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Abstract

Background

Atrial fibrillation (AF) affects over 1.4 million people in the UK, resulting in a five-fold increased stroke risk and a three to four times greater risk of severe, disabling stroke. AF, a chronic disease, requires monitoring, medication and lifestyle measures. A self-management approach supported by mobile health (mHealth) may empower AF self-care.

Aims

To assess the need to develop new mHealth self-management interventions for those with AF. This review aimed to identify commercially available AF self-management apps, analyse and synthesise a) characteristics b) functions c) privacy/security d) incorporated behaviour change techniques, and e) quality and usability.

Methods

We searched app stores for “atrial fibrillation” and “anticoagulation”, and included apps focused on AF self-management in the review. We examined app functions, privacy statements against best practice recommendations, the inclusion of behaviour change techniques using the App Behaviour Change Scale, and app quality/usability using the Mobile App Rating Scale.

Results

From an initial search of 555 apps, five apps were included in the review. Common functions were educational content, medication trackers and communication with healthcare professionals. Apps contained limited behaviour change techniques, lacked intuitive

functions and were difficult to use. Privacy policies were difficult to read. App quality rated from poor to acceptable and no app had been evaluated in a clinical trial.

Conclusion

The review reports a lack of commercially available AF self-management apps of sufficient standard for use in healthcare settings. This highlights the need for clinically validated mHealth interventions incorporating evidence-based behaviour change techniques to support AF self-management.

Key words

Atrial fibrillation, mHealth, medication adherence, self-management, anticoagulation, behaviour change

Introduction

Atrial fibrillation (AF), the most prevalent clinically significant arrhythmia,[1] increases the risk of a thromboembolic event five-fold.[2, 3] Estimates suggest that in the UK over 1 million adults will be diagnosed with AF by 2040[4] and at least 4.7% of individuals with AF will have an ischaemic stroke.[5] Of greatest concern, AF-related strokes are more likely to be fatal or severely disabling compared to stroke of other aetiology.[6] Consequently, the financial and social burden of AF-related stroke is much greater. AF has been estimated to cost the National Health Service (NHS) in the UK £770 million over a five-year period[7] and this is likely to increase as the prevalence of AF rises.[1, 8] Those with symptomatic AF, who suffer from breathlessness, palpitations and/or fatigue may experience reduced quality of life, poor functional status[1] and increased risk of hospital admission.[7] To mitigate health costs and improve patient outcomes, the National Institute for Health and Care Excellence (2014) recommends that AF treatment should emphasise the prevention of thromboembolic complications through increased stroke awareness and oral anticoagulation (OAC), concurrent with heart rate control.[9]

Adherence to medication is only part of the long-term management of AF. Globally, AF guidelines advocate a self-management approach. Chronic disease self-management generally encompasses a range of activities from tracking symptoms to increasing physical activity, adhering to a special diet and supporting mental health in an effort to engage patients to take an active role in their own care.[10] Patient self-efficacy is a key enabler of self-management and should be promoted through education.[11, 12]

Mobile health (mHealth) apps are an innovative potential solution to support self-management by monitoring behaviour, symptoms, medication and physiological measurements such as heart rate.[13, 14] mHealth apps, used independently or in conjunction with healthcare professional guidance, have been developed with the aim of improving clinical outcomes in cardiovascular health, diabetes and chronic lung conditions.[15] Due to their ability to provide updated, clinically relevant and targeted information to individuals, apps have the potential to be successful in a range of settings by offering far-reaching educational and tracking support.[16] Apps have the capacity to integrate behaviour change techniques (BCTs) within their software. BCTs are evidence based replicable components incorporated into health interventions to change or regulate behaviour patterns[17] and their presence or absence is often predictive of an interventions success.

Despite their potential, mHealth apps often lack the necessary components of self-management required to support patients with long term conditions, such as customised medical advice.[18] Complications arise when elements within an app transition it from a support tool to a medical device. Regulation as a medical device ensures apps are safe and of high quality[19] but once registered, they become less accessible to the general population. Most apps therefore, are not regulated and these widely available apps are what many will choose to support health behaviour change.

The lack of theoretical underpinning to inform and guide behaviour change, such as increasing medication adherence or physical activity levels, raises questions about app benefits for users.[20] Personal data privacy is a particular issue, with extreme variations in data protection principles identified in apps registered with the NHS Health Apps Library, a database designed to help the public find trusted health

apps.[21, 22] At present, poor regulation and easy accessibility to poorly evidenced apps pose significant legal and ethical implications.[15, 23] This could negatively influence patient and public perception of apps and act as a barrier to uptake of the technology among target populations. It is important that we understand what elements of mHealth apps are likely to increase adoption and influence behaviour, and how this could improve medication adherence in people living with AF.

Systematic reviews with content analyses have examined quality, functionality and underpinning behaviour change theory of mHealth apps used for hypertension,[20, 24] pain,[25] smoking cessation,[26] mental health,[27] and diabetes[28] but not AF. Therefore, this study aims to identify and evaluate commercially available AF self-management apps and explore a) app characteristics, b) functions, c) privacy and security, d) underpinning theoretical behaviour change, and e) quality and usability.

Methods

This study used publicly available data to perform a content analysis and review of apps supporting AF self-management. Where appropriate, we report results using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[29]

In September 2019, we undertook an electronic search of two major mobile application stores, Google Play (Android operating system) and Apple App Store (iPhone operating system). Data were collected from 2-8 September 2019. We separately searched the terms “atrial fibrillation” and “anticoagulation” in both stores with no restrictions on subcategories or number of applications. We also included the term INR and synonyms for atrial fibrillation but these did not yield any additional results.

Inclusion and exclusion criteria

Two investigators (AP and CLH) pre-screened apps for suitability based on the app descriptions and screenshots provided in the app stores. We included apps that were:

- Written in English and where *atrial fibrillation* was directly included in the key words or images accompanying the app description
- Intended for those with a diagnosis of AF
- Alluded to self-management capabilities in their description e.g. education, tracking, physical/mental health, symptom control and anticoagulation medication

We included both paid and free apps.

We excluded apps if:

- The app software did not function when downloaded
- They required identification, e.g. patient number/prescription access
- They were designed for use in one hospital or as part of a specific study
- They did not mention AF
- They had no self-management function, i.e. were intended as a self-diagnosis tool; focused on arrhythmia detection; or solely focused on evaluating stroke risk as a consequence of AF

Apps that appeared in both the Apple App and Google Play stores were independently analysed to account for differences in functionality across operating systems. Following initial identification, one investigator (AP) downloaded apps onto an Apple iPad Air (operational system iOS 12.4.1) and Samsung S7 (operational

system android 8.0) and subsequently re-evaluated against the same inclusion and exclusion criteria.

Data collection

For apps that met the selection criteria, we assessed a) app characteristics, b) functions, c) privacy and security, d) underpinning theoretical behaviour change, and e) quality and usability.

App characteristics

We recorded app name, developer, version date, operational system, price, rating, number of downloads and healthcare professional and/or patient involvement during the development of apps. We based this on app store descriptions or "about" sections within app and noted whether apps had been, or were undergoing, clinical trial.

App functions

One researcher (AP) used the apps concurrently for one week before classifying the presence and frequencies of app functions, as identified in previous medication adherence mHealth studies, under 'Educational Information', 'Self-Monitoring', 'App User Interaction', and 'Patient Medical and Support Network'.[16, 20, 24, 30, 31]

Privacy and security

We assessed app privacy and security against Online Trust Alliance *Best Practices: Privacy recommendations.*[32] Two independent reviewers (AP and SK) assessed apps against four elements: basic notice/disclosure, key compliance policies, protected privacy and protected sharing criteria, and miscellaneous privacy

elements. We analysed readability of privacy policies utilising the Flesch-Kincaid Reading Ease Score.[33]

Incorporated behaviour change techniques

Three reviewers (AP, CH, SK) completed online behaviour change taxonomy training[34] before assessing each app against the behaviour change technique (BCT) theoretical framework[17] for the 12 BCTs previously identified in apps targeting medication adherence.[35] Concurrently, BCTs were reviewed against a recently developed App Behaviour Change Scale (ABACUS).[36] Any discrepancies were resolved by discussion until consensus was agreed.

Quality and usability

The Mobile Application Rating Scale (MARS)[37] was utilised by six reviewers with backgrounds in nursing, digital health and behavioural change theory research (AP, CLH, SM, SS, SK, MZ) to assess overall app quality by evaluating four dimensions: engagement, functionality, aesthetic and information quality. Reviewers scored each element on a 5-point scale (1=inadequate to 5=excellent), with mean scores calculated for each dimension and an overall mean quality score calculated from the four objective dimensions. An additional subjective quality score provided a measure of whether reviewers believed those with AF would use the app, by considering apps from an end user perspective.

Statistical analysis

We analysed data using SPSSv26. We reported descriptive statistics for app functions, privacy and security best practice elements, and behaviour change techniques identified. Each subscale within the MARS was analysed using the mean value as per the original study methodology,[37] with interrater reliability analysed

using a two-way mixed intraclass correlation coefficient (ICC). The relationships among the MARS subscales were analysed by Spearman correlation.

Results

We identified 555 apps (487 Android OS and 68 iPhone OS) and screened these against the inclusion/exclusion criteria. We downloaded 32 apps for in-depth screening and included five apps in the comprehensive analysis (Figure 1).

App characteristics

Three apps were available through Android OS. Of the two apps available from Apple, one was a duplicate from the Google Play store but was assessed for functionality across both operating platforms. For the purposes of this review, these were classed as two separate apps (Table 1). All apps included in the final analysis were free of charge.

App functions

The most common functions were AF related educational content, symptom diaries and healthcare professional communication (Table 2). Four of the five apps contained self-monitoring functions for physiological measurements that relied on manual data entry. No app offered recording capabilities via wearables. Journals were found to be exportable in two apps via emailed PDF documents or in-app printable versions. Networking was available in 4/5 of apps, allowing users to communicate with healthcare professionals (4/5 apps), community networks (1/5 apps) and friends/family (1/5apps).

Privacy and security

Privacy policies were available in 4/5 apps prior to download (Table 3). All privacy policies were available in English and stated compliance with General Data Protection Regulation. Flesch Kincaid Reading scores ranged from 25 to 48 (<50 college level; <30 graduate level). The privacy policies of four apps explicitly stated the collection, but not distribution, of personally identifiable information. Four apps reported sharing non-identifiable data via cookies with third parties. Apps secured data by encryption.

Incorporated behaviour change techniques

We identified the presence of seven BCTs from a possible 12,[35] with a range of one to six per app. As highlighted by the ABACUS,[36] no app embedded goal setting capabilities or included instruction, demonstration and rehearsal for specific behaviours. There was consensus from both scales that knowledge, monitoring and feedback were the most commonly utilised BCTs (Table 4).

Quality and usability

The MARS score was used to rate quality of the apps. Across all apps the mean Overall Quality Total score was 3.5 (SD 0.65), indicating acceptable quality[37] (Table 5). Mean Subjectivity Quality (not included in the MARS calculated overall quality total) was 2.7 (SD 0.84). This gave apps a rating of poor to acceptable. No app received an overall average quality or subjectivity score ≥4, meaning that none of the apps achieved an overall good or excellent rating.

Strong positive correlations were found between Engagement and Aesthetics (r_s = 0.941, p= .005) and Subjectivity and Aesthetics (r_s = 0.941, p= .005). Positive relationships were also found within Functionality and Engagement (r_s = 0.824, p=

.044) and Information Quality and Engagement (r_s = 0.824, p= .044). No relationship could be determined between Functionality and Aesthetics (r_s = 0.765, p= .077) and Information Quality and Aesthetics (r_s = 0.765, p= .077). Interrater reliability across all MARS subscales and all included apps was excellent (2-way mixed ICC= 0.82).[38] Internal consistencies of the MARS subscales engagement, functionality and information quality showed moderate to good interrater reliability (2-way mixed ICC= 0.66, 0.76, 0.65 respectively), with the aesthetic quality showing very poor reliability (2-way mixed ICC= 0.26).

Discussion

This review provides a detailed analysis of freely available mHealth apps aimed at encouraging AF self-management. We identified four different apps, one of which was duplicated on Android and Apple platforms and performed identically across both. With a total of five apps to analyse, the most influential finding from this review is the lack of available AF self-management apps, a contrast to, for example, the plethora of hypertension apps (n=186).[20]

Of the five apps analysed, the most common functions were AF related educational content, symptom diaries and healthcare professional communication. Privacy policies were available for four out of five apps prior to download and one after download, but assessment of readability indicated potential issues with understanding the meaning and intent of the information for those without college level education. Most apps included some behaviour change techniques, for example self-monitoring and information about health consequences, but none contained goal setting, a common and often effective behaviour change technique.

The quality of apps ranged from poor to acceptable, as assessed using MARS.[37] This study reported mean values in line with the original study methodology in order to ensure that the review will be comparable to previous health app content analysis studies.[39, 40, 41, 42]

Educational content is an important element of an AF self-management app and is also commonly reported as the most common self-management feature identified within health apps.[20, 25, 27] This is because education, particularly tiered education[43] is considered a prerequisite to informed patient-centred care. Tailored education is a key recommendation within the 2016 European Society of Cardiology atrial fibrillation guidelines,[12] and is known to significantly promote self-management in the older adult population, in particular medication adherence, but also other aspects of self-care (e.g. dietary changes) by increasing competence and reducing anxiety.[44, 45] Despite this, education is not always a priority of mHealth apps. For example, in a review of systematic reviews of mHealth in chronic disease management, only eight interventions (n=30) identified education as an intervention modality compared with 19 supporting a tracking function,[46] indicating that mHealth apps emphasise observing behaviours over changing behaviours.[47] A positive outcome from our review was the comprehensive educational content across all five apps.

All five apps met the minimum MARS acceptable threshold score of three for the Information Quality dimension.[37] It is unclear what type of interactive material is desirable to relay educational content to the target population.[43] Apps included in this review lacked incorporated multimedia. Information was portrayed in unexciting text based formats, reflected in the average ‘poor’ MARS Subjective Quality dimension rating (MARS= 2.7). App design can greatly benefit from the input from end-users

(both existing and non-smartphone users) to improve aesthetic, content and engagement. However, to be an effective method for mHealth development the patient representative group must include a range of health literacy levels. The only app included within this review that reported involving patient representatives in the design stage (MyAF)[48] was found to be heavily text dense. To avoid an app-based health promotion tool that widens the health inequality gap, care must be given to developing and testing the app with participants with a range of health literacy levels.[49]

Health related app data management has frequently been reported to be no more secure than non-health related apps.[20, 50] As many as two-thirds of mHealth apps function without accessible privacy statements,[21, 27, 51, 52] leaving user's privacy and data security at risk. A lack of clarity and transparency in policy has previously been reported[51] and encouragingly this study obtained 100% of privacy statements for the included AF self-management apps. However, the high level of literacy required to understand privacy statements impedes the person's ability to scrutinise app integrity for themselves. Subsequently, a user's consent to download and use the app could be considered uninformed consent and therefore ethically dubious.[21, 50, 51] Since the mHealth apps' core functions rely on the use and storage of personally identifiable information (4/5 apps), substantial improvements are required to ensure future comprehensive and transparent data security principles.

No app included within this review claimed that functions were aligned with behaviour change techniques (BCTs). Although it is recognised that self-management effectiveness would be improved if supported by integrated BCTs,[17, 35, 43] we found the number of identifiable BCTs within the evaluated AF apps were low.

This is a common finding in other chronic disease self-management apps. For example, in a study analysing 44 French mHealth chronic disease self-management apps as few as 0-5 BCTs were identified.[47] Similarly, within 40 diabetes apps, a mean of only 4.4 BCTs out of a possible 26 were classifiable.[28] A surprising finding within this review was the lack of goal setting functions in any app analysed. Goal setting is considered integral to digital interventions, coupled with tailored feedback to provide motivation, accountability and guidance to achieve desired health outcomes.[53] An example goal in AF self-management would be time in anticoagulation therapeutic range, achieved through medication adherence. The absence of such an integral BCT negatively affects an app's ability to help users achieve long-lasting lifestyle changes. The lack of BCTs found within the apps analysed could be a result of omitting behaviour-change specialist input during early app development stages. mHealth apps are also consistently developed without clinical input. One study investigating over 650 self-management apps found as little as 12.3% of apps benefitted from healthcare professional involvement.[54] Although 50% of apps included within this review stated the involvement of healthcare professionals, no app underwent evaluation in a clinical trial, a finding consistent with other health app reviews,[20, 25] therefore regardless of the presence or absence of BCTs, effectiveness was not evaluated or demonstrated.

As scored by MARS, functionality and information quality were rated positively.[37] However, engagement and subjective quality dimensions failed to score >3, indicative that apps would fail to retain user interaction.[55] The strongly positive correlation between engagement and aesthetics MARS quality scores suggests that untargeted, cumbersome and unintuitive design would be linked with low uptake.[56] Interrater reliabilities were used within this study to gauge whether the MARS scale

would provide objective measurement of an otherwise subjective domain. Despite interrater reliability across all MARS subscales performing comparably, if not better, than the original authors (2-way mixed ICC= 0.82)[39] an aesthetics domain ICC of 0.26 is suggestive that the MARS tool was not able to negate subjectivity bias within this category.

Strengths and Limitations

To our knowledge this is the first review to analyse and synthesise the content of apps that help support self-management of AF. Although this study employed an extensive search strategy with no restriction placed on the number of apps scanned, it is still recognised that the speed of software development means there is always the potential for new apps to reach the market and thus not be included in this review. Search terminology presented two limitations to this study. Firstly, just two search terms were utilised, this was due to the large number of duplicated identified apps across the two searches. Secondly, app store search algorithm sensitivity varied greatly across the two stores, and it is acknowledged that this could have resulted in the accidental omission of apps. The method used to gather information on whether apps had undergone clinical trial could be further improved by performing a bibliometric database search. However, as it is often common practice for developers to state clinical trial information within app store descriptions as an advertisement for the authenticity and effectiveness of the app to potential end users, we considered that for the purpose of this study, app description review was sufficient.

It is recognised that the most important stakeholders are people living with AF. In this scoping review, assessments of usability were completed by professionals. Future

studies would benefit from asking end users, alongside researchers to undertake a concurrent MARS assessment. Comparable interrater reliabilities between the two groups would be a good indication whether the scale is capable of overcoming any potential reviewer bias introduced through prior knowledge of digital health and behaviour change theory. Due to the low number of apps meeting the inclusion criteria, the authors recognise the weak generalisability of this review to other mHealth apps. However, the results reflect the current state of play regarding the small number of available apps targeted towards AF.

Conclusion

This review reports a lack of commercially available AF self-management apps that are of sufficient standard for use in healthcare settings. This review highlights the need for a comprehensive, co-designed, clinically validated AF self-management app with deeper integration of BCTs, data security and transparency.

Implications for Practice

- In the future mHealth apps to improve self-management in patients with atrial fibrillation should be co-designed with end users and healthcare professionals.
- Currently available atrial fibrillation self-management apps lack the required behaviour change techniques likely to affect beneficial long-lasting lifestyle changes.
- To gain the trust of end users, there is a need to develop a clinically validated atrial fibrillation self-management app that prioritises data security and user readability.

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Figures and Tables

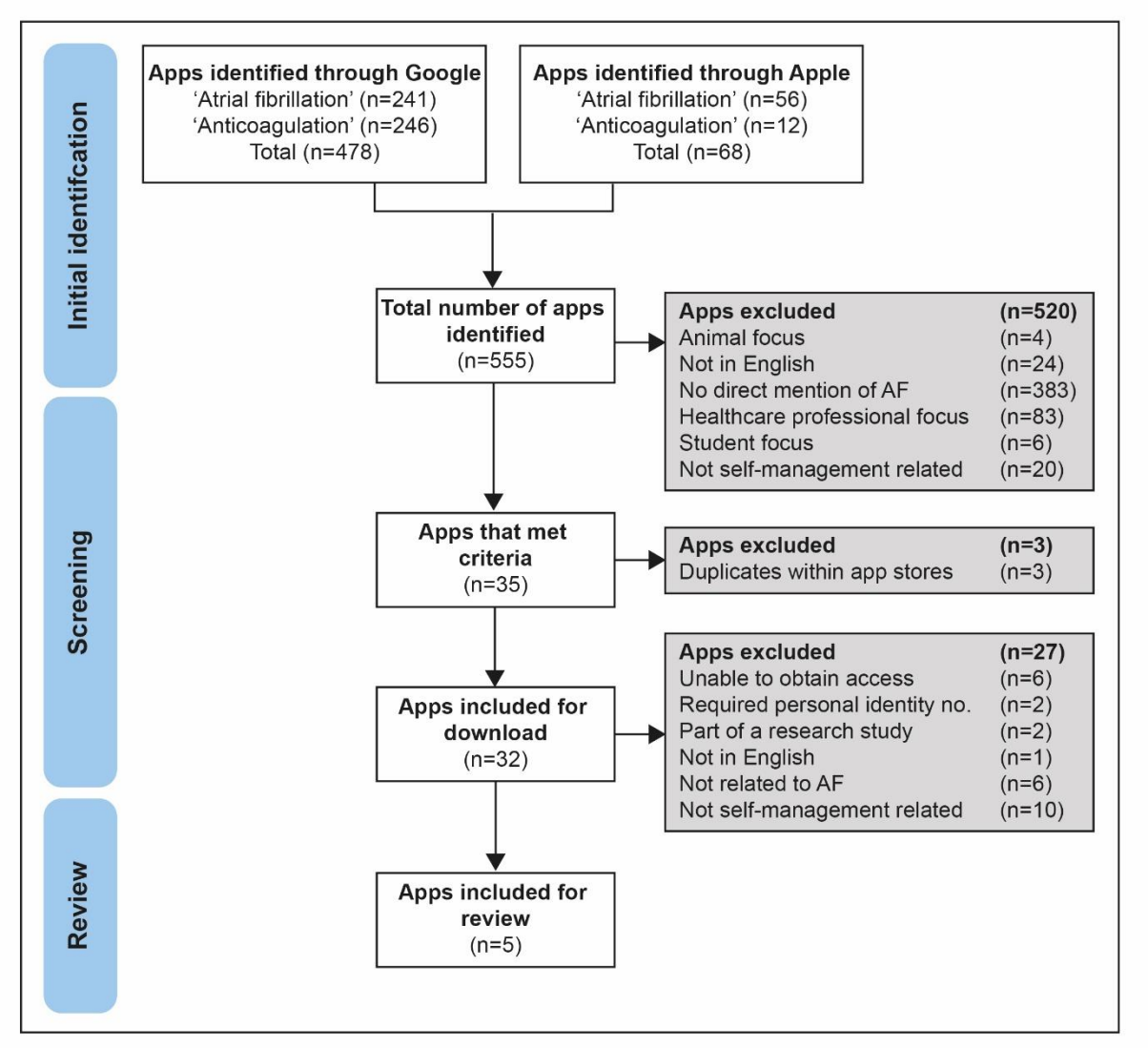

Figure 1. PRISMA diagram of app screening and selection process[30]

(AF)= Atrial Fibrillation

Table 1. App characteristics

Name	Platform	App Store Description	No. of Downloads	Last Updated	App Store Star Rating	Affiliations	Healthcare Professional Involvement*
MyAF	Google	"An educational resource and tool for people with Atrial Fibrillation, that records symptoms and quality of life data that can be shared with the healthcare team before each hospital visit."	1,000+	04/08/19	4.4	Non-Government Organisation	Yes- European Society of Cardiology
Pill Reminder and Medication Tracker	Google	"Combining a pill tracker, mood tracker and a health journal, this app puts all your medication needs in one place"	1,000,000+	21/05/17	3.3	Commercial	No
Manage Your Health	Google	"To help manage long term conditions, an app to support patients to manage their condition - Atrial Fibrillation"	1,000+	08/07/19	3.6	NHS, Keele University	Yes- Pharmacy
Afib Manager	Apple	"Getting the full picture with your Atrial Fibrillation-Afib Manager can help you manage the symptoms that affect you every day. Track your progress, manage your medications and treatments including reminders"	Not Given	11/07/19	No Rating	Commercial	Unknown
MyAF	Apple	"An educational resource and tool for people with Atrial Fibrillation, that records symptoms and quality of life data that can be shared with the healthcare team before each hospital visit."	Not Given	16/04/19	5	Non-Government Organisation	Yes- European Society of Cardiology

***Healthcare Professional Involvement: Where a healthcare professional was involved in the design and content of app development. This does not pertain to the app function of being able to contact a healthcare provider from within the app.**

Table 2. App functions

	Google Apps			Apple Apps	
Functions	**MY AF**	**Pill Reminder & Medication Tracker**	**Manage Your Health**	**Afib Manager**	**My AF**
Education					
Text-based educational information	✓	-	✓	✓	✓
Multimedia	-	-	-	-	-
Links to external education	-	-	-	✓	-
Functioning multimedia/links	-	-	-	-	-
Self-monitoring					
Symptom/trigger diary	✓	✓	-	✓	✓
Medication tracker	-	✓	-	✓	-
Health data input e.g. heart rate	✓	-	-	✓	✓
Goal setting	-	-	-	-	-
App user interaction					
Reminders/alerts	-	✓	-	✓	-
Refill tracker	-	✓	-	-	-
Encourage check in	-	✓	-	-	-
Export data	-	✓	-	✓	-
Reward system	-	-	-	✓	-
Patient medical information					
Stores medical information	✓	-	-	-	✓
Calculates AF related health scores	✓	-	-	-	✓
Stores lab results	✓	✓	-	-	✓
Support network					
Healthcare professional communication	✓	✓	-	✓	✓
Community network	-	-	-	✓	-
Friends/family support	-	✓	-	-	-

(AF)= Atrial Fibrillation

Table 3. Privacy policy description data[33]

Privacy Element	Android N=3 (%)	iPhone N=2 (%)	Total N=5 (%)
Basic notice/disclosure			
The privacy policy is easily discoverable	2 (66)	2 (100)	4 (80)
The privacy policy is downloadable without downloading the app	2 (66)	2 (100)	4 (80)
There is a short form notice (in plain English) highlighting key data practices	2 (66)	2 (100)	4 (80)
The privacy statement is available in other languages	1 (33)	0 (0)	1 (20)
Key compliance policies			
The privacy policy provides a summary of the data retention policy	2 (66)	2 (100)	4 (80)
The privacy policy includes a specific timeframe/reason for data retention	1 (33)	1 (50)	2 (40)
Protect privacy and define protected sharing			
The app collects personally identifiable information	2 (66)	2 (100)	4 (80)
The app shares personally identifiable information with a 3rd party	0 (0)	0 (0)	0 (0)
The app shares data with a 3rd party	2 (66)	2 (100)	4 (80)
The app use 'cookies'	2 (66)	2 (100)	4 (80)
Miscellaneous			
The policy states whether data encryption is used to enhance security	2 (66)	2 (100)	4 (80)
The policy states compliance with General Data Protection Regulations	3 (100)	2 (100)	5 (100)

Table 4. Assessment of behaviour change techniques

Behaviour Change Techniques	Google Apps			Apple Apps	
As assessed by Morrissey et al.[37]	**MY AF**	**Pill Reminder & Medication Tracker**	**Manage Your Health**	**Afib Manager**	**My AF**
Action planning	-	✓	-	✓	-
Prompt/cues	-	✓	-	✓	-
Self-monitoring	-	✓	-	✓	-
Feedback on behaviour	-	✓	-	✓	-
Monitoring of behaviour by others without feedback	✓	✓	-	✓	✓
Social support (unspecified)	-	✓	-	-	-
Information about the antecedents	-	-	-	-	-
Instruction on how to perform a behaviour	-	-	-	-	-
Information about the health consequence	✓	-	✓	-	✓
Demonstration of the behaviour video	-	-	-	-	-
Social comparison	-	-	-	-	-
Behavioural practice/rehearsal	-	-	-	-	-
As assessed by ABACUS[38]					
App knowledge and information					
Has the ability to customise and personalise some features	-	✓	-	-	-
Was created with expertise and/or provides information consistent with national guidelines	✓	-	✓	-	✓

Asks for baseline information	✓	✓	-	✓	✓
Provides instruction on how to perform the behaviour	✓	-	-	-	✓
Provides information about the consequences of continuing and/or discontinuing behaviour	✓	-	-	-	✓
App goal and planning					
Asks for willingness for behaviour change	-	-	-	-	-
Allows for goal setting	-	-	-	-	-
Has the ability to review goals, update and change when necessary	-	-	-	-	-
App feedback and monitoring					
Gives the user the ability to understand the difference between current action and future goals	-	✓	-	✓	-
Has the ability to allow the user to easily self-monitor behaviour	-	✓	-	✓	-
Has the ability to share behaviours with others and/or allow for social comparison	-	✓	-	✓	-
Has the ability to give the user feedback	-	✓	-	✓	-
Has the ability to export data from the app	-	-	-	✓	-
Provides a material or social reward or incentive	-	-	-	-	-
Provides general encouragement	-	-	-	-	-
App actions					
Has reminders and/or prompts or cues for activity	-	✓	-	-	-
Encourages positive habit formation	-	✓	-	-	-
Allows or encourages for practice or rehearsal, in addition to daily activities	-	-	-	-	-
Provides opportunities to plan for barriers	-	-	-	-	-
Assists with or suggests restructuring the physical or social environment	-	-	-	-	-
Assists with distraction or avoidance	-	-	-	-	-

Table 5. MARS Mean Quality Rating Scores (1= Inadequate, 5= Excellent)

App Name	Engagement	Functionality	Aesthetics	Information Quality	Overall Quality Total	Subjective Quality Total
MyAF (Android)	3.0	4.2	3.6	4.1	**3.7**	2.9
Pill Reminder and Medication Tracker	2.9	3.6	2.9	3.7	**3.3**	2.7
Manage Your Health	2.2	2.4	3.3	3.5	**2.8**	1.7
Afib Manager	3.7	4.1	3.7	3.9	**3.9**	3.6
MyAF (Apple)	3.0	4.2	3.6	4.1	**3.7**	2.9