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Identifying an effective mobile health application for the self-management of allergic rhinitis and asthma in Australia.

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Title

Identifying an effective mobile health application for the self-management of allergic rhinitis and asthma in Australia.

ABSTRACT

Objective: People with Allergic Rhinitis (AR) often self-manage in the community pharmacy setting without consulting health care professionals and trivialize their comorbidities such as asthma. A mobile health application (mHealth app) with a self-monitoring and medication adherence system can assist with the appropriate self-management of AR and asthma. This study aimed to identify an app effective for the self-management of AR and/or asthma.

Methods: MHealth apps retrieved from the Australian Apple App Store and Android Google Play Store were included in this study if they were developed for self-management of AR and/or asthma; in English language; free of charge for the full version; and accessible to users of the mHealth app. The mHealth app quality was evaluated on three domains using a two-stage process. In Stage 1, the apps were ranked along Domain 1 (Accessibility in both app stores). In Stage 2, the apps with Stage 1 maximum score were ranked along Domain 2 (alignment with theoretical principles of the self-management of AR and/or asthma) and Domain 3 (usability of the mHealth app using Mobile App Rating Scale (MARS) instrument).

Results: Of the 418 apps retrieved, 31 were evaluated in Stage 1 and 16 in Stage 2. The *MASK-air* achieved the highest mean rank and covered all self-management principles except the doctor's appointment reminder and scored a total MARS mean score of 0.91/1.

Conclusions: *MASK-air* is ranked most highly across the assessment domains for the self-management of both AR and coexisting asthma. This mHealth app covers the majority of the self-management principles and is highly engaging.

MAIN TEXT

Introduction

Allergic rhinitis (AR) is a chronic respiratory condition that is highly prevalent, affecting up to 40% of the population worldwide(1). AR carries a significant burden on individuals and society. Up to 85% of the AR population have insufficient control(2) with a significant impact on their quality of life (QOL) and poses a substantial socioeconomic burden(3). The association between AR and asthma is high and cannot be underestimated or undervalued because in the extreme case, it can be fatal (4).

Self-management is the mainstay for the management of both AR and asthma in the real world. However, their management is dynamic and includes care pathways with an interaction between health care professionals (HCPs) and particularly community pharmacists and physicians. It includes the recognition of the disease, appropriate medication selection, correct treatment management and review of the effectiveness of medications(9-11). Patients with AR and asthma often trivialise their condition; underestimating the severity of their symptoms and overestimating their ability for effective self-management(12). They frequently do not engage with their doctor, to obtain a diagnosis for their condition(13, 14). The lack of HCPs engagement results in patients self-selecting suboptimal medications(2). The majority of AR medications are available over-the-counter (OTC) and patients can easily bypass interacting with a pharmacist(2, 15-17), and self-select AR medications, whereas the majority of asthma medications are available only on prescription. However, the OTC availability of short-acting beta agonist reliever medications in some states such as Victoria, Australia, favours overreliance on this reliever medication.

Smartphones are revolutionising the current trend of health care in an attempt to improve the self-management of chronic disease(18). One strategy is the use of mobile health applications (mHealth apps) which run on smartphones. Smartphone users account for 38% of the 8 billion mobile phone users internationally(19). The portability of smartphones has shifted smartphone users to a “do-it-yourself” approach, enabling patients to access health information and

interventions at any time(20, 21). and have real-time, on-demand communications with HCPs (20, 22). Mhealth apps can support health care services, improve health outcomes through self-monitoring and medication adherence(23-25).

mHealth apps can support AR and asthma and change the current inappropriate self-management of these diseases (23, 26). Although there are mHealth apps that manage both conditions, AR has never been the main focus. MHealth apps are increasingly being used for the management of asthma(18), therefore high incidence and the co-morbid relationship between asthma and AR, it is important that these apps include AR management within them. This does not only optimise AR control but also helps reduce the challenge of controlling asthma for those who have coexisting asthma.

There is a need for evidence-based evaluations for apps that can improve the self-management of AR and/or asthma daily. These should be easily identifiable(27, 28) within the information section provided in the app stores which is currently limited and non-validated(29-31). The wide availability of mHealth apps in the app stores confuses people with AR and/or asthma as to which mHealth app best suits their needs (29-31). Therefore, it is important to identify one mHealth app that can be recommended for its effectiveness in supporting self-management. However, while an evaluation of the effectiveness of the mHealth apps with regards to patients' clinical outcomes has been undertaken with several AR(32-34) or asthma(18, 27, 35, 36) apps, the use of these apps has been highly integrated with health care delivery. If patients are seeking an approach that involves the minimal interaction with a HCP (10,11) as is the case for AR(37) then it is crucial that these mHealth apps are evaluated in terms of self-management principles, as self-management seems to be what patients want with regards to AR. The principles were based on Carpenter *et al.*, 2016 (30) which targets the main features of managing AR appropriately. Alternative therapies were excluded in this study as the focus is on the evidence-based therapies recommended in treatment guidelines.

This study aimed to identify a mHealth app that is effective for the self-management of AR and/or asthma; one which is closely aligned with the self-management principle of AR and asthma management. The mHealth apps available on the Apple App Store and Android Google Play Store in Australia were evaluated based on three domains using a two-stage process. In Stage 1, the mHealth apps were ranked along Domain 1; the accessibility of the apps in the app store(s). In Stage 2, the apps with the maximum score from Stage 1 were then ranked along Domain 2; the alignment of the app with the theoretical principles of self-management of AR and/or asthma(30) and Domain 3; the usability of the mHealth app assessed using the Mobile App Rating Scale (MARS) instrument(21).

Methods

Study Design

The overall study design is summarised in Figure 1. The study was initiated with a search strategy conducted in the Australia Apple App Store (Apple Inc.) and the Android Google Play Store (Google Inc.) which are the leading operating systems globally(38), whereby mHealth apps were retrieved after screening using the inclusion and exclusion criteria (Table 1). These apps were then reviewed and evaluated for their effectiveness in the self-management of AR and/or asthma.

Search strategy

The search for AR and/or asthma apps was conducted in the Australia Apple App Store (Apple Inc.) and the Android Google Play Store (Google Inc.). The search was conducted between October 26, 2017, and November 8, 2017, using four search terms; allergic rhinitis, asthma, hayfever and hay fever.

The screening process for mHealth apps

The titles of all mHealth apps resulting from the four search terms were screened, by one of the authors (RT), for eligibility based on the product description as listed for each mHealth app. The

mHealth apps were included for review if they fulfilled all the inclusion criteria and did not violate the exclusion criteria (Table 1).

Review of mHealth apps

Once a mHealth app was included in the study, a full-detailed review was performed. The mHealth app review included a descriptive analysis of the name of the app, name of the app developer, app store(s) in which the app was available, the search term(s) that retrieved the app, the year in which the app was updated and the self-management features present in each app. The mHealth Apps that were available in both app stores and were identified as a duplicate, i.e. similar names or developer names, were only reviewed once. This information was analysed descriptively using IBM SPSS version 24.0 (IBM Corporation, Armonk, N1Y) and summarised with frequencies and proportions.

Quality evaluation of mHealth apps

The quality of mHealth apps was evaluated based on the following three domains using a two-stage process. Summary of the features of each domain and assessment criteria utilised are provided in Supplementary Material S1. It gives a rational description of each feature within the three domains in detail. It explains why each feature is important for the evaluation of each app. Each app was given a score for each domain.

Stage 1: mHealth Apps were ranked along Domain 1.

Domain 1; the accessibility of the mHealth app in the app store(s). Two points were allocated for being currently updated in 2016/2017 and another two points allocated for the availability of the mHealth app in both the Apple App Store and the Android Google Play Store (25). The total score ranged from 0-4 points.

Stage 2: mHealth Apps with Stage 1 maximum score ranked along Domain 2 and Domain 3.

Domain 2; the alignment of the app with the theoretical principles of self-management for AR and/or asthma. The mHealth apps were evaluated based on six self-management principles that align with the principles of self-management of AR and/or asthma based on the literature and a panel consensus (RT, SBA and BC). The principles evaluated were symptom(s) control self-assessment, symptom(s) monitoring, medication reminder, medical history chart, doctor's appointment reminder and HCPs communication (30). The symptom(s) control self-assessment evaluates the disease control and record the outcome on a measuring instrument to let the users understand their level of disease control. The symptom(s) monitoring allows patients to keep track of their symptoms and their severity. The medication reminders remind users to take their medications regularly. The medication history chart keeps a record of all symptoms, severity of symptoms, daily peak flow measurements - to demonstrate their disease control to their doctors. A doctor's appointment reminder helps users follow up on their treatment outcome with their doctors. HCPs communication's feature allows patients and doctors to communicate using the same platform.

Each mHealth app was given one point for each self-management principle covered. The total score ranged from 0-6 points. Additionally, the proportion of self-management principles that were covered by the apps were determined using descriptive statistics and analysed descriptively to compare the differences in the self-management principles covered in each app.

Domain 3; The usability of the mHealth app assessed using the Mobile App Rating Scale (MARS) instrument (21). The MARS instrument is a 23-item scale, a validated tool which provides a deeper evaluation of the effectiveness of the app by testing the app live for a minimum of 10 minutes and evaluating the app in five sections; *user engagement, functionality, aesthetics, information and app subjective quality* (39). The total MARS mean score indicates the overall quality of the app and the mean score for the individual subscale indicates the strength and weaknesses of the app in specific aspects (21). The usability of the app was assessed by a panel of four assessors; SBA, BC, EA and RT ; researcher pharmacists and a researcher who have had experience with managing AR and/or

asthma. The assessments were carried out independently without the influence of other assessors. The final score given to the mHealth apps was a mean score from all four assessors. To ensure the validity of assessments, these four researchers were trained using the online MARS implementation tutorial (<http://www.c4tbh.org/seminar/title-tba-5/>). Each item in each section in the MARS instrument was scored using a 5-point scale (1-Inadequate, 2-Poor, 3-Acceptable, 4-Good, 5-Excellent) and based on a formula, each section was given a mean score ranging from 0 to 1, where a score of 0 meant inadequate quality and a maximum score of 1 equated to excellent quality as per Stoyanov et al., 2015. The formula is: Mean Score = Total Score of the section/Number of items of the section applicable (21). For example, the mean score for *user engagement* is the total score divided by 5, as there are 5 items in the *user engagement* section and the mean score for *aesthetics* would be the total score divided by 3, as there are 3 items in the *aesthetics* section (21). This ensured that there was no undue bias in the scoring based on the number of questions in each section.

Overall ranking of mHealth apps across the three domains

The overall ranking of the mHealth apps was based on the mean rank score across the three domains. The app with the highest mean rank score would be the most effective app for the self-management of AR and/or asthma.

Results

A flowchart of mHealth apps included and excluded in this study is shown in Figure 2. A total of 418 mHealth apps were found in the Australian Apple App Store and Android Google Play store, using the four search terms; 18.4% (31/418) were eligible for full-detailed review and Stage 1 quality evaluation. Of these apps, 19.4% (6/31) targeted both AR and asthma, 67.7% (21/31) targeted asthma and 12.9% (4/31) targeted AR only. The majority of apps excluded were not in the English language (21.7%, 91/418) (Figure 2).

Stage 1: mHealth apps ranked along Domain 1.

Domain 1; The accessibility of the mHealth apps in the app store(s)

Of the 31 apps included, 51.6% (16/31) were available in both app stores with 93.5% (29/31) updated in 2016/2017. Sixteen apps scored 4 points, updated in 2016/2017 and available in both app stores (Table 2), which were eligible for Stage 2 quality evaluation.

Stage 2: mHealth apps with Stage 1 maximum score ranked along Domain 2 and Domain 3.

Domain 2; The alignment of the mHealth apps with the theoretical principle of the self-management of AR and/or asthma: the number of self-management principles covered

The self-management principles covered in each of the 16 mHealth apps are tabulated in Table 3. The total score ranged from 1 to 5 points as none of the apps covered all 6 self-management principles. The highest ranking mHealth apps with 5 out of 6 self-management principles are *MASK-air*, *Asthma Tracker*, *My Asthma Manager* and *My AAP Asthma Tracker for Adolescents* (all lacking a doctor's appointment reminder) and *Asthma Test* and *e-symptoms* (both lacking a medication use reminder; Table 3).

The proportion of self-management principles covered across the 16 mHealth apps are summarised in Figure 3. The most common principle covered was symptom(s) monitoring (100%, 16/16), followed by medical history chart (87.5%, 14/16) and medication(s) reminder (50%, 8/16) (Table 3). The most common self-management principle not covered within these apps was doctor's appointment reminder (6.25%, 1/16) (Figure 3).

The type of symptom(s) control self-assessment differed the most amongst these 16 mHealth apps; some used validated questionnaires such as Visual Analog Scale (VAS) (*MASK-air* and *AllergyMonitor*) and Work Productivity and Activity Impairment Allergic Specific (WPAI-AS) (*MASK-air*), Asthma Control Test (*Asthma Tracker*). VAS is a global psychometric measuring instrument that can rapidly and statistically measures the severity of disease-related symptom(s) in patients(44). It is validated to assess the effectiveness of treatment outcomes for AR in real life(44). The WPAI measures the negative impact of symptoms on the patient's quality of life, especially in patients with

moderate-severe AR(45). Some used non-validated questionnaires; 27-item question test (*e-symptoms*), 5 questions test (*AAP Asthma Tracker for Adolescents*) and Rhinitis Total Symptom Scores (RTSS) (*Allergy Monitor*). The second biggest contrast in the self-management principle was the type of HCP communications provided by the app. Differences noted were related to method of communicating with physicians via email or phone (*AAP Asthma Tracker for Adolescents*), sharing a medical report in pdf with physicians (*Asthma Test*, *e-symptoms*, *SaniQ Asthma*, *Asthma MD*, *Asthma Action Hero*) and sharing data with physicians on a website to monitor patient's symptoms and quality of life as patients enter data daily (*MASK-air*, *Asthma Tracker* and *Kiss My Asthma*).

Domain 3; The usability of the mHealth app assessed using the Mobile App Rating Scale (MARS) instrument

Table 4 summarises the rank and score of the usability of the 16 mHealth apps that were current and available in both app stores, assessed with the MARS instrument. On the basis of the MARS assessment, *MASK-air* ranked the highest, achieving the highest mean score of 0.91 out of 1 point (Table 4); this app was very engaging (0.76/1), scored almost full points for its functionality - intuitive to use and easy to navigate, scored the highest in both visual appeal (0.91/1) and the quality of information (0.97/1).

Overall ranking of mHealth apps

The mean rank score across three domains for each of the 16 mHealth apps are tabulated in Table 5. Overall, *MASK-air* ranked first across all three domains (Table 5). It covered 5 out of 6 self-management principles, i.e. symptom(s) control self-assessment, symptom(s) monitoring, medication reminder, medical history chart and HCPs communication, except doctor's appointment reminder (Table 3). It was also highly rated in the usability of apps using the MARS instrument (Table 4).

Discussion

This is the first study to determine the quality of mHealth apps designed for AR and/or asthma, available in the Australian Apple App Store and Google Play Store. A total of 31 mHealth apps were evaluated across three domains, with half of these apps available in both app stores and developed for asthma alone. The majority of the apps were updated in 2016 and 2017. Overall, the *MASK-air* was the most highly ranked mHealth app; accessible in both app stores, covering all but one essential self-management principle (except doctor's appointment reminder), and was highly ranked by MARS to be very engaging, highly intuitive to use, highly visually appealing and to providing high-quality information. HCPs should recommend this app to assist the self-management of their patients with AR and/or asthma conditions.

The generalisability of this study is limited by the fact that mHealth apps found only within the Australian app store were available for inclusion. This study would have missed mHealth apps that are not available or accessible to Australia but available in other countries, excluded in this study (Supplement S1). It should also be noted that in conducting the mHealth app evaluations, a hybrid philosophy in which the fundamental principles underpinning the app and user feedback were combined to determine rankings. It can be argued that there may be some value in separating these two areas of assessment. However, from this study, the outcomes of rankings would not have changed.

The framework to determine the most effective app for AR and/or asthma was developed based on three domains; the accessibility of the app, the alignment of the app with the theoretical principle of the self-management of AR and/or asthma and the usability of the app using MARS instrument. Only 16 mHealth apps were further analysed in the second and third domains as it was very important that an effective self-management app should be updated recently and widely available for patients in leading app stores. The theoretical principle of the mHealth apps was based

on Carpenter *et al.*, 2016 (30). Many of the apps included a range of principles, however, none of the apps covered all 6 self-management principles. The most common principle covered was symptom(s) monitoring and the most commonly omitted feature was the doctor's appointment reminder.

In terms of the usability of the mHealth app, it has been proposed that an app should be interactive, easy to use, visually appealing, provide good quality information for each user (21), for patients to embrace it within their daily routine(40-42). While MARS is a validated instrument, this research shows that the completion of the MARS questionnaire is subject to user bias and patient preference. However, the use of MARS is very subjective to patients' preferences. This influences the design and development of an app, which is dependent on population characteristics, study domain and outcome of interviews and the focus groups(23, 27, 36). Future app development should take into consideration the patients' preference, being sufficiently flexible for patients to personalise to their needs(23).

While the *MASK-air* was evaluated to be the highest mean ranked app across the three domains assessed, it differed from other apps in that it enabled patient to self-assess the severity of symptoms experienced and not only their presence on any particular day" This app is a daily monitoring tool which allows recording of the overall management; self-assessments of symptom(s) using VAS and quality of life using WPAI-AS and also the recording of medication use(43). These features allow patients to be aware of the ongoing severity of their condition and not only the impact of their symptoms on their quality of life which is the hidden burden of AR(16, 37). In contrast with the other assessments covered in *e-symptoms*, *AAP Asthma Tracker for Adolescents* and *Allergy Monitor*, the simplicity and validity of VAS and WPAI-AS allows consistency and accurate measurement of severity of the overall condition (43) which is often underperceived by the individual patient. Although not a criteria for an evaluation in this study, it should be noted that the *MASK-air* also covered AR and asthma. This is an extremely important aspect to consider, given the high prevalence of AR in patients who have asthma and the fact that poorly controlled AR is a risk

factor for poorly controlled asthma(46). Further to this, it should be noted that the *MASK-air* is also the only mHealth app evaluated that is a global research tool for the de-identified capture of data relating to patterns of patient monitoring, medication use and AR and asthma control(43). This contributes to its ability to impact on future AR and asthma initiatives.

Adherence to AR treatment has been a problem(47, 48), therefore it was really important for the app that helps patients self-manage to have a feature that reminds patients to take their medications. Six apps that addressed the medication reminder self-management principle within the 16 mHealth apps that were current and available in both app stores. The medication reminder covered in *MASK-air* allows patients to record their medication and to set reminders for the administration of medications(43). Similarly, the apps *AsthmaTracker*, *SaniQ Asthma*, *AsthmaMD* and, *Asthma Action Hero* covered these functions. This differs from *KissMyAsthma* which only allows logging the time of medication intake. Poor adherence to medications is one of the most obvious indicators of suboptimal self-management of AR(48). Some patients self-medicate as needed, ceasing their treatment when they think their symptoms are “controlled”(47, 48), while others forget to take their medication unintentionally(49). The medication reminder in these apps can assist in adherence to medication intake, which has particular implications for patients with AR and asthma. Intranasal and inhaled corticosteroids should be used on a continual basis rather than on a needs basis to effectively treat AR and underlying asthma(50).

The HCPs communication self-management principle was addressed in 11 out of the 16 mHealth apps that were current and available in both app stores. The monitoring of patients’ ongoing conditions is covered in the apps *MASK-air*, *Asthma Tracker* and *Kiss My Asthma* apps and sharing of medical reports in pdf with their HCPs are covered in the *Asthma Test*, *e-symptoms*, *SaniQ Asthma*, *Asthma MD*, *Asthma Action Hero* apps. This is important especially for patients who find it difficult to communicate their conditions with HCPs, as the control of conditions is often interpreted differently between patients and HCPs(26). This is particularly important for patients with AR who self-medicate as they “need”, i.e. when they think their symptoms worsen and would stop their

treatment when they think they are “controlled”(47, 48). These terms “need” and “control” are often interpreted differently between patients and HCPs(13, 26). With the overall management recorded in the app, this information will bridge the communication gap between HCPs and patients, interpreting the control of one’s condition using the same platform; disease control and treatment outcome(13, 26). The e-connectivity which promotes communication between the patient and doctor about the patient’s medical condition has been promoted as a useful tool for improving patients’ self-management (51) and tailored intervention for individual patients(52). The MASK-air app provides a platform for HCPs and patients to communicate, keeping a record of daily symptoms and their severity using the validated VAS instrument allows patients to communicate their condition on a real-time basis with HCPs. This also allows HCPs to see the cause of suboptimal treatment outcome if any.

In considering the role of the HCPs and the optimal management of AR and/or asthma, the key is to evaluate patients’ conditions frequently as it varies over time due to several circumstances; the different level of allergen exposure, travelling in different regions or even change in the immune system due to ageing. All these circumstances may worsen the control of AR and asthma. Therefore, HCPs regularly monitoring patient’s chronic condition would allow the following opportunities to occur: 1) doctor’s identification of the cause of the ineffectiveness of medication and 2) doctor’s recommendation of appropriate medications for the patients’ with suboptimally controlled symptoms. The common lack of doctor’s appointment reminders in the apps evaluated in this study has implications for these opportunities to be missed.

Conclusion

In the current technology world, the use of mHealth apps has become more and more popular and a promising tool when it comes to the self-management of AR and/or asthma as seen in this study. Unfortunately, little evaluation of these tools has been conducted thus far. In the Australian context, it was found that only approximately half of the available mHealth apps are current, with

the MASK-air ranking most highly across the assessment domains for self-management. Currently, many of the other mHealth apps fall short of the self-management principles. And finally, most apps within this field only deal with either AR or asthma and it can be argued that this is a significant failing of these apps. Given the intimate relationship between AR and asthma, it should be considered whether all AR apps should also have the provision for people who have coexisting asthma, and vice versa.

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DECLARATION OF INTEREST

Rachel Tan reports no conflicts of interest.

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Table 1: Inclusion and exclusion criteria for the mHealth apps that manages AR and/or asthma.

Inclusion Criteria	Exclusion Criteria
For Self-management of AR and/or asthma;	Focused on alternative therapy, i.e. alternative medications and breathing exercise;
English language;	Not specifically for the self-management of AR and/or asthma;
Free of charge for full version of the app;	Focused on medical knowledge or assessments;
Accessible to users of the app	Game apps developed for AR and/or asthma patients;

	Location-based apps - provided information outside of Australia, i.e pollen count or the location of HCP outside of Australia;
	Not accessible, i.e. require access code from a HCP prior to using the app.

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Table 2: The rank and score of Domain 1; the accessibility of the apps in the app store(s) (n=31).

Rank	Name of the app	Accessibility of the app		^a Score
		Available in both app stores	Updated in 2016 or 2017	
1	MASK-air	2	2	4
1	AllergyMonitor	2	2	4
1	Asthma Tracker	2	2	4
1	Kiss My Asthma	2	2	4
1	Brisbane Pollen Count	2	2	4
1	Canberra Pollen Count	2	2	4
1	Melbourne Pollen Count	2	2	4
1	Sydney Pollen Count	2	2	4
1	SaniQ Asthma	2	2	4
1	AsthmaMD	2	2	4
1	ELFy Asthma - Reminders & Info	2	2	4
1	AirRater	2	2	4
1	e-symptoms	2	2	4
1	Asthma Action Hero	2	2	4
1	Allergy Pollen Count	2	2	4
1	Activ8rlives Wellness and Food Diary	2	2	4
17	Breathcount /asthma app	0	2	2
17	My Asthma Manager	0	2	2
17	Asthma Test (Geo)	0	2	2
17	ASTHMA	0	2	2
17	Condition Diary	0	2	2
17	Pulmonent	0	2	2
17	Sensio Air	0	2	2
17	AAP Asthma Tracker for Adolescents	0	2	2
17	Asthma Australia - Asthma App	0	2	2
17	My Asthma Score	0	2	2
17	Asthma Flare Up Tracker	0	2	2
17	Allergy Symptoms and Food Diary Pictures	0	2	2
17	DailyBreath	0	2	2
30	Asthma Tracker and Log	0	0	0
30	Asthma Test	0	0	0

^aScore, 2 points for being available in both app store and 2 points for being updated in 2016 or 2017.

Table 3: The rank and score of the self-management principles covered by the apps that were current and available in both app stores (n=16).

Rank	Name of the app	^a Self-management principles						^b Score
		Symptom(s) Control Self- Assessment	Symptom(s) Monitoring	Medication Reminders	Medical History Chart	Doctor's Appointment Reminder	HCP Communication	
1	MASK-air	1	1	1	1	0	1	5
1	Asthma Tracker	1	1	1	1	0	1	5
1	e-symptoms	1	1	0	1	1	1	5
4	Asthma Action Hero	0	1	1	1	0	1	4
4	AsthmaMD	0	1	1	1	0	1	4
4	Kiss My Asthma	0	1	1	1	0	1	4
4	SaniQ Asthma	0	1	1	1	0	1	4
8	Activ8rlives Wellness and Food Diary	0	1	1	1	0	0	3
8	AllergyMonitor	1	1	0	1	0	0	3
8	Brisbane Pollen Count	1	1	0	1	0	0	3
8	Canberra Pollen Count	1	1	0	1	0	0	3
8	Melbourne Pollen Count	1	1	0	1	0	0	3
8	Sydney Pollen Count	1	1	0	1	0	0	3
14	AirRater	0	1	0	1	0	0	2
14	ELFy Asthma - Reminders & Info	0	1	1	0	0	0	2
16	Allergy Pollen Count	0	1	0	0	0	0	1
Proportion of self- management principles covered in the apps		50%	100%	50%	88%	6%	44%	

^a See supplementary material for the description of the 6 self-management principles.

^b Score, a composite of 1 point from each self-management principles covered.

Table 4: The rank and score of the usability of the apps that were current and available in both app stores (n=16), assessed with the Mobile App Rating Scale (MARS) instrument.

Rank	Name of the app	Engagement	Functionality	Aesthetics	Information	Subjective quality	^a MARS total mean score
1	MASK-air	0.76	0.97	0.91	0.97	0.44	0.82
2	Asthma Tracker	0.80	0.95	0.87	0.83	0.46	0.79
3	e-symptoms	0.68	0.80	0.60	0.71	0.50	0.77
4	Kiss My Asthma	0.88	0.75	0.82	0.84	0.80	0.76
4	SaniQ Asthma	0.84	1.00	0.67	0.66	0.45	0.76
6	AsthmaMD	0.9	0.90	0.80	0.49	0.30	0.75
7	Asthma Action Hero	0.76	0.80	0.80	0.57	0.70	0.74
8	AllergyMonitor	0.76	0.95	1.00	0.91	0.60	0.71
8	Brisbane Pollen Count	0.64	0.90	0.93	0.80	0.45	0.71
8	Canberra Pollen Count	0.64	0.90	0.93	0.80	0.65	0.71
8	Melbourne Pollen Count	0.64	0.90	0.93	0.80	0.65	0.71
8	Sydney Pollen Count	0.64	0.90	0.93	0.80	0.65	0.71
13	Activ8rlives Wellness and Food Diary	0.67	0.68	0.75	0.49	0.60	0.66
14	ELFy Asthma - Reminders & Info	0.90	0.80	0.70	0.66	0.65	0.65
15	AirRater	0.68	0.70	0.67	0.83	0.65	0.64
16	Allergy Pollen Count	0.64	0.65	0.60	0.69	0.65	0.61

^a MARS Total mean score ranges from 0 to 1 (0 = inadequate quality, 1 = excellent quality) (25).

Table 5: Overall ranking of the apps across the three domains (n=16).

Rank	Name of the app	Accessibility of the app	Self-management principle	^a MARS total mean score	Mean Rank
1	MASK-air	1	1	1	1.0
2	Asthma Tracker	1	1	2	1.3
3	e-symptoms	1	1	3	1.7
4	Kiss My Asthma	1	4	4	3.0
5	SaniQ Asthma	1	4	6	3.7
5	AsthmaMD	1	4	6	3.7
6	Asthma Action Hero	1	4	7	4.0
7	AllergyMonitor	1	8	8	5.7
7	Brisbane Pollen Count	1	8	8	5.7
7	Canberra Pollen Count	1	8	8	5.7
7	Melbourne Pollen Count	1	8	8	5.7
7	Sydney Pollen Count	1	8	8	5.7
8	Activ8rlives Wellness and Food Diary	1	8	13	7.3
9	ELFy Asthma - Reminders & Info	1	14	14	9.7
10	AirRater	1	14	15	10.0
11	Allergy Pollen Count	1	16	16	11.0

^a MARS Total mean score ranges from 0 to 1 (0 = inadequate quality, 1 = excellent quality) (25).

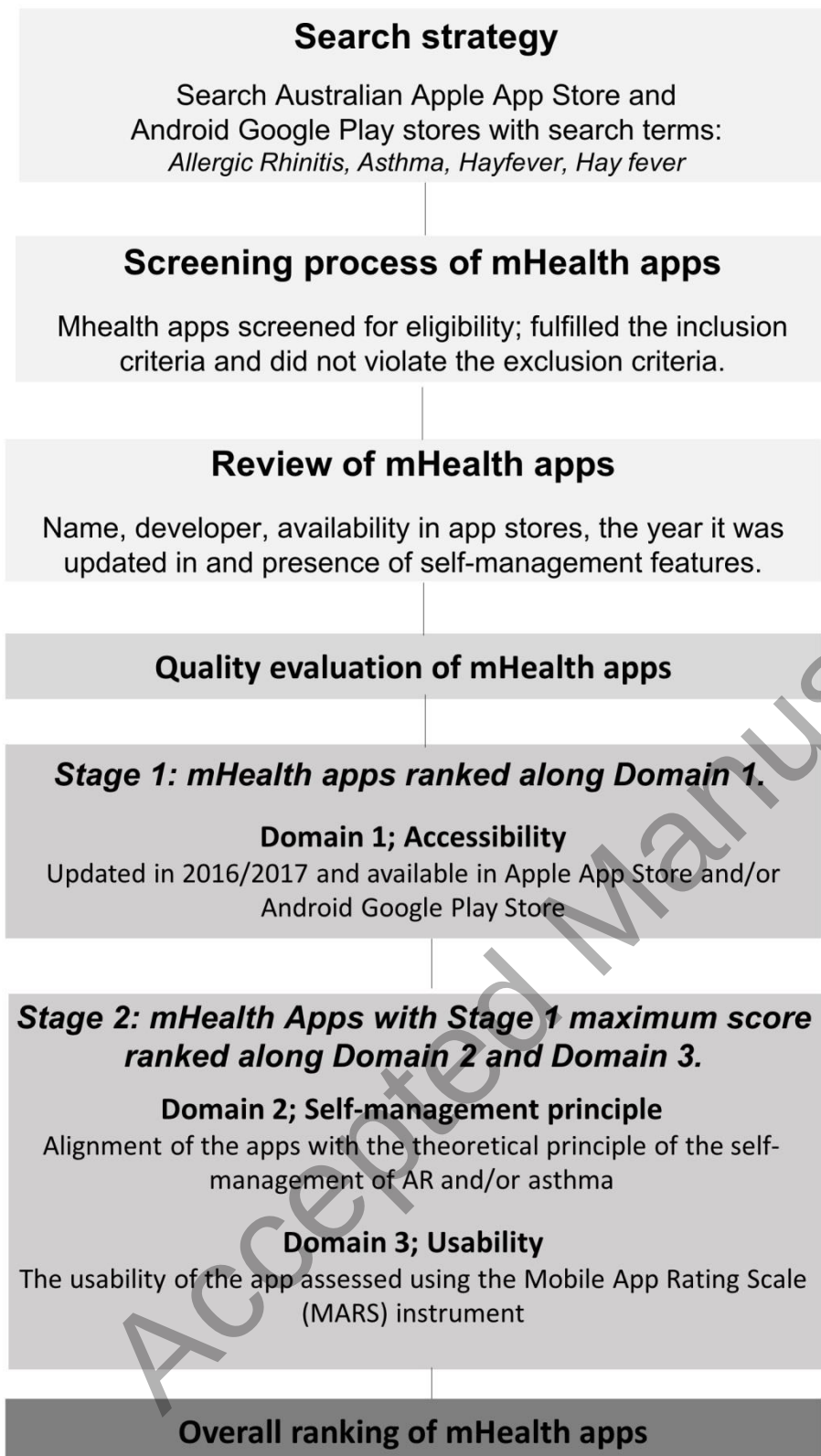


Figure 1: Overall study design.

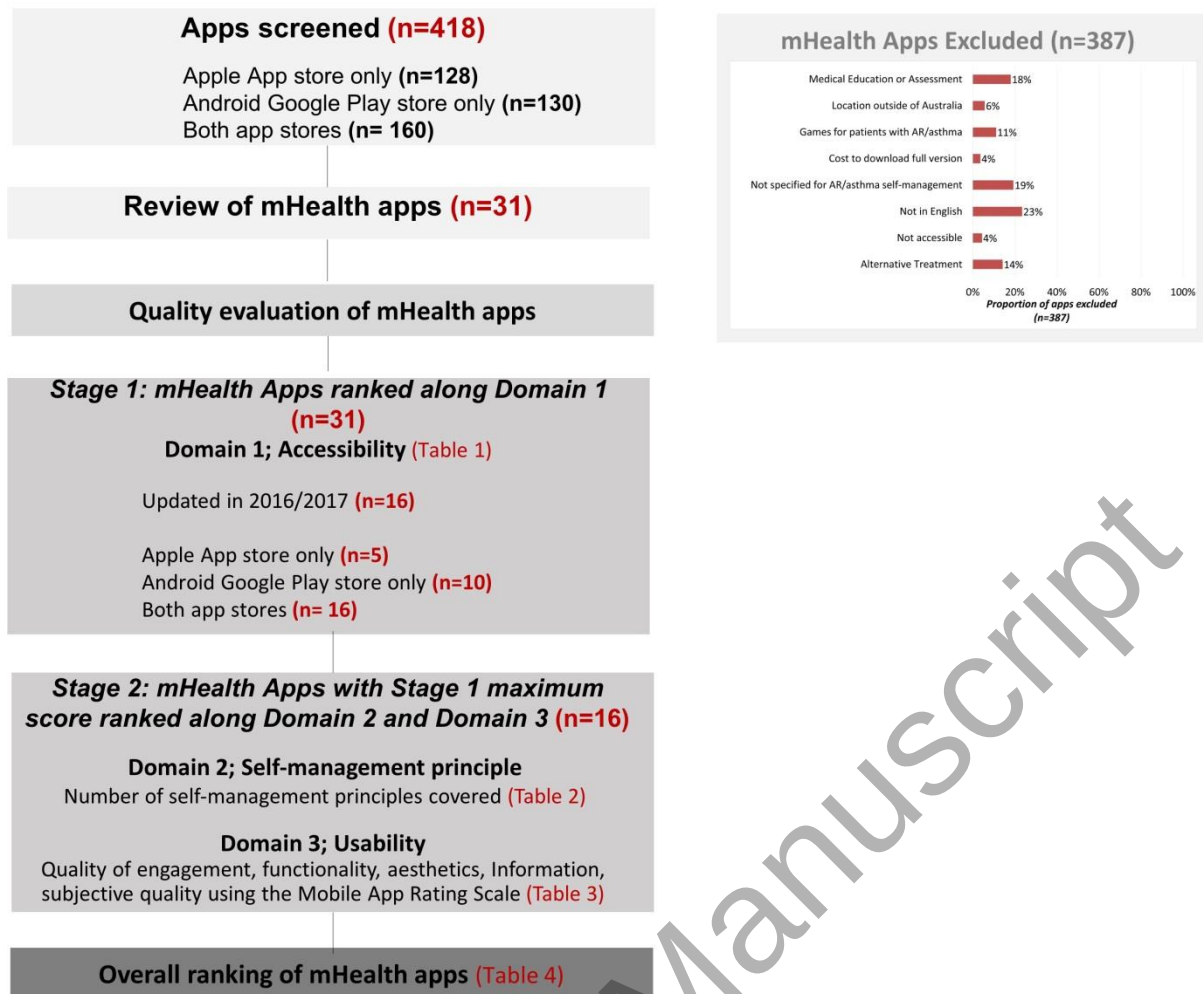


Figure 2: Flowchart of apps included and excluded in the study.