneider et al. (2015) [19]	Germany	To propose a new approach for tracking menstruation via a app	Review of apps (n=13), online survey (n=196 women) and in-lab usability testing with participants (n=5)	Experimental study	Review of apps (comments from users focusing on common pitfalls). Google Play and Apple iTunes Stores were searched. Online survey and usability (UX) testing with pre-existing period tracking apps. Laboratory based. From June 2014 – first prototype was released	NetMoms Cycle Calendar App (iOS and Android)	Lab-based study only; usability testing conducted with 5 participants only
Haile (2018) [21]	Egypt, Ghana, India, Jordan, Keyna, Nigeria and Rwanda	To market test the CycleBeads app in developing countries to assess whether women were interested in and able to use a fertility app, learn the profile of users, and their purpose for using it	356,520 app downloads	In-app micro surveys over a 6-cycle period	Culturally-appropriate Facebook campaigns were used to market the app to women aged between 18-39 using Android smartphones. Descriptive statistics were derived from survey questions	CycleBeads app (Android)	All data self-reported; in India app is available in Hindi but survey questions were not asked in the Hindi version; Indian data may therefore be skewed
Blödt et al. (2018) [31]	Germany	To investigate the effectiveness of app-based self-acupressure in women with menstrual pain	Women (n=221) aged 18 to 34 years Mean age: 24.0±3.6	2-armed, randomized, pragmatic trial	Self-reporting of cramping pain of 6+ on a numeric rating scale. Women were randomized to either app-based self-acupressure (n=111)	AKUD app	Longer follow-up time might have provided more information on long-term use; impact of treatment may be

					or followed usual care (n=110) – with a total of 6 follow up cycles. All questionnaires were integrated into the app. Baseline data was taken.		overestimated due to short follow-up; high risk of bias due to lack of blinding
Lee et al. (2015) [22]	South Korea	To understand human factors of using mobile application to manage woman's health in menopause and to identify design consideration based on the user study and propose a system design for apps to assist women in menopause	Women (n=9) aged 45-60 years. Experienced menopause symptoms within 5 years; n=4 'family members'	Qualitative user study	Participants recruited via online menopause community; semi-structured interviews and focus group carried out	Development of guideline for designing health management system for women experiencing menopause	Relatively small study; number of focus groups and interviews not clearly defined by authors; limited information on recruitment via online community
Pregnancy planning							
Sodha et al. (2017) [16]	Japan	To clarify how the data obtained from a self-tracking health app for female mobile phone users can be used to improve the accuracy of prediction of the date of next ovulation	155,000 users were screen from 8,000,000. Age ranged 20-45 years, (mean age 32.94)	Secondary data analysis	Data from 7043 women via mobile phone app (via a healthcare service) was analysed; between the length of the menstrual cycle, follicular phase and the luteal phase.	Luna Luna app available as part of commercial Japanese women's health service	Two of the authors are employees of the Luna Luna app developer, MTI Ltd and both have a patent pending; profile data not available for all users; potential selection bias
Freis et al. (2018) [9]	Germany	To develop a scoring system for rating menstruation apps that claim to support conception; to pilot 12 apps currently available in German and English using that scoring system	12 menstruation cycle apps	Evaluation study	Assessment of plausibility of cycle apps by considering the state-of-the-art. Developing a scoring system to rate menstruation cycle apps according to eight criteria.	Menstruationskalender Pro, Flo Menstruationskalender, Clue Menstruations, Period Tracker Deluxe, Maya-Mein Periodentracker, WomanLog-Pro-Kalender, Ovy; Natural Cycles; myNFP; Lady Cycle, Lily and, Ovuvue apps	Study focuses on plausibility rather than efficacy; apps did not evaluate privacy, data protection, security or cost
Setton et al. (2016) [27]	USA	To evaluate the validity of fertility web sites and applications (apps) by comparing the predicted fertile window of these modalities to the actual fertile window of a standard 28-day cycle	2 studies, #1 top 20 websites: search terms: "ovulation calendar" and "fertility calendar." And study #2 is apps, search term: "fertility calendar"	Descriptive study	Top 20 free apps were downloaded and last menstrual period of January 1, 2015, and a 28-day cycle length with 4 days of menstruation were used. Prediction of data: "predicted dates of ovulation were compared with an assumed actual date of ovulation of cycle day 15, January 15, 2015. If a date of ovulation was predicted, it	Samsung Galaxy phone used, using the Google Play and Apple iOS stores.	Only free apps were included using a strategy of identifying the top 20 apps from Google Play and Apple iStore. Paid apps were excluded; study assumes 'perfect cycle'; descriptive study only

					was deemed accurate if this date resulted or inaccurate if any other date resulted. The fertile windows were compared with an assumed actual fertile window consisting of the date of ovulation and the preceding 5 cycle days, 10–15 (January 10–15).”		
Moglia et al. (2016) [26]	USA	To identify smartphone menstrual cycle tracking applications (apps) and evaluate their accuracy, features, and functionality		Evaluation study	“an application accurate if menstrual cycle predictions were based on average cycle lengths of at least three previous cycles, ovulation (when included) was predicted at 13–15 days before the start of the next cycle, and the application contained no misinformation.”	One app store was searched: Apple iTunes store for free menstrual cycle tracking apps.	Only free apps were included; paid apps were excluded. Availability, content, features and functionality may have changed since the evaluation although app version information is given to allow for independent assessment
Pregnancy prevention							
Berglund Scherwitzl et al. (2015) [12]	Sweden	To evaluate the ability of a novel web and mobile application to identify a woman’s ovulation day and fertile window, in order to use it as a method of natural birth control	317 women aged 18 to 39 years	Retrospective study	Basal body temperatures, ovulation test results and date of menstruation into the application.	NaturalCycles app (iOS and Android)	Two authors are the app developers and owners of NaturalCycles Nordic AB; retrospective study
Berglund Scherwitzl et al. (2016) [13]	Sweden	To investigate the contraceptive efficacy of the mobile application by evaluating the perfect- and typical-use Pearl Index	n=22,785 Paying users of the app between 1 st August 2014-2016 Registered n=26,967 Included in the study n=22,785 Contributed N3 months n=19,534 Contributed N6 months n=15,224 Contributed N12 months n=6944 Contributed N18 months 2684	Prospective observational study	Users had to log at least 20 days of data such a daily log can contain any combination of menstruation, BBT, LH test, pregnancy test result, sexual activity and personal notes ‘[...] a total of 18,548 woman-years of data into the application. We used these data to calculate typical- and perfect-use Pearl Indexes, as well as 13-cycle pregnancy rates using life-table analysis.’	NaturalCycles app (iOS and Android)	Two authors are the app developers, founders and shareholders of NaturalCycles Nordic AB; another author is an employee of this company; the study was funded by NaturalCycles Nordic AB; retrospective study
Berglund Scherwitzl et al. (2017) [14]	Sweden	To retrospectively evaluate the effectiveness of a fertility awareness-based method supported by a mobile-based application to prevent unwanted pregnancies as a method of natural birth control	n=4054 Age groups: <20 (n=54, 1%) 20–24 (n=1263, 32%) 25–29 (n=1729, 43%) 30–34 (n=672, 17%) 35–39 (n=205, 5%) ≥40 (n=70, 2%)	Retrospective evaluation study	‘application’s efficiency as a contraceptive method was examined on data from 4054 women who used the application as contraception for a total of 2085 woman-years’ 10-item survey completed 3 weeks prior to the study ending. A total of n=1186 women completed the survey	NaturalCycles app (iOS and Android)	Two authors are the app developers, founders and shareholders of NaturalCycles Nordic AB; another author is an employee of this company; two authors serve on NaturalCycles Nordic AB’s medical advisory board and have received honorarium; the study was funded by NaturalCycles Nordic AB

Li et al. (2016) [15]	USA	To propose a new approach to estimating fertile days, using data recording from the first day of menses.	Study #1 n=68 sexually active women (171 cycles) with either intrauterine device of tubal ligation. Up to 3 menstrual cycles of data provided. Study #2 n=221 (696 cycles), planned to become pregnant by discontinuing birth control, no known fertility problems	Retrospective analysis; simulation studies	Data taken from two existing studies. Study 1: WHO study of the ovulation method of natural family planning. Study 2: North Carolina – Early Pregnancy Study (EPS)	Dot app	One author is an employee of the app developer, Cycle Technologies; study funded by Cycle Technologies; data based on studies focusing predominantly on white, young and well educated women which may not be typical of the population of future Dot users; efficacy may be overestimated due to assumption that women would not have unprotected intercourse on fertile days
Jennings et al. (2019) [11]	USA	To investigate the effectiveness of the Dot app in calculating perfect- and typical-use failure rates	718 women using Dot to prevent pregnancy (6616 cycles between February 2017 and October 2018)	Prospective 13-cycle observational study	Users provided data on menstrual start dates, daily sexual activity and prospective intent to prevent pregnancy; pregnancy was determined through participant-administered urine pregnancy tests and/or written/verbal confirmation; perfect- and typical-use failure rates were calculated using multi-censoring, single decrement life-table analysis, and sensitivity, attrition and survival analyses were carried out.	Dot app (iOS and Android)	One author is a former employee of app developer Cycle Technologies; data will be made available through the US Open Data Act
Koch et al. (2019) [30]	Germany	To investigate whether an app improves usability of a medical device	Women (n=125), Cycles (n=2076) Average age of women = 29 years	Evaluation feasibility study	Use of DaysyView, a free mobile app to augment the use of the Daysy fertility monitor. All Daysy users with a DaysyView account were invited to the study and asked to complete an online questionnaire. The survey recorded birth, height and weight.	Daysy and DaysyView app (iOS and Android)	The study is funded by Valley Electronics AG, Zurich Switzerland, the manufacturer of Daysy and DaysyView; one of the authors is an employee of Valley Electronics; due to retrospective study design researchers could not control data collection; the majority of participants used the device for less than 13 cycles due to the short time on market of the device
Starling et al. (2018) [23]	USA	To explore the user profile and preferences in fertility apps for preventing pregnancy among women that have used, currently use, or intend to use a fertility app	1,000 female users of fertility apps aged 18-39	Exploratory pilot study	Participants recruited to study via Facebook. Data collected about interest in and current use of fertility apps; user intentions and goals in relation to pregnancy prevention; survey included questions on reproductive cycle and knowledge about fertility	Use and preferences using a fertility app rating the appeal of app features, functionality and reputation	Use of social networking platform and self-reporting limits generalisability of findings to broader population; diversity of fertility app users outside of USA not represented; survey questions not validated; small sample size for actual fertility app users compared to intended users
Duane et al. (2016) [25]	USA	To develop a rating tool with specific criteria to quantify an app's response to real cycle data based on the clinical guidelines evaluated in level 1 studies	7 cycles were observed, based on real data (determine accuracy)	Evaluation study	The rating system was developed based on criteria used by the Family Practice Management. A 5-pt Likert scale was used against a 10-item predefined criteria	apps (n=95) across iTunes, Google and Google Play searches.	Free and paid-for apps were included in study; study acknowledges that user behaviour is important to performance of apps, but this was not included in evaluation

ADDITIONAL EDUCATIONAL RESOURCES

- Marston, H.R. & Hall, A.K. (2015). Gamification: Application for Health and Health Information Technology Engagement. In D. Novak, B. Tulu, & H. Brendryen (Eds.) Handbook of Research on Holistic Perspectives in Gamification for Clinical Practice (pp.78-104). Hershey, PA: Medical Information Science Reference. DOI: [10.4018/978-1-4666-9522-1.ch005](https://doi.org/10.4018/978-1-4666-9522-1.ch005).
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- Smith, C., Gold, J., Ngo, T.D., Sumpter, C., & Free, C. (2015). Mobile phone-based interventions for improving contraceptive use. Cochrane Database of Systematic Reviews ;6 CD011159. DOI: 10.1002/14651858.CD-11159.pub2.