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## Mobile apps for travel medicine and ethical considerations: A systematic review

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### ABSTRACT

**Background:** The advent of mobile applications for health and medicine will revolutionize travel medicine. Despite their many benefits, such as access to real-time data, mobile apps for travel medicine are accompanied by many ethical issues, including questions about security and privacy.

**Methods:** A systematic literature review as conducted following PRISMA guidelines. Database screening yielded 1795 results and seven papers satisfied the criteria for inclusion. Through a mix of inductive and deductive data extraction, this systematic review examined both the benefits and challenges, as well as ethical considerations, of mobile apps for travel medicine.

**Results:** Ethical considerations were discussed with varying depth across the included articles, with privacy and data protection mentioned most frequently, highlighting concerns over sensitive information and a lack of guidelines in the digital sphere. Additionally, technical concerns about data quality and bias were predominant issues for researchers and developers alike. Some ethical issues were not discussed at all, including equity, and user involvement.

**Conclusion:** This paper highlights the scarcity of discussion around ethical issues. Both researchers and developers need to better integrate ethical reflection at each step of the development and use of health apps. More effective oversight mechanisms and clearer ethical guidance are needed to guide the stakeholders in this endeavour.

### 1. Introduction

Travel, whether for leisure, business, or visiting friends and relatives (VFR) is an important global phenomenon, with significant impacts on spending, employment, and also health. In 2019, there were 1.5 billion international inbound tourists, with Europe having the largest number of international tourists and the most spending on tourism [1,2]. With the growth of international travel, however, comes an increased risk to traveler health, and of the possibility of the spread of infections to new areas. Travelers may be at risk of contracting illnesses such as malaria, traveler's diarrhea, arboviruses (such as dengue, Zika, and chikungunya), sexually transmitted infections, and more recently, the novel coronavirus SARS-CoV-2 [3–6].

Travel medicine plays an important role in preventing and treating travel-related illnesses. In Europe, travel medicine is a diverse field with a variety of national and local guidelines, and is administered by a wide range of health professionals, including nurses, general practitioners, travel clinics, and pharmacists [2]. Prevention is key for maintaining traveler health, and can include vaccinations, prophylaxis, travel safety information, insect bite prevention, and more [7]. Also relevant is the role of travelers as sentinels for infection and in surveillance of imported infections associated with travel. As travel increases and diversifies in destinations, and numbers and types of travelers, so too must travel medicine respond to the changing landscape of travel.

One method that has shown promise is the use of smartphone apps, or mHealth apps [8]. Monitoring traveler health behavior as well as

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encountered risks has become easier and more reliable due to advances in the quality of mobile health technology and widespread use of smartphones, allowing for real-time data collection [9,10]. For instance, in the context of the COVID-19 pandemic, apps for digital contact tracing, and potentially for storing individuals' vaccination certificates, became popular across Europe and beyond [11,12]. An ambitious new project called Illness Tracking in Travellers (ITTT) aims to collect data on traveler illness in collaboration with the World Health Organisation (WHO), with a goal of facilitating rapid public health responses [13].

However, many travel medicine apps are not up to date, lack accurate and evidence-based content, or were not developed with the involvement of health professionals [14]. This is consistent with the broader literature on health apps [15–17]. Research has shown that questions of data security, confidentiality, liability, and trust are at the forefront of the discussion about health apps (including those developed to fight COVID-19), despite their many advantages [15,18–20]. Effectiveness and accessibility are also mentioned frequently as reasons for the use or rejection of health apps [21,22]. Equity of access is another important ethical issue. Although the average number of mobile phone subscriptions worldwide was 104 per 100 people in 2018 [23], certain populations are underrepresented, including older individuals and those with a lower socioeconomic status [24,25]. This information is particularly relevant for studies of travel health apps: despite their intention to collect information from a variety of settings and population groups, these studies might be biased towards subgroups already owning and comfortably using mobile devices [26]. These issues are important to address in order to avoid bias. User trust is another important issue and lack of trust can result in poor uptake [27].

The goal of this systematic review is to evaluate ethical issues around mobile health apps for travelers, identify important deficits, and suggest key ethical areas to address in future travel medicine apps.

## 2. Methods

### 2.1. Identification and selection of studies

The systematic review was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines [28] and registered in the Prospero database (CRD42021231857). A systematic search of the Medline, Scopus, Web of Science, Embase, IEEE Xplore, Science Direct, Cochrane Central Register of Controlled Trials (CENTRAL), SSRN, and medRxiv databases was performed on January 7th, 2021 by a librarian scientist. The search strings can be seen in [Appendix A](#).

Titles and abstracts were imported into the reference manager software Endnote20® (Clavirate, 36T3 Boston, MA 02210), and duplicates were removed. Titles and abstracts were then imported into the knowledge synthesis software Rayyan QCRI [29] and examined for eligibility by two independent reviewers, with the consultation of a third in case of disagreement. Finally, the full text of the remaining studies was examined for relevance, and relevant studies were included in this review (see [Appendix B](#) for the excluded papers list) The reference lists of included papers were examined for additional relevant studies not included in the initial search. A team of three co-authors completed the abstract screening, full-text review, and data extraction. Any disagreement among the authors was resolved through discussion.

### 2.2. Eligibility criteria

Only studies meeting the inclusion criteria were considered. Reviewed studies were written in English, German, French, or Italian, and published until the 31st December 2020. Preprints, dissertations, and peer-reviewed studies with all study designs (qualitative, mixed methods, quantitative) were included, while books, conference abstracts, editorials, and papers without an available full text were excluded. Duplicates and irrelevant papers were also excluded. In order

to be considered relevant, papers had to report on mobile phone apps for travel medicine for travelers over eighteen (international and intranational), and these apps must have been developed for the primary purpose of traveler health/travel medicine. Apps for children and youth were excluded, as well as apps not designed specifically for travel medicine, even though they may still collect data useful for travel medicine research (such as social media apps collecting epidemiological data), or may be used in some way by travelers (such as holiday booking apps, apps for tourist leisure activities). Reference to ethical implications of developing and using mobile applications for travel medicine was an additional inclusion criterion. Reasons for exclusion from the review were noted in Rayyan QCRI [29].

### 2.3. Data extraction

The primary outcome was ethical considerations of the development and use of mobile phone apps for travel medicine purposes, and the secondary outcome was the opportunities and challenges in ethical considerations. Relevant information was extracted through a deductive coding process. In consultation, all authors agreed on a list of categories to code the studies accordingly. When an ethical consideration included in the text could not be coded under any existing category, it was temporarily designated “unclassified”. Subsequently, the authors decided whether this code should generate a separate category (introduced through an inductive process) or be grouped under an existing one. The extracted information was presented in tabular form using Excel software ([Appendix C](#)).

### 2.4. Risk of bias assessments

Quality assessment of the studies was conducted simultaneously. At the study level, quality was assessed with different tools according to the study design (Randomized trials – Cochrane risk of bias tool, Observational studies – STROBE, Narrative articles – SANRA) [30]. At the outcome level, we assessed the types of reasons supporting each ethical statement: supported by empirical evidence, justified by rationally articulated arguments (potentially supported by the literature), or uncorroborated (without an explicit justification). This categorization allowed for higher precision in identifying the gaps in the ethical reflection on travel medicine apps [31]. The quality assessment (recorded in [Appendix C](#)) was once again conducted independently by two authors, and disagreement was resolved through discussion with a third.

### 2.5. Data synthesis

All papers that met the eligibility criteria were included in the narrative synthesis [32]. Similarities and differences across studies were analyzed, and homogeneous studies were clustered. Study characteristics, type of intervention adopted, context of the intervention, opportunities and challenges brought by the intervention, and ethical considerations of developing and adopting mobile apps for travel medicine purposes were all considered in the synthesis. As a qualitative synthesis, the findings were clustered thematically according to the reasons used to justify the ethical considerations.

## 3. Results

A total of 1795 studies were found through the literature search. Of these, 636 were duplicates, and 1133 were excluded through the abstract screening. The full text of the remaining 26 papers were screened, and of these, six were included. In addition, one paper was found through the screening of reference lists of the included papers, resulting in seven papers being included in the review. [Fig. 1](#) provides an overview of the screening process.

Of the seven included papers, two were cohort studies and five were qualitative analyses or narrative reviews. Characteristics of included

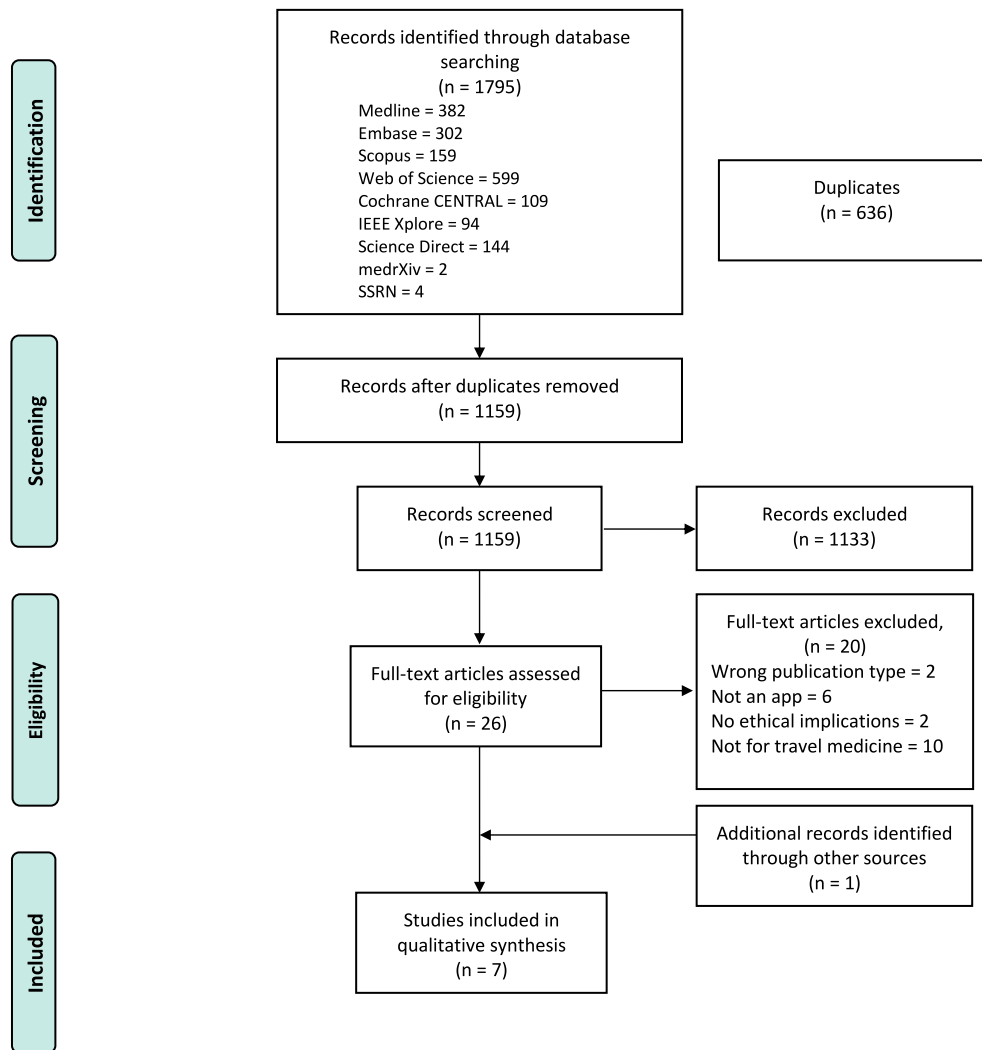


Fig. 1. PRISMA flowchart of identification and selection of studies to be included in the systematic review.

papers can be found in Table 1. The two cohort studies described the same app called the *Tourist* app, which was pilot tested in the 2018 paper [33]. The 2020 paper focuses on novelties and upgrades of the app, as well as participant willingness to use the app. Three papers described specific apps for travel medicine: Du et al. (contact tracing) [34], Subramaniaswamy et al. (food recommendations while travelling) [35], and Sethia et al. (electronic health record access while travelling) [36]. Finally, two papers provided a review of several apps. Seed et al. [14]

offered an overview of travel medicine apps available in 2016, and Lai et al. [37] reviewed the literature on benefits and challenges of travel medicine mHealth.

All included papers were rated for quality using the STROBE guidelines for the cohort studies, and the SANRA guidelines for the qualitative/narrative analyses (Table 2). The two cohort studies and the paper by Lai et al. [9] had the highest quality ratings, while the papers by Seed et al. [14] and Subramaniaswamy et al. [35] had lower scores.

Table 1  
Characteristics of included papers.

Author	Year	Title	Journal	Study Type	Field
Baroutsou et al.	2020	TOURIST2 – Tracking of urgent risks in swiss travelers to the 6 main travel destinations – Feasibility and ethical considerations of a smartphone application-based study	Travel Medicine and Infectious Disease	Cohort Study	Epidemiology
Farnham et al.	2018	Streaming data from a smartphone application: A new approach to mapping health during travel	Travel Medicine and Infectious Disease	Cohort Study	Epidemiology
Du et al.	2020	COVID-19 Contact Tracing Apps: A Technologic Tower of Babel and the Gap for International Pandemic Control	JMIR MHealth and UHealth	Qualitative Analysis	Epidemiology
Lai et al.	2019	Measuring mobility, disease connectivity and individual risk: a review of using mobile phone data and mHealth for travel medicine	Journal of Travel Medicine	Qualitative Analysis	Epidemiology
Subramaniaswamy et al.	2018	An ontology-driven personalized food recommendation in IoT-based healthcare system	Journal of Supercomputing	Qualitative Analysis	Computing
Sethia et al.	2018	Smart health record management with secure NFC-enabled mobile devices	Smart Health	Qualitative Analysis	Travel Medicine
Seed et al.	2016	Identification and review of mobile applications for travel medicine practitioners and patients	Journal of Travel Medicine	Brief Communication/ Qualitative Analysis	Travel Medicine

**Table 2**  
Quality rating of papers included in the systematic review.

Paper	Quality Rating System	Quality Rating
Baroutsou et al., 2020	STROBE <sup>a</sup>	21/22
Farnham et al., 2018	STROBE <sup>a</sup>	20/22
Du et al., 2020	SANRA <sup>b</sup>	10/12
Lai et al., 2019	SANRA <sup>b</sup>	11/12
Subramaniaswamy et al., 2018.	SANRA <sup>b</sup>	9/12
Sethia et al., 2018	SANRA <sup>b</sup>	10/12
Seed et al., 2016	SANRA <sup>b</sup>	9/12

<sup>a</sup> Strengthening the Reporting of Observational studies in Epidemiology (STROBE) checklist was created to help authors submit high-quality observational studies by grading them on a total scale of 22 points.

<sup>b</sup> Scale for the Assessment of Narrative Review Articles (SANRA) aimed to improve the quality of narrative reviews by rating them on a 12-point scale.

### 3.1. Benefits and challenges

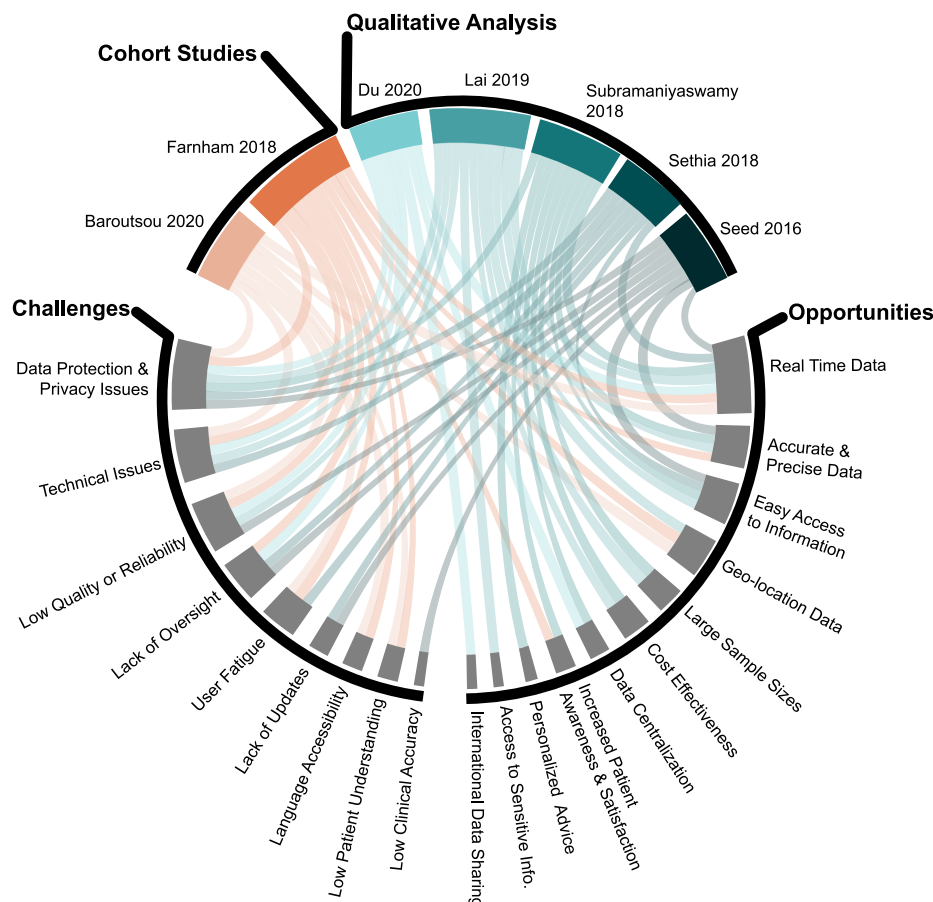
Each paper mentioned opportunities and challenges of using mobile apps for traveler health, with reference to travel app users, researchers, and developers (Fig. 2). The most commonly stated opportunity of travel medicine apps was to collect real-time data, thereby reducing recall bias and allowing users to access resources when needed. This was followed closely by the accuracy and precision of the data and easy access to information and resources, which are also related to reduced recall bias. Several papers mentioned linked geolocation data as a benefit of the apps, as well as the possibility of larger sample sizes and reduced costs. Geolocation benefits both researchers, enabling them to link location to risk events [37] or examine contact between users (as in COVID tracking apps) [34], and users, allowing for personalized information based on location [35]. Finally, opportunities mentioned once or twice included

personalized advice, data decentralization, and easier international data sharing. Conversely, all of the papers recognized data protection and privacy issues as a challenge for travel health apps. Other potential weaknesses included technical issues, low-quality data, and low reliability. The lack of clear governance or oversight during app development was also highlighted as troublesome. Frequently mentioned challenges associated with mobile travel health apps included potential for user fatigue due to data overload, language accessibility concerns, lack of updates leading to outdated information, and low traveler understanding. The mentioned opportunities and challenges of mobile apps for traveler health are presented in Fig. 2.

### 3.2. General ethical issues

In five of the seven papers, a full section was dedicated to discussion of ethical issues, while two papers discussed ethical issues only briefly, devoting less than a paragraph to the topic. Sixteen distinct ethical issues were touched upon across all papers. However, despite the emphasis on ethical considerations, almost half were not explored in detail, with no justification of their relevance provided in the text. Instead, many issues were mentioned in passing in the methods section (Fig. 3). More recently published papers tended to discuss a greater number of ethical issues and examine them in more detail than those published a few years ago. Furthermore, the recently published papers were more likely to contain evidence-based justification or stronger theoretical arguments in support of their ethical reasoning, in comparison with the older papers (Fig. 4). In fact, only the cohort study by Baroutsou et al. [8] had evidence-based reasons concerning topics such as secondary use of data, institutional trust, and age or chronic disease status of participants.

Looking more closely at the ethical considerations mentioned,



**Fig. 2.** Challenges and opportunities identified for mobile apps used for travelers' health.

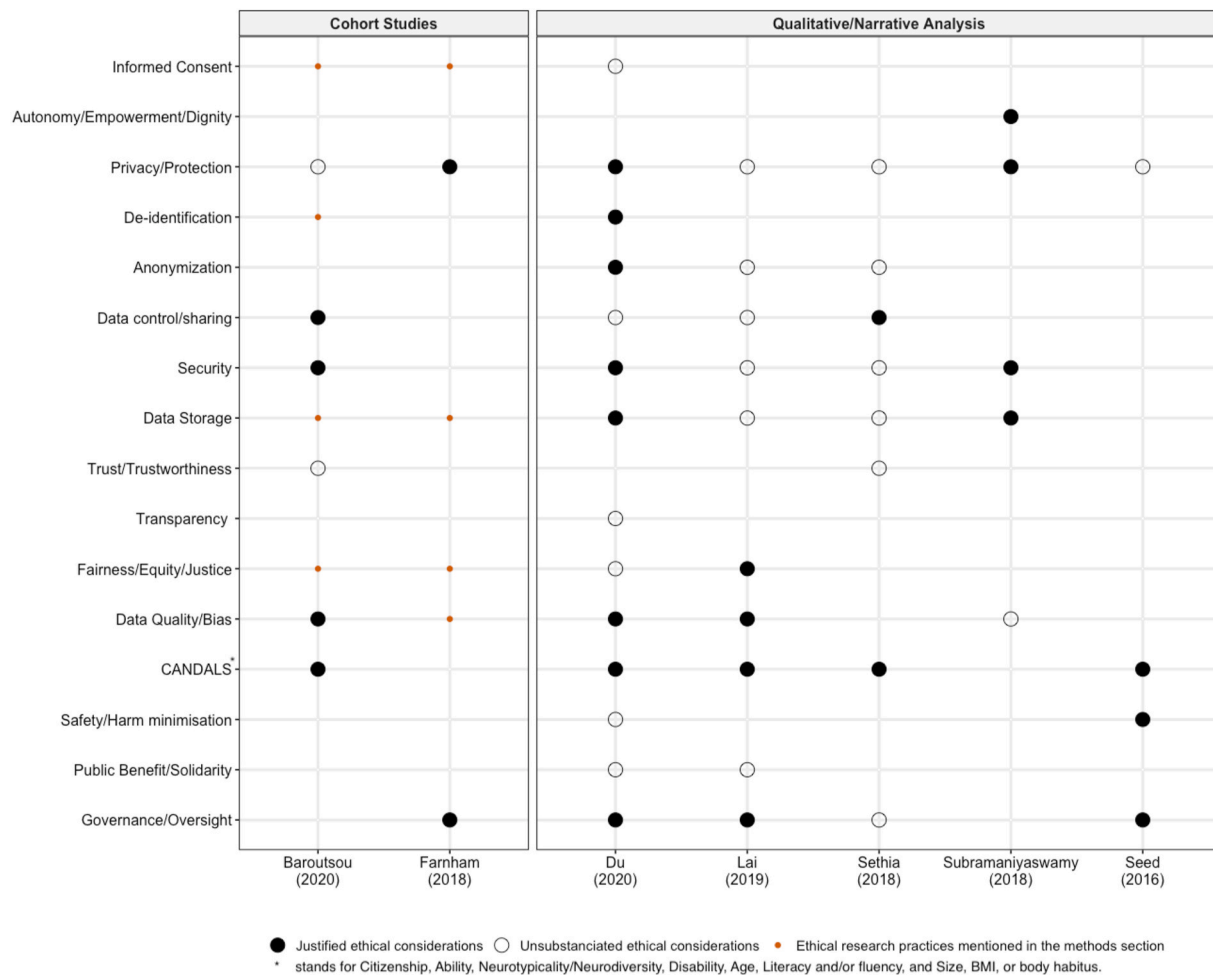


Fig. 3. Cleveland's Dot Plots of sixteen ethical considerations identified in the papers included in the systematic review.

privacy issues were most frequently discussed, being addressed by all of the papers, followed closely by issues included in the “CANDALS” classification [38] (Citizenship, Ability, Neurotypicality/Neurodiversity, Disability, Age, Literacy and/or fluency, and Size, BMI, or body habitus.) The papers discussed how age, disease status, ethnicity, lower-income country status, and health literacy can impact the adoption and usability of mobile health apps by individuals across countries, social classes, and cultures. Another frequently mentioned ethical issue was data storage, in relation to both data security (risk of cyber-attacks) and efficiency (e.g., saving energy in resource limited settings). Conversely, the least discussed ethical issues included transparency, autonomy, and individual traveler empowerment.

### 3.3. Cohort studies

Both cohort studies focused on the importance of protecting user privacy, an increasingly relevant topic for the general public. The 2018 paper by Farnham et al. [37] highlighted the lack of clear guidance at an international level, rendering it difficult to develop apps compliant with privacy laws across countries. The 2020 paper by Baroutsou et al. [8] goes beyond privacy issues, discussing the ethical implications of sharing data for secondary purposes, through surveying participant opinions of this topic before and after the study, and examining their reasoning. This highlights the importance of trust in the institutions responsible for app development, to engage app users and address data security concerns.

Looking at additional ethical issues taken into account in the

research methodology, Baroutsou et al. [8] mentioned e-consent forms and data de-identification and storage, as well as the concept of fairness, e.g., providing mobile devices to participants without access to one. They reflected further on data bias, as only individuals already interested in the app took part in the cohort study.

### 3.4. Qualitative/narrative papers

The paper by Du et al. [34] highlighted the greatest number of ethical concerns of all the included papers. Particularly, the paper discussed the data de-identification and anonymization as ways to preserve user privacy, as per the principle of data minimization. This paper also mentioned data security with regard to collection, storage, and use of sensitive data, as well as to individual harms that could emerge from a data breach. More specifically, it examined GPS location data used by apps such as those developed for COVID tracing, and the harms related to the potential theft of this information.

The qualitative papers mention ethical considerations not considered in the cohort studies, such as transparency, public benefit, solidarity, safety, and harm minimization. Concerning the last point, Seed et al. mentioned inaccuracy, lack of a medical background, and outdated information due to a lack of updates as potential sources of harm for people using travel medicine apps, especially those with low health literacy. Sethia et al. [36] examined data control, emphasizing the importance of selective access to data for data security, and the importance of regulating data access. Furthermore, data quality (and its link to bias) was a concern mentioned by Du, Lai, and Subramaniaswamy [9, 34,35]. Inaccurate data collection or heterogeneity of mobile phone



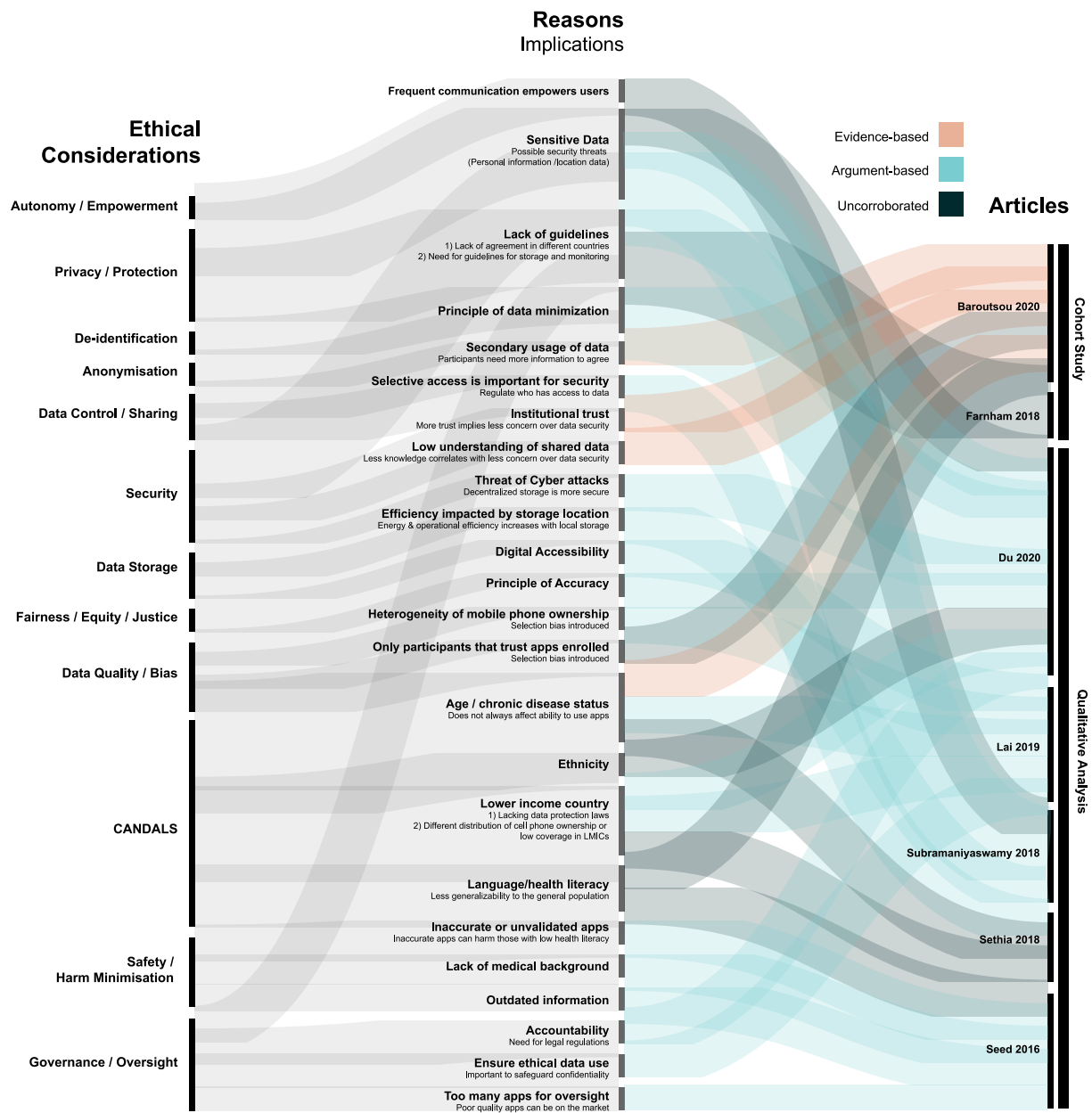


Fig. 4. Types of reasons justifying the ethical considerations and their implications.

ownership may result in selection bias, which can negatively affect data analysis and provide inaccurate feedback to users. The majority of the qualitative papers also mentioned issues of data governance, specifically the lack of adequate oversight for mHealth apps in the field of travel medicine. Du et al. stressed the need for legal regulation to address accountability [34], in the case of a security breach or inaccurate recommendations made by an app. Lai et al. [9] recommended introducing oversight to ensure that privacy is taken into account during travel medicine app development. Finally, Seed et al. [14] reflected on the exponential number of apps developed in recent years, and the lack of effectiveness of current oversight mechanisms to keep pace with this rapidly evolving sector.

#### 4. Discussion

This review found that privacy is the most pressing ethical issue for travel medicine apps. This may be partially explained by researcher and developer concerns about compliance with privacy and security

regulations. These concerns are justified, due to the lack of clear ethical standards and data regulation at the international level [39]. Apart from the General Data Protection Regulation in Europe, there are no defined minimum global standards for storage and sharing of personal data for secondary purposes [40,41]. Medical travel apps (as all health apps) must comply with each individual country's privacy law [37]. Baroutsou et al. [8] showed that trust in the institutions developing and implementing health apps can reduce user fears about data security and confidentiality. It is therefore essential to develop international data governance standards, endorsed by a variety of stakeholders, that not only guide researchers when developing their applications, but also increase user trust in the technology [42].

Given the types of papers assessed (cohorts and papers describing app development) it is not surprising that data quality and bias were also predominant issues. As the papers were written from the perspectives of app developers and researchers, concerns about potential biases and other technical issues were highlighted over issues that might have been emphasized by ethicists. Examining data quality in more detail, self-

reported user data introduces two issues of ethical relevance. The first is data accuracy. Although real-time self-reporting of data can reduce recall bias, positively influencing data quality, researchers can struggle to verify whether the information provided is precise, complete, and mirrors reality. For this reason, using GPS and metadata collected directly through the phone (without user input) might compensate for potential errors and biases. The ability to access these data represents a significant advantage of travel applications over other travel medicine strategies. Nevertheless, rigorous data quality control is still required. The second issue is data representativeness. Our analysis showed that effort should be made to include minorities as well as other population subgroups (CANDALS) in the design and deployment of health apps, as factors such as age, language and health literacy, or living in a lower-middle income country play a role in app use [9,36]. Selection bias introduced due to the heterogeneity of mobile phone ownership or user comfort with mobile technology directly affects data quality. This in turn may give incorrect or misleading feedback to users, which is particularly problematic for travel medicine apps, when user health is at stake.

Conversely, researchers dedicated only minimal attention to issues of equity and justice. Although a few articles [9,37] discussed accessibility through lending a mobile phone or SIM card to participants, no reference is made to the social implications of these applications, or whether they extend access to health information in an equitable way to all population groups.

Similarly, though the apps are used by individuals with various needs and health concerns, it can seem that researchers developed these tools without adequately considering the context, resulting in a “one size fits all” application. Only the more recent cohort study considered engaging users in the app development process and receiving feedback. Following on this point, it is important to note that informed consent, central to mHealth literature, has scarcely been discussed. Informed consent is mentioned in the cohort study methodology without further development, though their protocols reference it often. Of the qualitative studies, informed consent is only briefly referenced in Du et al. [34]. Many of the papers seem to view informed consent more as a task to be completed to avoid legal repercussions, than as a real ethical concern. However, in the interest of increasing trust, researchers should engage users. This might include clearly communicating the app’s objectives and addressing the data confidentiality concerns of users. Moreover, researchers should focus on user satisfaction, providing an app that is intuitive and accessible on multiple platforms. Finally, it could be important not only to be transparent about the user’s consequences from using the app, but also to stress the benefit for the broader community. As with COVID-19 digital contact tracing apps the notification of a potential close encounter with a COVID-19 positive individual might result in limiting individual freedoms (e.g., limiting freedom of movement with quarantine). However, this downside for the app user could be justified in light of a collective benefit. If researchers succeed in increasing willingness to use the app, they may also indirectly increase the quantity and quality of data that they collect.

Accompanying the user on their journey, travel medicine apps can offer individualized advice although this would mean that the app becomes a “medical device” and would thus require regulation. However, whether or not these apps are actually effective in providing timely advice and suggestions was not discussed in the papers evaluated here. On the contrary, as pointed out in Seed et al. [14], there is potential for harm due to a lack of medical background of app developers and app users and poor data accuracy. This should be considered carefully by researchers, as it may negatively influence user willingness to adopt the apps, especially those that collect highly sensitive data [18]. More research is needed to evaluate the ethical and societal implications of travel medicine apps. Simultaneously, future policies should provide detailed guidance about user experience and public involvement at each phase of app development, strategies for risk prevention and mitigation before releasing the apps, and transparent data collection, usage, and

storage.

## 5. Strengths and limitations

This is the first systematic review to examine the important and quickly growing topic of ethical aspects of travel medicine apps. A major strength of this work is the evaluation of key health equity stratifiers using the CANDELS classification to show how age, disease status, ethnicity, lower-income country status, and health literacy can impact the adoption and usability of mobile health apps by individuals across countries, social classes, and cultures. In the modern age, digital technology will play an expanding role in travel, emphasizing the importance of analyses such as this one. One limitation of this review is the quality of ethical assessment within the selected papers. Although the seven included papers matched the inclusion criteria and were of good quality, the depth of ethical assessment was often superficial, with only a short section devoted to ethics and little evidence to support the issues discussed. This reinforces the need for more research into ethical issues surrounding travel medicine apps, and health apps in general. Another limitation of this analysis is the inclusion and analysis of both cohort and qualitative studies, even though they employ different methodologies. However, the discussion of ethical issues can occur across all study designs, leading to comparability, and the quality assessment of the selected studies indicates strong results across study types. A final limitation is the use of a qualitative thematic methodology to extract ethical issues. This procedure might be subject to subjective biases, which were addressed by 1) having an inductive table of ethical issues and using a deductive approach to collect the issues, and 2) having multiple researchers working in parallel. However, it is not possible to completely rule out bias in the data extraction.

## 6. Conclusion

This systematic review identified 1159 unique articles of which seven (0.6%) met our pre-defined inclusion criteria. We found that although some ethical issues are widely debated (privacy, security and data quality), many are just mentioned (justice, fairness, risk assessment), and some are disregarded (effectiveness, user involvement). While it is true that travel applications constitute a relatively new approach to collecting data and engaging users, this result revealed gaps that exist regarding ethical considerations in travel medicine literature. These gaps highlight the need for developers and researchers working with travel medicine apps to do a careful risk-benefit assessment, not only exploring potential risks, but employing strategies to mitigate such risks. In light of the fast-evolving landscape of digital health and health apps, oversight mechanisms should be updated to support researchers and developers in making ethically aligned choices.

## Author contributions

AF, NH and TL selected the articles, compiled the results, drafted the manuscript. All authors participated in the design of the project, the development of the final manuscript, and approved the submitted version.

## Data availability

All search strings used are available in [Appendix A](#), listed by database to ensure an easy replication. [Appendix C](#) provides the papers’ quality assessment as well as the extracted data.

## Declaration of competing interest

None declared.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.tmaid.2021.102143>.

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