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Full length article

Prevention, diagnosis and pharmacological treatment of infections in pregnancy: The mobile app GAIA! for healthcare providers and patients



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ABSTRACT

Objective: To develop and assess the GAIA! app, designed to assist pregnant women and healthcare professionals in managing infectious diseases during pregnancy, and to bridge the information gap between health professionals and expectant mothers.

Study Design: This collaborative initiative in Italy involved partnerships with the University of Florence, Careggi University Hospital, and other institutions. The app, built on the Ionic framework, is available on both Apple and Google App Stores. It offers two distinct modes: “healthcare providers” and “patients.” Content for the app was derived from extensive literature reviews and clinical guidelines.

Results: Since its August 2022 launch, the GAIA! app has garnered over 2,500 downloads, indicating its effectiveness and acceptance within the community. The app differentiates itself from others, such as the Sanford Guide, by focusing specifically on the needs of pregnant women. It ensures cross-platform compatibility, a user-friendly interface, and offline functionality.

Conclusions: The GAIA! app has successfully addressed a niche in infectious disease management for pregnant women, gaining significant traction within the community. While it has seen substantial success, challenges like continuous updates and potential language expansion remain. Future endeavors will address these challenges and further evaluate the app’s impact on maternal and child health.

Acronyms and abbreviations used in the text: GAIA!, Gravidanza App Infezioni Alt! (Pregnancy App Infections Stop!); HIV, Human Immunodeficiency Virus; COVID-19, Coronavirus Disease 2019; HTLV-1, Human T-cell Lymphotropic Virus type 1; GPT, Generative Pre-trained Transformer.

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Introduction

Infectious diseases significantly impact morbidity and mortality in pregnant women and their fetuses, as pregnancy compromises immunity, heightening vulnerability to viral, bacterial, fungal, and parasitic infections. Pathogens like cytomegalovirus, herpes simplex virus, rubella, toxoplasmosis, hepatitis B, syphilis, and HIV can transmit from mother to child during pregnancy, delivery, or breastfeeding, causing congenital or neonatal complications [1,2]. Other infections, such as chickenpox, listeriosis, group B streptococcus and bacterial vaginosis, can cause spontaneous abortion, preterm childbirth, stillbirth and neonatal sepsis [3,4].

Diagnosing and managing infections in pregnancy demands weighing benefits and risks for both mother and fetus. Treatments for common infections like urinary tract infections, influenza, sexually transmitted diseases, and vaginitis must be both safe and effective during pregnancy [5]. Infections that could harm the developing fetus may be preventable through vaccination (e.g., rubella, hepatitis B), screening and treatment (e.g., syphilis, HIV), or prophylaxis (e.g., malaria). Those transmissible during delivery or breastfeeding can be mitigated by cesarean section (e.g., herpes simplex virus), intrapartum antibiotics (e.g., group B streptococcus), or antiretroviral therapy (e.g., HIV) [5].

The prevention and control of infectious diseases in pregnancy are essential for improving maternal and neonatal health outcomes [6,7]. Pregnant women should receive appropriate prenatal care, including immunizations, screening tests, counselling and education on preventive measures [8,9].

Challenges in managing diseases during pregnancy include detecting asymptomatic or non-specific conditions, ensuring treatment safety and efficacy that might be contraindicated or risky during pregnancy, and requiring long-term follow-up of maternal and fetal outcomes post-infection [10–12]. Finally, some are connected to the emergence or re-emergence of infections due to environmental changes, human migration or antimicrobial resistance [13–15].

To overcome these challenges, accessible informatics tools, web tools, and mobile apps are needed to help healthcare professionals and patients prevent and manage infectious diseases during pregnancy. Several tools offering comprehensive antimicrobial therapy information for various infections are already available [16–24]. However, Italy lacks a tool that fully meets the informational needs of healthcare workers and women of childbearing age on managing infectious diseases before and during pregnancy. This study aims to describe the creation, testing, and use of an app for managing pregnancy infections, as part of the GAIA! Project.

Material and methods

Partners

The GAIA! Project was funded by Cassa di Risparmio di Firenze Foundation. University of Florence, Careggi University Hospital, the Local Health Authority of Central Tuscany, and CiaoLapo Foundation, a non-profit organization providing assistance during pregnancy, were the project partners. The companies involved in the technical development of the app were the computer science companies Dynamedics and Spindox.

Technical development

From a technical standpoint, the cross-platform mobile app developed was based on the Ionic framework [25]. The interface of the app was built to meet the needs of both clinicians and patients. The development process involved creating and testing various versions of the app with small groups of patients and healthcare professionals from the participating clinical and healthcare institutions. The app can store all information on infectious diseases and pregnancy therapies locally on

the user's device, allowing full access to the app's functions even in the absence of an internet connection. The user interface was refined and optimized based on feedback received from a panel of professional experts and non-clinical users.

Contents creation

A comprehensive narrative review of literature (PubMed and Embase) and clinical guidelines was performed to create the content of each item included in the app, i.e., infective agents, vaccines, and pharmacological treatments (antibiotics for systemic use, antiviral agents, and antifungals). The text of each review was drafted in two different versions, a detailed one for healthcare professionals and a simplified one for patients. A content tree was used to organize all the information.

The scientific text review process engaged the project's clinical and scientific team for years, further complicated by clinical commitments during the COVID-19 emergency. In some instances, this led to as many as ten revisions of the text for each entry, ensuring that the most up-to-date scientific evidence on infectious diseases in pregnancy was accurately translated and succinctly summarized for the two target audiences (clinicians and patients) the app is designed for.

Release and dissemination

The app was developed in three years. Once the technical work on the two versions of the app (iOS and Android) was completed, the app was submitted to the Apple and Google stores for validation and publication, and it was finally published on the stores in early August 2022, freely available to all users, patients, and healthcare professionals.

After the release, the App was promoted both online in social media channels and through posters and flyers that directed users, via a QR code, to the app's download sites.

Monitoring

The number of downloads, their rate over time, the session/active device ratio, the conversion rate (the percentage of users who successfully completes the process of downloading and installing the app after encountering a promotional or marketing campaign), and the ratings of users were monitored.

Clinical insights and real-world validation in the GAIA! project

Our methodology is founded on the insight that the GAIA! app's development is deeply rooted in the practical experience of a premier infectious disease department in Italy, further enhanced by the collective expertise of a wide-ranging network of gynecologists and obstetricians both nationally and internationally to ensure that the app accurately addresses the needs of healthcare providers and patients by mirroring the actual challenges and advancements encountered in healthcare settings. Monitoring metrics were defined and used to verify the app's effectiveness and applicability in fulfilling the real-world clinical demands identified by clinicians actively participating in the study and guarantee that the GAIA! app remains relevant and beneficial for healthcare professionals and patients navigating the complexities of infectious diseases in pregnancy, making it not only a cutting-edge technological solution but also an indispensable asset for enhancing maternal and child health.

Results

Download and first-time use

The GAIA! app is available in both Apple (<https://apps.apple.com/it/app/gaia-infezioni-e-gravidanza/id1633439883>) and Google App

(<https://play.google.com/store/apps/details?id=it.spindex.gaia&hl=it&gl=US>) Stores for download.

Upon opening the app, users are presented with a screen that allows them to choose between the “healthcare provider” and the “patient” mode (Fig. 1). Both sections provide access to a gestational calculator, which was included based on requests from both user groups, healthcare providers, and patients. Once users enter their respective section, they are presented with a navigable content tree organized according to the following structure:

- Infectious Diseases
 - o Bacterial:
 - Chlamydia
 - Gonorrhoea
 - Listeriosis
 - Lyme disease
 - Pertussis

- Syphilis
- Group B Streptococcus
- o Viral:
 - Cytomegalovirus
 - COVID-19
 - Hepatitis B
 - Hepatitis C
 - Genital herpes
 - Human papillomavirus
 - HIV
 - HTLV-1
 - Influenza
 - Hand, foot, and mouth disease
 - Measles
 - Parvovirus B19
 - Rubella
 - Varicella and herpes zoster
 - Zika virus
- o Parasitic:
 - Malaria
 - Chagas disease
 - Schistosomiasis
 - Toxoplasmosis
- Vaccinations:
 - Recommended before pregnancy
 - Recommended during pregnancy
 - Contraindicated during pregnancy
 - Not recommended during pregnancy
 - Possible if the benefit outweighs the risk
 - Recommended in the postpartum period
- Antimicrobials:
 - Antibiotics
 - Antifungals
 - Antivirals



Fig. 1. GAIA! app, selection of the healthcare provider or patient mode.

The content of the sections varies significantly depending on the mode of use, healthcare provider or patient. An internal search engine is included to allow users to promptly search for content of their interest.

Resources for the healthcare provider

Each infectious diseases listed in their respective category allows the user to explore the following topics through expandable sections: pathogen, transmission, incubation period, contagious period, maternal disease clinical features, infection peculiarities during pregnancy, risk of maternal-fetal transmission, neonatal outcomes, screening, management in case of contact, management in case of infection, postpartum indications, prevention, bibliography (Fig. 2).

Similarly, for the vaccination section, the informative fields from which the clinician can obtain information from the app include therapeutic indications, qualitative and quantitative composition, dosage and administration, pharmacodynamic properties, contraindications, adverse effects, interactions with other medications and other forms of interaction, information on fertility, pregnancy, and breastfeeding (Fig. 2).

Regarding antimicrobials, the informative sections include: pharmacological class, former Food and Drug Administration classification [26], the Australian categorization system for prescribing medicines in pregnancy category [27], Micromedex classification [28], and information about risks, pregnancy, and breastfeeding (Fig. 2).

Each entry includes an appropriately referenced bibliography section for healthcare providers, as a solid foundation evidence for the information presented.

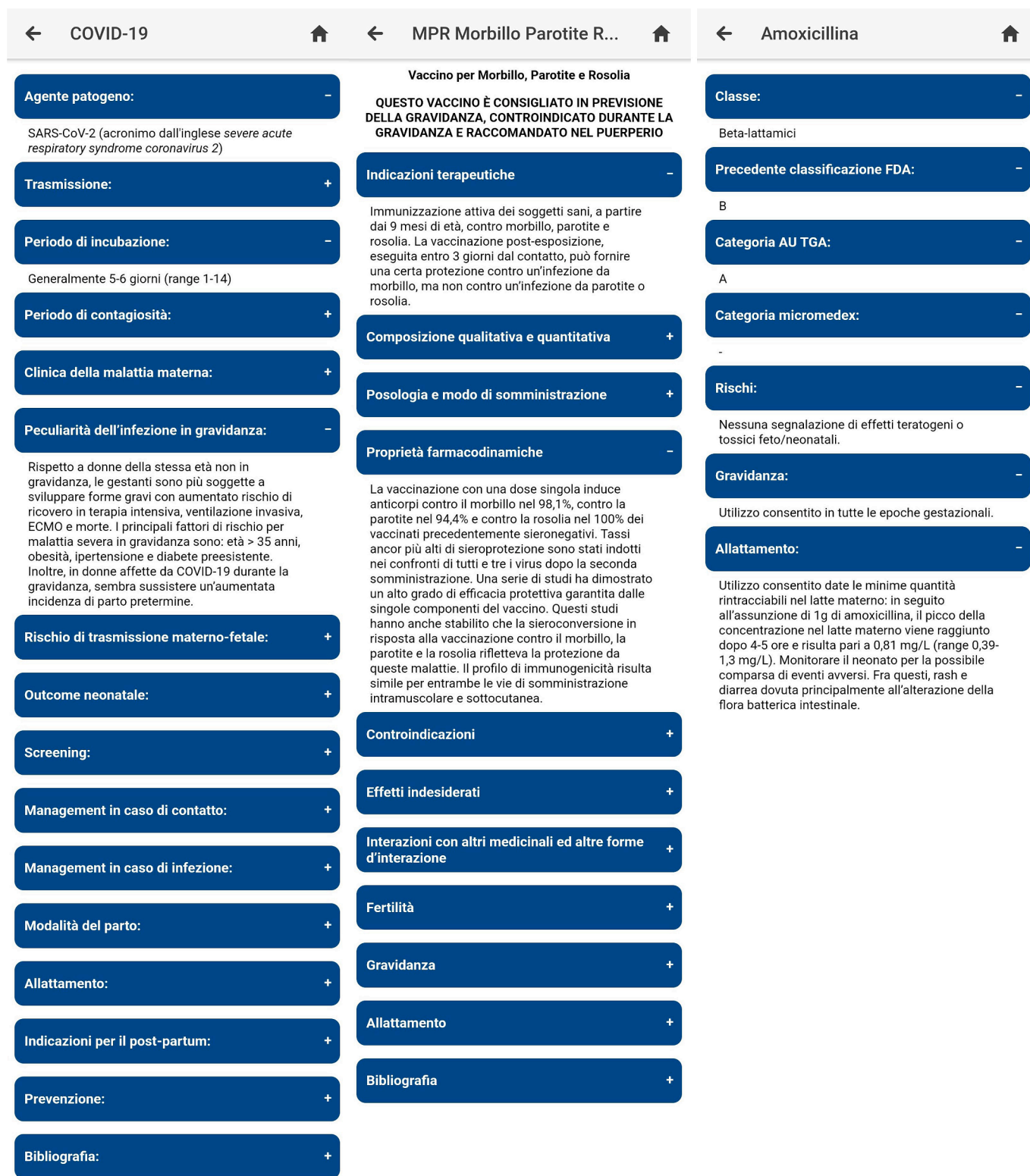


Fig. 2. GAIA! app, examples of items of the healthcare provider sections: COVID-19 (infectious diseases section), MMR vaccine (vaccination section), Amoxicillin (antimicrobials section), some sections are expanded to give a snapshot of how the app is structured.

Resources for the patient

Regarding infectious diseases, the expandable fields are indicated by simple questions for each specific disease to which the app provides answers to the patient: “What is the cause?”, “How is it transmitted?”, “What are the symptoms?”, “What is the risk for the fetus?”, “What

should be done in case of a high-risk contact?”, “What should be done in case of infection?”, “How to prevent the infection?” (Fig. 3).

For vaccinations, the informative fields include vaccine name and composition, administration method, mechanism of action, contraindications, adverse events, interactions with other medications and other forms of interaction, information concerning fertility, pregnancy, and

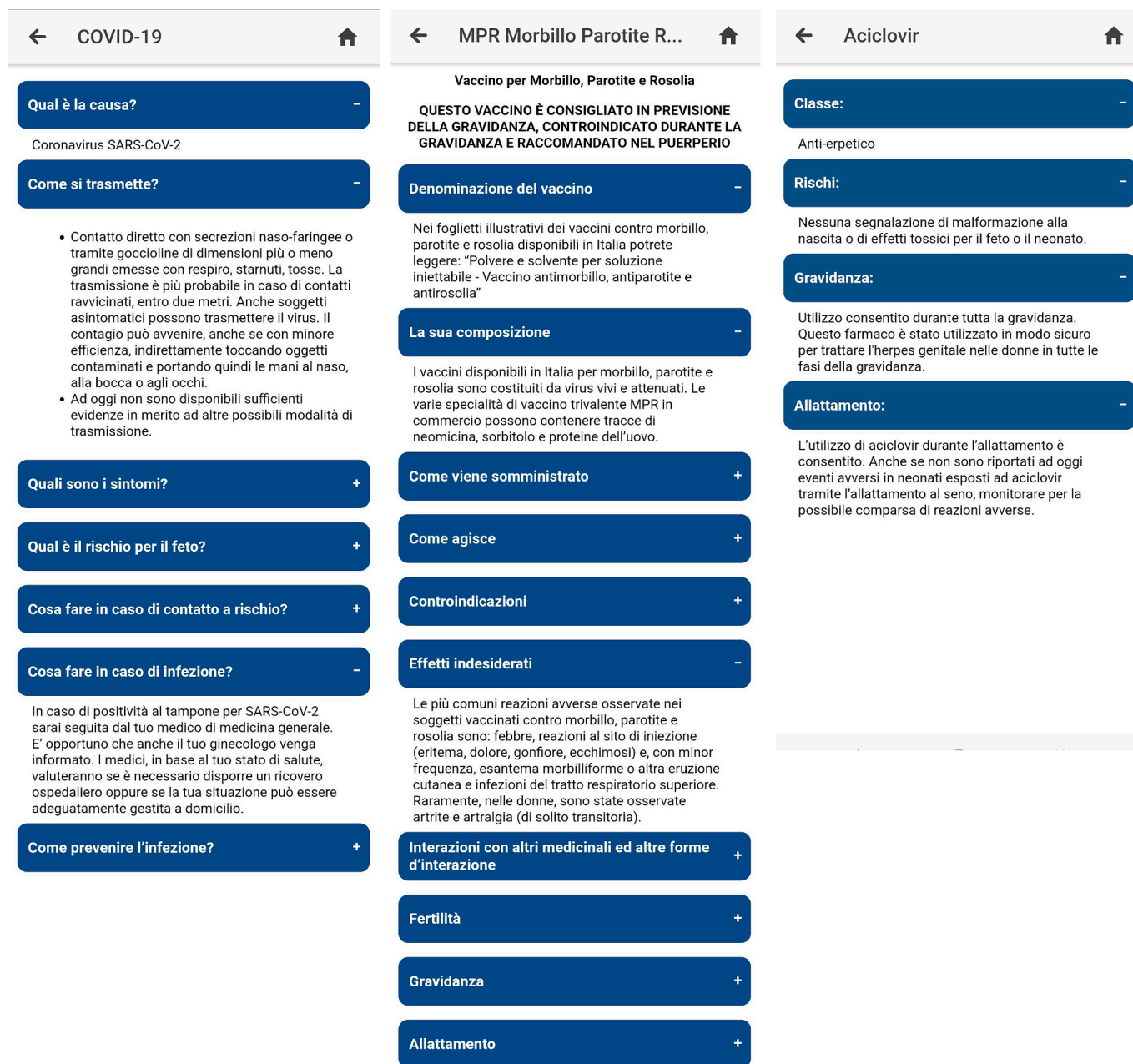


Fig. 3. GAIA! app, examples of items of the patient sections: COVID-19 (infectious diseases section), MMR vaccine (vaccination section), Acyclovir (antimicrobials section), some sections are expanded to give a snapshot of how the app is structured.

breastfeeding (Fig. 3). As for the antimicrobials, the informative fields accessible to patients include pharmacological class, and information about risks, pregnancy, and breastfeeding (Fig. 3).

For the patients, a user-friendly approach has been adopted to facilitate access to relevant and reliable information sources. A single section titled “Useful References for Patients” has been included, which comprises the curated list of high-quality sources from which information was drawn. These sources are authoritative, official, and written in a manner that is easily comprehensible for individuals without a medical or healthcare background. The inclusion of this section on the patients’ home page ensures convenient accessibility (Fig. 4).

Utilization data

To accelerate the adoption of the app, in the first months of its release, it was heavily promoted on social media and partners internet

channels (Fig. 5). As can be seen from Table 1, Fig. 6 and Fig. 7, the maximum number of downloads and the majority of the app’s user base occurred during the first months, when the promotion of the app on social media was active (August-October 2022). However, over time, there has been a relatively constant rate of downloads and installed audience.

In the initial months of usage, the conversion rate was of 26.3 % (Fig. 8). The app consistently maintains a session/active device ratio above 1.50. For example, in the months from April to June 2023, the app has session/active device ratio of 1.95 (Fig. 9). The session/active device ratio value of 1.95 indicates that, on average, users of the GAIA! app open it to consult it almost twice a day.

The app has received excellent ratings from users on both app stores, currently corresponding to 5 out of 5 stars.

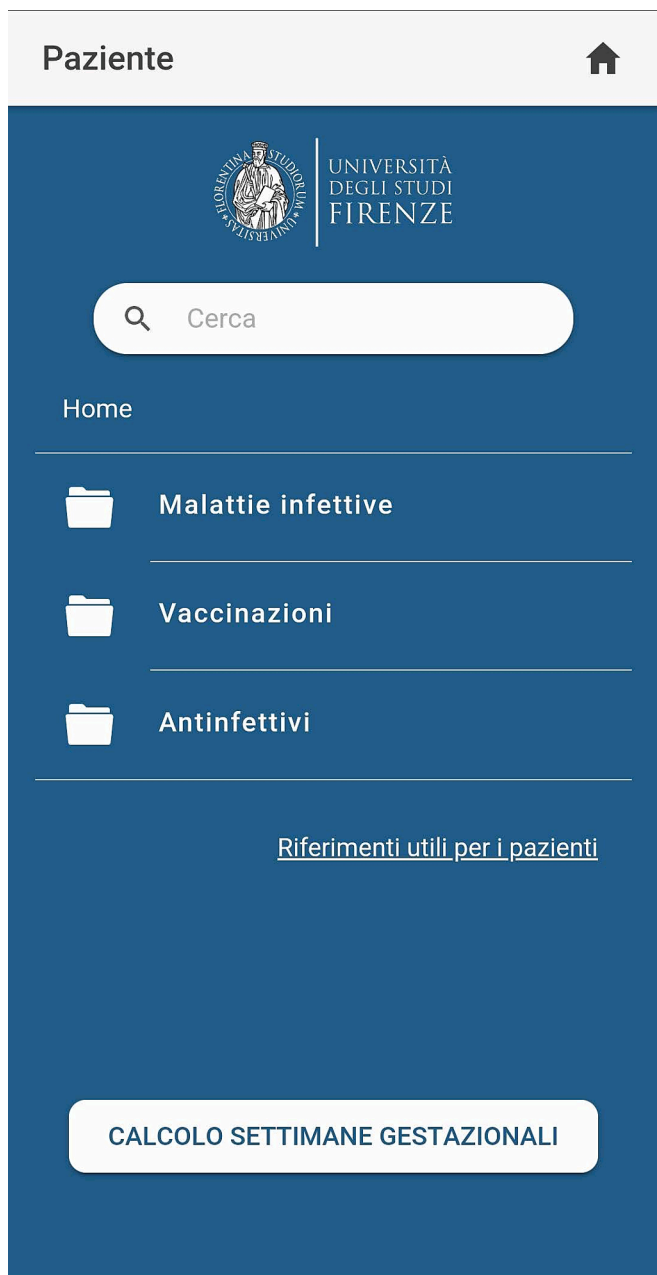


Fig. 4. GAIA! app, patients' homepage with the link to the "Useful References for Patients" section.

Discussion

The results of this study demonstrate the feasibility and usefulness of developing a mobile app that can assist health care workers and patients in the knowledge and management of infectious diseases during pregnancy. The GAIA! app is an innovative tool in the Italian medical landscape that offers comprehensive and evidence-based information on various aspects of infectious diseases, vaccinations, and antimicrobials that are relevant for the management of pregnancy; it acts as a vital bridge between health professionals and expectant mothers, offering a comprehensive and user-friendly platform to ensure the health and safety of both mother and child. For health professionals, the app provides rigorous scientific information on emerging infectious diseases, evidence-based guidelines for risk assessment, and tailored recommendations for pregnant patients. Several applications assist clinicians in managing infectious diseases. The Sanford Guide [21] provides



Fig. 5. The app promoted on social media (LinkedIn).

Table 1
Total downloads of the app.

Month	Apple Store Downloads	Google Play Store Downloads	Total Downloads (per month)
August 2022	296	269	565
September 2022	331	325	656
October 2022	262	371	633
November 2022	55	66	121
December 2022	47	43	90
January 2023	53	39	92
February 2023	41	36	77
March 2023	46	35	81
April 2023	44	32	76
May 2023	31	25	56
June 2023	28	39	67
Total	1234	1280	2514

comprehensive antimicrobial therapy advice but lacks pregnancy-specific features, unlike the GAIA! app which offers targeted guidance for managing infections in pregnant women. While general medical apps like UpToDate [22] and Medscape [23] provide extensive information, they do not specialize in obstetric care. The Pregnancy + app [24] covers overall pregnancy health but not infectious diseases. In contrast, GAIA! delivers detailed, pregnancy-focused infectious disease information,



Fig. 6. Installed Audience of the app (Google Play Store).

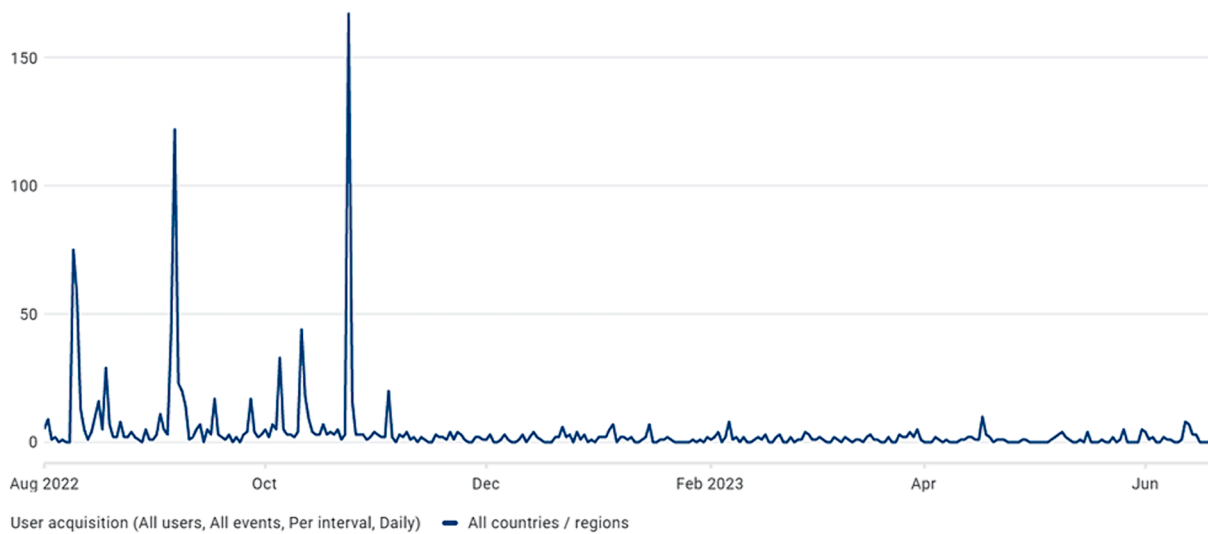


Fig. 7. User acquisition (Google Play Store).

IMPRESSIONS^(*), PRODUCT PAGE VIEWS^(), CONVERSION RATE^(*),**

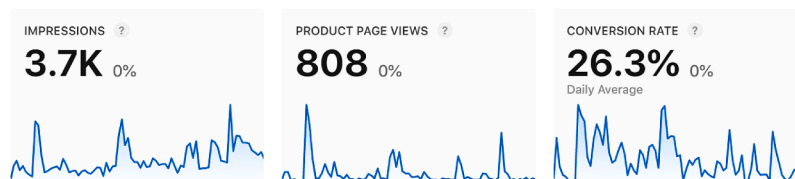


Fig. 8. Impressions, product page views and conversion rate for the GAIA! app.

uniquely filling a critical gap in obstetric support. The GAIA! app equips healthcare providers with up-to-date information for effective decision-making and interventions, while pregnant women benefit from accessible preventative resources and educational materials. This collaborative tool enhances maternal health and protects pregnancies. It offers

reliable, comprehensive information on managing infectious diseases in pregnancy, drawing from international scientific literature and guidelines. Features include bibliographic references, a simple design, an internal search engine, and a gestational age calculator. Available for free on iOS and Android, the app works offline, ensuring usability in areas

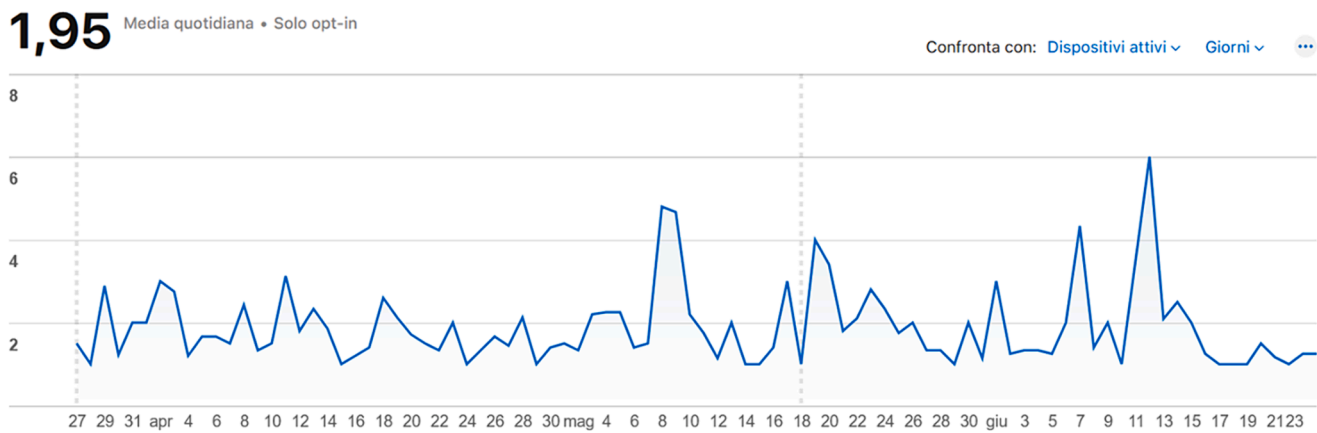


Fig. 9. Session/active device ratio.

with limited internet access.

The app has been downloaded by more than 2,500 users since its launch in August 2022, with a higher number of downloads in the first three months when the app was actively promoted on social media and partners' internet channels. The app's conversion rate of 26.3 % is very good, indicating that a large proportion of users who interacted with the promotional campaign actually went on to download and install the app. Moreover, a high session/active device ratio of 1.95 has been observed, suggesting that users are actively using the app multiple times on average, indicating a successful and engaging app experience and that the app has achieved a good level of dissemination and adoption among both healthcare workers and patients.

Study's limitations

Our study highlights key challenges for the GAIA! app, including the need for its broader dissemination and adoption among healthcare providers and patients. It's crucial to regularly update the app with the latest scientific evidence and clinical guidelines to maintain relevance. Additionally, the app's current availability only in Italian limits its accessibility to non-Italian speakers, underscoring the importance of expanding to multiple languages and adapting to various cultural contexts. Addressing these issues will involve promoting the app more widely, ensuring ongoing updates by medical experts, and translating and culturally adapting the content.

Conclusions

In conclusion, GAIA! is a novel and innovative mobile app that aims to provide support to health care workers and patients on the knowledge related to the prevention, diagnosis and pharmacological treatment of infections in pregnancy. The app has been developed by a multidisciplinary team of experts, using a cross-platform framework, and has been published on the Apple and Google App Stores.

The app has shown promising results in terms of downloads, conversion rate, session/active device ratio, indicating a high level of user engagement and satisfaction. However, the app also needs further improvement and evaluation to overcome some challenges and limitations related to its dissemination, updating, and expansion.

Future work will focus on addressing these issues and assessing the impact of the app on maternal and neonatal health outcomes. One of the planned developments of the app is to make its content updatable in real time by medical experts in infectious diseases and in clinical pharmacology, ensuring its validity and reliability.

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Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used GPT 3.5 in order to improve English language. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

CRediT authorship contribution statement

Roberto Bonaiuti: Conceptualization, Supervision, Writing – original draft, Writing – review & editing. **Lorenzo Zammarchi:** Funding acquisition, Methodology, Validation, Writing – review & editing, Conceptualization. **Susanna Giaché:** Data curation. **Giulia Modi:** Data curation. **Beatrice Borchini:** Conceptualization, Writing – review & editing. **Irene Campolmi:** Writing – review & editing. **Michele Trotta:** Conceptualization. **Claudia Ravaldi:** Data curation. **Sara Ornaghi:** Writing – review & editing. **Mariarosaria Di Tommaso:** Conceptualization, Writing – review & editing. **Alessandro Bartoloni:** Methodology. **Paolo Costa:** Resources, Software. **Niccolò Lombardi:** Data curation, Writing – review & editing. **Giada Crescioli:** Data curation, Writing – review & editing. **Alfredo Vannacci:** Conceptualization, Data curation, Methodology, Writing – review & editing. **Miriam Levi:** Data curation, Methodology, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

- [1] Leeper C, Lutzkanin A. Infections during pregnancy. *Prim Care* 2018;45:567–86. <https://doi.org/10.1016/j.pop.2018.05.013>.
- [2] PrabhuDas M, Piper JM, Jean-Philippe P, Lachowicz-Scroggins M. Immune regulation, maternal infection, vaccination, and pregnancy outcome. *J Womens Health* 2002;20(30):199–206. <https://doi.org/10.1089/jwh.2020.8854>.
- [3] Sappenfield E, Jamieson DJ, Kourtis AP. Pregnancy and susceptibility to infectious diseases. *Infect Dis Obstet Gynecol* 2013;2013:752852. <https://doi.org/10.1155/2013/752852>.
- [4] Jamieson DJ, Theiler RN, Rasmussen SA. Emerging infections and pregnancy. *Emerg Infect Dis* 2006;12:1638–43. <https://doi.org/10.3201/eid1211.060152>.
- [5] Collins S, Arulkumaran S, Hayes K, Arambage K, Impey L, Collins S, et al., editors. *Infectious diseases in pregnancy*. Oxf. Handb. Obstet. Gynaecol., Oxford University Press; 2023, p. 0. <https://doi.org/10.1093/med/9780198838678.003.0004>.
- [6] Money D, Allen V. The prevention of early-onset neonatal group B streptococcal disease. *J Obstet Gynaecol Can JOGC J Obstet Gynecol Can JOGC* 2016;38(12S):326–35. <https://doi.org/10.1016/j.jogc.2016.09.042>.
- [7] Kribs JM. Infectious diseases in pregnancy: issues of screening, prevention, and treatment. *J Perinat Neonatal Nurs* 2008;22:214. <https://doi.org/10.1097/01.JPN.0000333922.07458.e0>.
- [8] Goswami R, Pavon CG, Miller I, Berendam S, Williams C, Rosenthal D, et al. Prenatal immunization to prevent viral disease outcomes during pregnancy and early life 2022;2. <https://doi.org/10.3389/fviro.2022.849995>.
- [9] Lassi Z, Mansoor T, Salam RA, Das JK, Bhutta Z. Essential pre-pregnancy and pregnancy interventions for improved maternal, newborn and child health. *Reprod Health* 2014;11:2. <https://doi.org/10.1186/1742-4755-11-S1-S2>.
- [10] Twanow J-D-E, McCabe C, Ream MA. The COVID-19 pandemic and pregnancy: impact on mothers and newborns. *Semin Pediatr Neurol* 2022;42:100977. <https://doi.org/10.1016/j.spen.2022.100977>.
- [11] Kourtis AP, Read JS, Jamieson DJ. Pregnancy and infection. *N Engl J Med* 2014;370:2211–8. <https://doi.org/10.1056/NEJMra1213566>.
- [12] Shata MTM, Hetta HF, Sharma Y, Sherman KE. Viral hepatitis in pregnancy. *J Viral Hepat* 2022;29:844–61. <https://doi.org/10.1111/jvh.13725>.
- [13] Khan S, Rashmi SP, Siddiqui Z, Ansari M. Pregnancy-associated asymptomatic bacteriuria and drug resistance. *J Taibah Univ Med Sci* 2015;10:340–5. <https://doi.org/10.1016/j.jtumed.2015.01.011>.
- [14] Zorrilla CD, García García I, García Fragoso L, De La Vega A. Zika virus infection in pregnancy: maternal, fetal, and neonatal considerations. *J Infect Dis* 2017;216: S891–6. <https://doi.org/10.1093/infdis/jix448>.
- [15] Romani L, Pane S, Severini C, Menegon M, Foglietta G, Bernardi S, et al. Challenging diagnosis of congenital malaria in non-endemic areas. *Malar J* 2018;17:470. <https://doi.org/10.1186/s12936-018-2614-9>.
- [16] Outbreaks Near Me. Outbreaks Me n.d. <https://outbreaksnearme.org> (accessed June 20, 2023).
- [17] Ahn E, Liu N, Parekh T, Patel R, Baldacchino T, Mullavey T, et al. A Mobile app and dashboard for early detection of infectious disease outbreaks: development study. *JMIR Public Health Surveill* 2021;7:e14837.
- [18] Beatty AL, Peyser ND, Butcher XE, Carton TW, Olgin JE, Pletcher MJ, et al. The COVID-19 citizen science study: protocol for a longitudinal digital health cohort study. *JMIR Res Protoc* 2021;10:e28169.
- [19] Ebrahimi S, Khanababaei H, Abbasi S, Fani M, Soltani S, Zandi M, et al. CRISPR-Cas system: a promising diagnostic tool for Covid-19. *Avicenna J Med Biotechnol* 2022;14:3–9. <https://doi.org/10.18502/ajmb.v14i1.8165>.
- [20] Wood CS, Thomas MR, Budd J, Mashamba-Thompson TP, Herbst K, Pillay D, et al. Taking connected mobile-health diagnostics of infectious diseases to the field. *Nature* 2019;566:467–74. <https://doi.org/10.1038/s41586-019-0956-2>.
- [21] Sanford Guide | Antimicrobial Stewardship n.d. <https://www.sanfordguide.com/> (accessed September 26, 2023).
- [22] Phua J, See KC, Khalizah HJ, Low SP, Lim TK. Utility of the electronic information resource UpToDate for clinical decision-making at bedside rounds. *Singapore Med J* 2012;53:116–20.
- [23] Berauk VLA, Murugiah MK, Soh YC, Sheng YC, Wong TW, Ming LC. Mobile health applications for caring of older people: review and comparison. *Ther Innov Regul Sci* 2018;52:374–82. <https://doi.org/10.1177/2168479017725556>.
- [24] Pregnancy + | Tracker App. App Store 2024. <https://apps.apple.com/us/app/pregnancy-tracker-app/id505864483> (accessed April 5, 2024).
- [25] Gupta A, Gaffar HA. Hybrid application development using Ionic Framework & AngularJS 2016.
- [26] US Food and Drug Administration Content and format of labeling for human prescription drug and biological products; requirements for pregnancy and lactation labeling. *Fed. Regist.*, vol. 73, 2008, p. 30831–68.
- [27] Administration (TGA) TG. Australian categorisation system for prescribing medicines in pregnancy | Therapeutic Goods Administration (TGA) 2022. <https://www.tga.gov.au/australian-categorisation-system-prescribing-medicines-pregnancy> (accessed September 27, 2023).
- [28] Micromedex Products: Please Login n.d. <https://www.micromedexsolutions.com/home/dispatch> (accessed September 27, 2023).