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Digital tools in allergy and respiratory care

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ABSTRACT

Patient care in the allergy and respiratory fields is advancing rapidly, offering the possibility of the inclusion of a variety of digital tools that aim to improve outcomes of care. Impaired access to several health care facilities during the COVID-19 pandemic has considerably increased the appetite and need for the inclusion of e-health tools amongst end-users. Consequently, a multitude of different e-health tools have been launched worldwide with various registration and access options, and with a wide range of offered benefits. From the perspective of both patients and healthcare providers (HCPs), as well as from a legal and device-related perspective, several features are important for the acceptance, effectiveness, and long-term use of e-health tools. Patients and physicians have different needs and expectations of how digital tools might be of help in the care pathway. There is a need for standardization by defining quality assurance criteria. Therefore, the Upper Airway Diseases Committee of the World Allergy Organization (WAO) has taken the initiative to define and propose criteria for quality, appeal, and applicability of e-health tools in the allergy and respiratory care fields from a patient, clinician, and academic perspective with the ultimate aim to improve patient health and outcomes of care.

Keywords: E-health, Allergy, Rhinitis, Asthma, Chronic rhinosinusitis, Digital tools, Mobile application, App, Quality criteria, Standardization

INTRODUCTION

Allergies and chronic respiratory conditions like asthma and rhinosinusitis have reached epidemic

proportions, underscoring the need for prevention, adequate diagnosis, and timely treatment. Asthma affects between 1 and 18% of the world's population, varying widely from one country to another.¹ The prevalence of allergic rhinitis (AR) is 10–40%.² Chronic rhinosinusitis (CRS) affects 5.5–28% of the general population.³ A significant percentage of patients, suffering from these respiratory diseases, remains uncontrolled despite available therapy and international guidelines of care. The high incidence of uncontrolled disease forces the health community to improve existing care pathways and consider embracing novel strategies for better patient care, including e-health tools.

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Applications (Apps) for smartphones and tablets have become part of daily practice in different domains of healthcare and can bring value for healthcare improvement.⁴ Mobile health tools have become popular in the area of chronic conditions like diabetes mellitus,^{5,6} cardiovascular disease,^{7,8,9} and neurologic disorders.^{10,11} They have a variety of benefits such as access to information on the disease, help in its assessment, support to define adequate treatment, and follow-up with monitoring of symptoms. All this while minimizing the barriers of time and distance, resulting in cost-effectiveness and lifetime health gain for patients and society, and enhancing personalized follow-up.^{12,13,14,15,16} For healthcare providers (HCPs) and the healthcare system, e-health tools can help to evaluate and monitor the evolution of symptoms and medication use, and anticipate areas for improvement.^{12,17,18,19}

E-health tools designed for respiratory care are defined in this paper as medical mobile applications providing patient education, information, and feedback with the target to improve the overall burden of disease for patients suffering from allergies or chronic respiratory conditions. They should be available on a global platform for app distribution. In this document e-health tools are interchangeably phrased as mobile health applications or digital tools.²⁰

In allergy and respiratory care many e-health tools are available, although with limited acceptance in healthcare systems and restricted implementation in daily practice. In everyday life, the assistance of e-health tools is still called upon too little.^{21,22,23-25} In the fields of allergy and chronic respiratory diseases, e-health tools can, however, play a supporting role in optimizing outcomes of care. Patients can be offered educational materials on their disease and guidance on effective treatment options. Furthermore they can receive personalized feedback on the degree of disease control achieved as well as the benefits and potential adverse effects of treatment over time. HCPs might also benefit from e-health tools but they must be convinced that these tools provide additional personalized information on disease severity, clinical outcomes and evolution over time, treatment schemes followed (including side-effects), therapy adherence, symptom control, and latest

updates on international guidelines of care. Patients and HCPs will likely have different needs, priorities, and motivations to use and rely upon digital apps with the ultimate goal of improving the health status of patients.²⁴

The current landscape with e-health tools for allergies and chronic respiratory diseases such as asthma and chronic rhinosinusitis (CRS) is dispersed, without a uniform appreciation of the potential benefit or estimated effect on outcomes. During the COVID-19 pandemic, these shortcomings surfaced even more prominently.²⁶ Therefore, there is an unmet need to create transparency and objectivity on the benefits and quality criteria of currently available e-health applications in this medical domain.²⁷ At present, no international consensus on quality standards or criteria for e-health tools in the areas of asthma, allergic rhinitis, and chronic rhinosinusitis exists, despite availability of a multitude of e-health tools. The Upper Airway Diseases Committee of the World Allergy Organization (WAO), constituted of global experts working in allergy and respiratory care, joined forces to structure and propose quality criteria for e-health tools, in order to assist the stakeholders in their choice for the most appropriate digital e-guidance tool for a specific patient, thereby improving patient health and outcomes of care.

Current challenges of e-health in allergy and respiratory care

The market of e-health tools for managing respiratory allergies and chronic respiratory diseases is growing. Artificial intelligence (AI) and machine learning are rapidly evolving fields in various sectors, including healthcare. AI, implemented in digital tools, could transform physician workflow and patient care through its applications, from assisting physicians and replacing administrative tasks to augmenting medical knowledge.²⁸ At present no algorithms are validated for allergy and respiratory disease management. Should they become available in the future, we expect a further increase in the multitude of digital tools available today.

This proliferation is associated with the challenge for both HCPs and patients of selecting the right tool. Currently, most end-users of available e-health tools in medicine fail to use such devices for

the long term, given the lack of perceived benefit for both end-user groups.^{29,30} However, gathering data on critical input and output variables in allergies and respiratory diseases, including CRS and asthma, is likely to lead to improved and more holistic solutions that may reduce their societal burden.²⁰ The large amount of data provided by e-health tools, has the capacity to either overload the HCP with information or provide the assistance needed to optimize care by providing relevant and/or personalized information. High quality e-health tools should help both patients and physicians fill the gaps in clinical practice, by enhancing education, disease awareness, and/or personalized care.³¹

In daily practice, there is a certain degree of resistance to the integration of e-health tools amongst a portion of physicians and patients. Some physicians fear that mobile health applications would challenge their professional judgment, or worse, provide counter-productive input into the health process. Providing physicians with a scoring system for e-health tools, would both assist them in selecting the most appropriate tool for a specific patient and help to deter their reluctance to utilize mobile health tools in clinical practice. Of note, the WAO Upper Airway Diseases Committee agrees that the use of e-health tools is not about replacing doctors, or other HCPs, but about empowering both the patients and HCP with practical, reliable, and personalized information. Opposition and reluctance are also seen among patients, some of whom feel more confident in the use of mobile health tools than others. Socioeconomic status, age, and medical literacy are factors determining the eagerness of patients to accept and utilize e-health tools. Additionally, resistance to the use of mobile health tools for some patients may relate to their concerns regarding privacy of medical information.

MATERIALS AND METHODS

The WAO Upper Airway Diseases Committee is a group of international experts with extensive clinical experience and relevant publications in the field of allergy and clinical immunology. During an online semester meeting in December 2020, a discourse was set up regarding digital tools in allergy and chronic respiratory care. To find relevant literature we performed systematic searches. We searched the following databases: MEDLINE (via

PubMed), Cochrane Central Register of Controlled Trials (CENTRAL), and Trip database. Search terms were adapted appropriately to suit each database structure. The results of our search were collected until March 2021, with a filter for English language. In literature scoring systems for the quality of e-health tools covering all health applications were available, but limited rating scales in the field of chronic respiratory diseases were developed. The quality criteria considered in existing studies were listed. A meeting with the committee was held on April 2021, where the proposed quality criteria were evaluated by the expert panel. After extensive debate some criteria were rejected and others added. All committee members subsequently reviewed and suggested changes to the quality criteria, leading to the current consensus. An updated list of quality criteria was developed and renewed after a following round of written feedback by the members of the committee.

Presently, there is a scoring system for the quality of e-health tools covering all health applications, ie, Mobile Application Rating Scale (MARS).³² It covers 4 objective quality domains: engagement, functionality, aesthetics, information quality, and 1 subjective quality rating, each of these divided in subitems to conclude to an 23-item scoring system. Besides this, an end user version of the MARS (uMARS), containing 20 quality items, has been developed. Where the MARS rating scale requires training and expertise in mHealth in a particular relevant health field, the uMARS rating scale is a simplified version that can be reliably used by end-users without expertise.³³ The committee members feel that the existing (u)MARS scoring system is insufficient to determine the overall quality of an e-health tool targeting respiratory diseases and that refinements are needed. Some quality items used in the (u)MARS Rating Scale could be adopted, a few are irrelevant, and others need further elaboration; furthermore, there are important criteria that are missing.

In 2019 a mobile application rating scale in the field of chronic respiratory diseases was developed, "the patient empowerment index through mobile technology",²⁰ where they focus on quality criteria important through patient empowerment, ie, self-monitoring, personalized feedback, and patient education. While this index focuses on patient empowerment, it omits other important

quality criteria we consider important in quality assessment of mHealth tools in allergy and respiratory care. In literature, we could not find other additional rating scales to evaluate digital tools in the field of allergy and respiratory care.

The co-authoring WAO Upper Airway Diseases Committee members here propose a new quality scoring framework, independent from the existing scoring tools, but incorporating certain strengths of those tools.

SIXTEEN QUALITY ASSURANCE CRITERIA FOR E-HEALTH IN ALLERGY AND RESPIRATORY CARE

We suggest that the e-health tools quality evaluation in allergy and respiratory care can be based

on 16 criteria arbitrarily grouped into 4 domains. The more criteria an e-health tool fulfills, the more appealing the e-health tool will be. Fig. 1 illustrates and summarizes the framework. Thereafter, we will describe those 16 proposed criteria grouped by domain.

Domain 1: Patient-related quality criteria

Criterion 1

Education on the disease, comorbidities, treatments, and correct use of medication by providing correct and relevant information. This information should match or be aligned with currently available, unbiased information from academic centers or qualified organizations and/or international guidelines and can be offered in different formats,



Fig. 1 Sixteen quality assurance criteria for e-Health in allergy and respiratory care. Domain 1: Patient perspective (left-above) – Domain 2: Healthcare provider perspective (right-above) – Domain 3: Legal perspective (left-beneath) – Domain 4: Device perspective (right-beneath).

such as written information, demonstration videos, photographs.

Patient involvement plays an important role in achieving better disease control.

In the conceptual model of Bravo et al, 3 key elements of mobile technology that result in better patient empowerment were assessed,³⁴ namely, patient education, self-monitoring, and personalized feedback. Each of these elements can be found in 1 of the quality criteria we propose. We feel it is important in the domain of patient education to go a level deeper and propose both static and dynamic criteria.

Mobile health technologies create more involved patients by supplying quick access to practical, easily understandable information on the disease, comorbidities, and available management options.^{34,35,36} We consider this to be static information. Dynamic information is elaborated in criterion 2.

Criterion 2

Information on disease trigger factors, such as allergen exposure and/or air pollution, coming from officially recognized organizations at national or regional levels. Allergen exposure and air pollution, examples of dynamic information, are important for patients to better schedule their outdoor activities and plan their medication intake.³⁷ The ability of e-health tools to adapt to specific weather or climate conditions, eg, extreme temperatures, fog, desert storms, and thunderstorms, is of added value. This information should be interactive and adapted to the patient's individual circumstances, eg, residence, working environment, and outdoor activities.

Criterion 3

Self-monitoring and personalized **follow-up** including registration of symptoms and medication use, optionally supplemented by automated reminders on medication intake, might further improve the level of patient empowerment and encourage them to have better adherence and understanding of the therapeutic plan.^{38,39,14} Symptoms and/or medication use should be actively registered on a daily, weekly, or monthly basis by the patient.

Criterion 4

Feedback - by AI - on disease evolution and level of disease control. Feedback implies better insight into disease evolution and control level, which is of key importance in achieving the best outcomes of care. Feedback on disease evolution and/or control can be measured via validated tools, with or without the inclusion of biomarkers.

As AI is further evolving, at present and in future applications will additionally provide patients with personalized feedback, improving targeted medical care. There are e-health tools that use the information received from smart sensors or monitoring devices, eg, smartwatches monitoring blood pressure, heart rate, and oxygen saturation; the Oura smart ring scoring sleep, activity, and readiness; scales indicating weight; and spirometers evaluating lung function. The algorithms integrated in the application software of e-health tools have the capacity to integrate real-life data captured from devices. Of note, feedback that is given can be expanded by the use of biomarkers.⁴⁰ An example to illustrate the use of biomarkers for monitoring can be found in "The MyAirCoach project" developed for asthma patients. In this system, several parameters can be monitored, including lung function, the fraction of exhaled nitric oxide, exhaled breath temperature, respiratory rate, physical activity, and heart rate.⁴¹ We believe that the use of biomarkers will further expand in the future as additional technology and research become available.

Domain 2: Healthcare provider quality criteria

In this domain we address health care providers who can interact, treat, and subsequently support patients with allergy and respiratory diseases using mobile applications. These include ear-nose-throat (ENT) specialists, pharmacists, and nurses, among others.

Criterion 5

Information on the **impact and progression of disease.** E-health tools contribute to better medical care by providing HCPs data on disease control and acute exacerbations occurring repeatedly over a longer period of time. The latter can be linked to possible root causes, eg, respiratory viral

events, non-adherence to medications, and allergen exposure. An additional benefit is triaging patients who need further investigation or adjustment of therapy.⁴²

Criterion 6

Information on **treatment outcomes** could allow patients to be clustered based on lifestyle factors, person-related factors, and comorbidities. Each cluster may have a different response to a specific treatment. This can lead to more individualized therapy.

Criterion 7

Evaluation of **comorbidities** in e-health tools is of added value to the HCP, as this will likely modify the management of the patient in question.

Criterion 8

Providing HCP with **validated tools to follow up** on symptoms and patients' quality of life, thereby generating the ability to closely monitor the evolution and severity of disease. The inclusion of validated tools for patient reported outcome measures in the software of the application, such as Asthma control test, COPD assessment test, and visual analog scale (VAS-scale), will provide the HCP with more detailed information and facilitate continuous monitoring between in-person visits.

Criterion 9

Providing **research opportunities** by the registry and/or patient recruitment for trials. The multitude of details generated from these e-health tools will be of great value for additional research as it provides HCPs with clear and extensive data, covering patients and disease parameters that can be reported and included into more extensive databases. It can also ease the recruitment of patients for clinical trials.

Criterion 10

Providing HCPs with **updated education** on guidelines and/or evolving research on genetics, pathophysiology, diagnosis, and treatment for independent continuous self-motivated learning. By offering quick and easy access to evidence-based guidelines endorsed by professionally recognized organization, all HCPs, specialists, and non-specialists can benefit from these platforms.

Domain 3: Legal perspective

Criterion 11

Compliance with **General Data Protection Regulation** (GDPR). Since e-health tools collect personal data (from patients, HCPs and/or other "data subjects"), they will need to comply with the GDPR or its equivalent in other jurisdictions. Moreover, the set-up and functioning of such apps should be fully compliant with the local (privacy) laws of the country in which they are used, thereby ensuring the privacy of both patients and HCPs. As this is a delicate topic, the app developers may consult "the Code of conduct on privacy protection for mHealth apps".⁴³ It covers the European law on security and privacy for e-health tools. Note that the European data protection regime is overall much stricter than the regimes in other continents or countries such as the United States.

Criterion 12

Compliance with (local) **regulations and registration**. One should look into the applicable local registration and certification guidelines and rules. Since the rise of software as a medical device, several countries have enacted a myriad of soft- and hard-law instruments, which seek to regulate e-health apps and tools.⁴⁴ Competent government bodies, such as the Department of Health in the United Kingdom, the Food and Drug Administration (FDA) in the United States or the Therapeutic Goods Administration (TGA) in Australia, have developed codes of conduct, minimum standards, or other types of guidelines. In certain jurisdictions, not-for-profit organizations, such as the Institute for Health Records (EuroRec) in Europe, have taken up the role as center of expertise and certification body.

Domain 4: Device perspective

Criterion 13

User-friendliness, focusing on simplicity and feasible time management for both patients and HCPs, will lead to the use of e-health tools for a longer period of time and more widespread use. Simplicity is crucial, allowing almost all patients to use the application. The more complicated the tool, the fewer patients will be reached, and hence healthcare discrimination and limited and potentially inaccurate data will result. People in modern

societies are busy and will only keep using the tools if the considered time of its use is proportional to the benefits. Therefore, limiting the use of the e-health tools for actively collecting data on medication intake and symptom control to once a week seems a good compromise. Simplicity also represents the universal applicability of the e-health tools, ie, all mobile devices should be able to run the applications. Availability in local/national language is an example of user-friendliness, as tools in foreign languages are not appealing to end-users.

Criterion 14

Development in collaboration with patients, healthcare providers and scientists results in applications used for more days with end-user satisfaction; therefore, patients' involvement in developing and validating e-health tools is considered a key to maximizing patient empowerment.²⁰ In parallel, the knowledge of HCPs and scientists is of comparable importance in e-health tool development to guarantee that the most appropriate and useful information is collected. According to Huckvale et al, half of the evaluated asthma apps provide data not supported by evidence or guidelines.⁴⁵

Criterion 15

Integration into existing patient records, digital files, and/or e-health platforms used in clinics. User-friendliness for the healthcare provider also indicates the importance of integration,²⁰ and will make using the e-health tools less time-consuming and available data for research and trials more valuable. Additionally, data registry could benefit the report of side effects. Data should be able to join the health record and if needed vice versa. Proper coordination, agreement, and collaboration with all stakeholders are needed to achieve this goal.

Criterion 16

Regular (minimal annual) **updates after audit** of quality, utility, and design features will keep e-health tools compliant with evolving medical knowledge and clinical guidelines. Digital tools require at least an annual evaluation of quality and utility and need to have ongoing design

adjustments. After an audit, changes need to be carried out. When software demonstrates clinical benefit, it needs to become part of practice; on the other hand, features that provide limited value or are shown to have deficiencies should be reworked or removed. These updates should be made in accordance with feedback from patients and healthcare providers.

THE EXPECTED OUTCOME FOLLOWING THE INTRODUCTION OF THIS QUALITY FRAMEWORK

The quality framework as proposed by the WAO Upper Airway Diseases Committee will allow healthcare providers and patients to select the best available e-health tool for their own medical and local situation. In the following paragraph we describe expected outcomes of a rigorous selection of high-quality mobile health tools. We have elaborated the benefits along 3 domains of favorable outcome, ie, for patients, for healthcare providers, and for the healthcare system/society, as illustrated and summarized in Fig. 2. All these expected outcomes are only possible if the e-health tools are used for an extended period of time, making long-term use an important goal of this quality framework.

Going forward, more elaborate studies are needed to critically assess the overall outcomes of care when implementing these criteria. The feedback on outcomes from those detailed studies will be important to further develop and fine-tune the proposed quality framework. As an example, we expect that different criteria might carry a different weight in the overall assessment of an e-health tool.

Outcome for patients

The use of high-quality e-health tools has the final aim to result in better disease control and hence quality of life as proven in other non-communicable conditions such as diabetes and cardiovascular disease.^{5,6,9,46} In the fields of allergy and respiratory care, meeting the 16 quality criteria could help in achieving better outcomes of care, by providing a deeper understanding of the disease and its triggering factors, creating awareness of comorbidities,

PATIENT	HEALTHCARE PROVIDER	HEALTHCARE SYSTEM/SOCIETY
Better disease control	Staying up to date on current guidelines and evidence	Reduction of use of ineffective treatments/side effects (by better adherence to therapy and adequate reporting of side effects)
Better quality of life	Facilitation of research and registries	A happier population
Deeper understanding of the disease and its triggering factors and comorbidities	Deeper understanding of the disease development in relation to treatment and environment	Better informed patients may help others
Personalized follow-up and feedback	Close follow-up providing better feedback and personalized care	Individual variations become recognized
Cost saving	Time efficient outpatient visits	Cost saving
Secondary and tertiary prevention		Increased work productivity

Fig. 2 Expected outcomes following the introduction of this quality framework. Outcome for patients (left) - Outcome for healthcare providers (middle) -Outcome for healthcare system/society (right)).

offering a better explanation of treatment (hence achieving better adherence), and by building a more personalized approach of follow-up with a more holistic approach to feedback. In addition to a better quality of life, including both physical/psychological well-being and patient productivity, such as less absence from work, better quality of sleep, and fewer severe exacerbations, the introduction of a quality scoring of e-health tools will, in our opinion, result in lower healthcare expenses for both patient and society as a whole.

Secondary and tertiary prevention might become a reality by providing timely access to the right treatment and targeted medical care. If the implementation of e-health tools can achieve these ambitious goals, a huge step forward into precision medicine would be made.^{47,48}

Optionally, e-health applications could also be used to inform patients about non-pharmacological treatment options as add-on to their medical therapy, eg, lifestyle, diet and daily exercise.

Outcome for healthcare providers

Healthcare providers might be able to more fully understand the disease development in relation to treatment and environment, and subsequently provide better personalized care.⁴⁸ The gathering of and access to a multitude of relevant data will create an opportunity to better monitor, over a longer period of time, the course of disease, comorbidities, adherence, and side effects of therapy, and enable early identification of patients needing intervention. User-friendliness and simplicity, together with connectivity to existing healthcare platforms, will also render e-health tools timesaving and time-effective during outpatient visits. Separate from direct patient care, these quality criteria can result in facilitation of research and registries, due to the opportunity of establishing more expanded databases. Big data registry could also benefit from the reporting of disease complications and medication side effects. We feel these advantages could render the HCP more satisfaction at work.

Outcome for the healthcare system and the society

Finally, we expect high-quality and widely used e-health tools will be cost-saving and cost-effective for the national healthcare systems due to timely access to the most appropriate treatment to prevent unnecessary delays, lack of reversibility and long-term usage of ineffective treatments, better use of present resources.⁴⁹ Side-effects of therapy will be reduced due to adequate reporting; furthermore, individual variations of disease and therapy response will become more recognized. Moreover, e-health tools will contribute to patient satisfaction, better informed patients that help others with similar health issues, a better interaction between the patient and the healthcare system, and hence a reduction of the medical burden on society.

DISCUSSION AND CONCLUSION

The WAO Upper Airway Diseases Committee proposes a framework of 16 quality assurance criteria that could be considered valuable in the evaluation of the quality of e-health applications in the domain of allergy and respiratory care. In addition, the expected outcomes of using e-health tools by patients and/or physicians are listed.

Beyond the 16 quality criteria, there are other considerations to be taken into account in the choice and recommendation of e-health tools amongst patients. These include cost for the patient and/or healthcare provider, device storage space, and adaptability of the application to geographical need. The price of a mobile application will be an important factor when patients select a specific e-health tool. Does the healthcare system or the patient pay for the technology? We did not include the criterion "cost" in our assessment, as it does not reflect the quality offered. In the future, mobile health apps will become integrated into the health care system with insurance companies most likely willing to support implementation and usage. Consequently, this committee's quality criteria of e-health tools might in the future give guidance to reimbursement authorities. Secondly, the efficient use of storage might allow the e-health tool to run on more and cheaper devices and hence drive faster acceptance and broaden the use of the application. Thirdly,

adaptability to geographical need is another key point of discussion. Distance to medical care, socioeconomic status, and cost for medical care are important factors that might influence e-health tool utilization in different regions. However, this is beyond the scope of this paper. The proposed framework of quality criteria is applicable globally and can be further refined as needed according to geographical specificities. In addition to providing benefit to existing patients, e-health tools might help the respiratory care community and society, at large, by reaching previously undiagnosed or underdiagnosed patients and facilitating early diagnosis and timely access to care.^{50,51}

One limitation of developing these quality criteria is bias in diagnosis. Self-diagnosis of a respiratory disease using a mobile health application may be problematic and lead to unintended negative consequences. Therefore, involvement of a physician to correctly diagnose and manage the disease is needed.

Apart from implementing a quality criteria assessment of e-health tools as we have proposed, it is obvious that the underlying applications must be supported by a business model that is financially viable and involves ongoing research development and improvement to guarantee a high-quality product that serves patients/end-users for the long term. Financial simulations and payment models will need to be further elaborated to convince policy makers and payers to reimburse these e-health tools.²⁰ Our framework provides the first step in convincing policy makers and payers to imbed high-quality mobile health tools into the healthcare system.

As a next step, it will be important to assign different weights to the 16 criteria, based upon the specific diagnosis, eg, asthma, allergic rhinitis, and CRS. Thereafter, we need to score existing e-health tools that are being used to monitor these respiratory diseases, based on our 16 criteria. We expect that the existing e-health tools will have significant deficiencies. In this stage we feel it is too early to test a tool against the criteria. The initial scoring should provide feedback that will assist the developers of these applications to make improvements within the criteria to which they are most deficient. The above outlined next steps will entail serious research effort as there are a

multitude of available e-health tools. For practical reasons, we would propose to start with a limited selection of e-health tools for this test scoring phase, starting with those with the highest numbers of users. Unfortunately, the statistics on the number of end-users for a specific tool are not available today. We anticipate that with the rapid progress made in the domain of mobile health tools, statistics such as number of end-users will become available and provide a good basis for selection, test scoring, and adaptations. Following the assessment of existing tools by these 16 criteria, surveys for both patients and healthcare providers should investigate the real-life effect of the implementation of these criteria.

For now, the WAO Upper Airway Diseases Committee intended to move the field forward by defining academic criteria of quality for digital health tools in the allergy and respiratory field, which might support the implementation of e-health meeting these quality standards.

Abbreviations

HCP, healthcare providers; AR, allergic rhinitis; CRS, Chronic rhinosinusitis; Apps, Applications; MARS, Mobile Application Rating Scale; GDPR, General Data Protection Regulation; TGA, Therapeutic Goods Administration

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Availability of materials

Not applicable.

Author's contributions

E.V. and P.H. (co-chair of the WAO Upper Airway Diseases Committee) designed the entire manuscript based on the feedback and several rounds of committee members' virtual meetings and feedback in 2020 and 2021. The WAO Upper Airway Diseases committee virtually met at several occasions to develop the 16 quality criteria. Further writing of the report was performed by E.V. and P.H. Finally, all WAO Upper Airway Diseases Committee members critically reviewed and approved the final version of the manuscript.

Ethics approval

Not applicable.

Authors' consent for publication

All authors and members of the WAO Upper Airway Diseases Committee consent to publication of the work in the WAO Journal.

Declaration of competing interest

E.V. has no conflict of interest in relation to this study and the results described in the manuscript. P.H. is part of the executive board of EUFOREA that owns the mySinusitisCoach mobile health application. All the others have no conflict of interest to report in relation to this report.

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REFERENCES

- Committee GS. 2021 GINA Report. 2021.
- Wise SK, Lin SY, Toskala E, et al. International consensus statement on allergy and rhinology: allergic rhinitis. *Int Forum Allergy Rhinol.* 2018;8(2):108-352.
- Fokkens WJ, Lund VJ, Hopkins C, et al. European position paper on rhinosinusitis and nasal polyps 2020. *Rhinology.* 2020;58(suppl S29):1-464.
- Gopal G, Suter-Crazzolaro C, Toldo L, Eberhardt W. Digital transformation in healthcare - architectures of present and future information technologies. *Clin Chem Lab Med.* 2019;57(3):328-335.
- De Groot J, Wu D, Flynn D, Robertson D, Grant G, Sun J. Efficacy of telemedicine on glycaemic control in patients with type 2 diabetes: a meta-analysis. *World J Diabetes.* 2021;12(2):170-197.
- Jeffrey B, Bagala M, Creighton A, et al. Mobile phone applications and their use in the self-management of Type 2 Diabetes Mellitus: a qualitative study among app users and non-app users. *Diabetol Metab Syndrom.* 2019;11:84.
- Lane DA, McMahon N, Gibson J, et al. Mobile health applications for managing atrial fibrillation for healthcare professionals and patients: a systematic review. *Europace.* October 2020;22(10):1567-1578.
- Buss VH, Leesong S, Barr M, Varnfield M, Harris M. Primary prevention of cardiovascular disease and type 2 diabetes mellitus using mobile health technology: systematic review of the literature. *J Med Internet Res.* 2020;22(10):e21159.
- Franklin NC, Lavie CJ, Arena RA. Personal health technology: a new era in cardiovascular disease prevention. *Postgrad Med.* 2015;127(2):150-158.
- Matthews PM, Block VJ, Leocani L. E-health and multiple sclerosis. *Curr Opin Neurol.* 2020;33(3):271-276.
- Ginis P, Nieuwboer A, Dorfman M, et al. Feasibility and effects of home-based smartphone-delivered automated feedback training for gait in people with Parkinson's disease: a pilot randomized controlled trial. *Park Relat Disord.* 2016;22:28-34.
- Whitehead L, Seaton P. The effectiveness of self-management mobile phone and tablet apps in long-term condition management: a systematic review. *J Med Internet Res.* 2016;18(5):e97.
- Finkelstein J, Knight A, Marinopoulos S, et al. Enabling patient-centered care through health information technology. *Evid Rep Technol Assess.* 2012;(206):1-1531.
- Hamine S, Gerth-Guyette E, Faulx D, Green BB, Ginsburg AS. Impact of mHealth chronic disease management on treatment adherence and patient outcomes: a systematic review. *J Med Internet Res.* 2015;17(2):e52.
- de Jongh T, Gurol-Urganci I, Vodopivec-Jamsek V, Car J, Atun R. Mobile phone messaging for facilitating self-management of long-term illnesses. *Cochrane Database Syst Rev.* 2012;12(12):Cd007459.
- Slater H, Campbell JM, Stinson JN, Burley MM, Briggs AM. End user and implementer experiences of mHealth technologies for noncommunicable chronic disease management in young adults: systematic review. *J Med Internet Res.* 2017;19(12):e406.
- Dayer L, Heldenbrand S, Anderson P, Gubbins PO, Martin BC. Smartphone medication adherence apps: potential benefits to patients and providers. *J Am Pharmaceut Assoc.* 2003;53(2):172-181.
- Lee JA, Choi M, Lee SA, Jiang N. Effective behavioral intervention strategies using mobile health applications for chronic disease management: a systematic review. *BMC Med Inf Decis Making.* 2018;18(1):12.
- Bashshur RL, Shannon GW, Smith BR, et al. The empirical foundations of telemedicine interventions for chronic disease management. *Telemed J e Health.* 2014;20(9):769-800.
- Sleuys K, Seys SF, Bousquet J, et al. Mobile health tools for the management of chronic respiratory diseases. *Allergy.* 2019;74(7):1292-1306.
- Bédard A, Basagaña X, Anto JM, et al. Mobile technology offers novel insights into the control and treatment of allergic rhinitis: the MASK study. *J Allergy Clin Immunol.* 2019;144(1):135-143. e6.
- Cingi C, Yorgancioglu A, Cingi CC, et al. The "physician on call patient engagement trial" (POPET): measuring the impact of a mobile patient engagement application on health outcomes and quality of life in allergic rhinitis and asthma patients. *Int Forum Allergy Rhinol.* 2015;5(6):487-497.
- Farzandipour M, Nabovati E, Sharif R, Arani MH, Anvari S. Patient self-management of asthma using mobile health applications: a systematic review of the functionalities and effects. *Appl Clin Inf.* 2017;8(4):1068-1081.
- Simpson AJ, Honkoop PJ, Kennington E, et al. Perspectives of patients and healthcare professionals on mHealth for asthma self-management. *Eur Respir J.* 2017;49(5).
- Bousquet J, Ansotegui IJ, Anto JM, et al. Mobile technology in allergic rhinitis: evolution in management or revolution in health and care? *J Allergy Clin Immunol Pract.* 2019;7(8):2511-2523.
- Pattini S, Malizia V, Travaglini A, et al. Telemedicine for allergic patients during COVID-19. *Pediatr Allergy Immunol.* 2020;31(Suppl 26):102-104.
- Tinschert P, Jakob R, Barata F, Kramer JN, Kowatsch T. The potential of mobile apps for improving asthma self-management: a review of publicly available and well-adopted asthma apps. *JMIR Mhealth Uhealth.* 2017;5(8):e113.

28. Aung YYM, Wong DCS, Ting DSW. The promise of artificial intelligence: a review of the opportunities and challenges of artificial intelligence in healthcare. *Br Med Bull.* 2021;139(1):4-15.
29. Camacho-Rivera M, Vo H, Huang X, Lau J, Lawal A, Kawaguchi A. Evaluating asthma mobile apps to improve asthma self-management: user ratings and sentiment analysis of publicly available apps. *JMIR Mhealth Uhealth.* 2020;8(10):e15076.
30. Lombardi C, Bonini M, Passalacqua G. The role of mobile apps in allergic respiratory diseases: an Italian multicentre survey report. *Eur Ann Allergy Clin Immunol.* 2018;50(6):268-272.
31. Van Bulck P, Cools L, Soumya MS, et al. A multicenter real-life study on the multiple reasons for uncontrolled allergic rhinitis. *Allergy Rhinol.* 2021;11(10):1452-1460.
32. Stoyanov SR, Hides L, Kavanagh DJ, Zelenko O, Tjondronegoro D, Mani M. Mobile app rating scale: a new tool for assessing the quality of health mobile apps. *JMIR Mhealth Uhealth.* 2015;3(1):e27.
33. Stoyanov SR, Hides L, Kavanagh DJ, Wilson H. Development and validation of the user version of the mobile application rating scale (uMARS). *JMIR Mhealth Uhealth.* 2016;4(2):e72.
34. Bravo P, Edwards A, Barr PJ, Scholl I, Elwyn G, McAllister M. Conceptualising patient empowerment: a mixed methods study. *BMC Health Serv Res.* 2015;15:252.
35. Hellings PW, Borrelli D, Pietikainen S, et al. European summit on the prevention and self-management of chronic respiratory diseases: report of the European union parliament summit (29 March 2017). *Clin Transl Allergy.* 2017;7:49.
36. Bousquet J, Addis A, Adcock I, et al. Integrated care pathways for airway diseases (AIRWAYS-ICPs). *Eur Respir J.* 2014;44(2):304-323.
37. Sofiev M, Palamarchuk Y, Bédard A, et al. A demonstration project of global alliance against chronic respiratory diseases: prediction of interactions between air pollution and allergen exposure-the mobile airways sentinel Network-impact of air POLLution on asthma and rhinitis approach. *Chin Med J (Engl).* 2020;133(13):1561-1567.
38. Pizzulli A, Perna S, Florack J, et al. The impact of telemonitoring on adherence to nasal corticosteroid treatment in children with seasonal allergic rhinoconjunctivitis. *Clin Exp Allergy.* 2014;44(10):1246-1254.
39. Tran N, Coffman JM, Sumino K, Cabana MD. Patient reminder systems and asthma medication adherence: a systematic review. *J Asthma.* 2014;51(5):536-543.
40. Breiteneder H, Peng YQ, Agache I, et al. Biomarkers for diagnosis and prediction of therapy responses in allergic diseases and asthma. *Allergy.* 2020;75(12):3039-3068.
41. Honkoop PJ, Simpson A, Bonini M, et al. MyAirCoach: the use of home-monitoring and mHealth systems to predict deterioration in asthma control and the occurrence of asthma exacerbations; study protocol of an observational study. *BMJ Open.* 2017;7(1):e013935.
42. Bousquet J, Caimmi DP, Bedbrook A, et al. Pilot study of mobile phone technology in allergic rhinitis in European countries: the MASK-rhinitis study. *Allergy.* 2017;72(6):857-865.
43. <https://ec.europa.eu/digital-single-market/en/news/code-conduct-privacy-mhealth-apps-has-been-finalised> CoCopmahbflAf.
44. Rowland SP, Fitzgerald JE, Holme T, Powell J, McGregor A. What is the clinical value of mHealth for patients? *NPJ Digit Med.* 2020;3:4.
45. Huckvale K, Morrison C, Ouyang J, Ghaghda A, Car J. The evolution of mobile apps for asthma: an updated systematic assessment of content and tools. *BMC Med.* 2015;13:58.
46. Schwamm LH. Telehealth: seven strategies to successfully implement disruptive technology and transform health care. *Health Aff (Millwood).* 2014;33(2):200-206.
47. Prokopakis E, Vardouniotis A, Bachert C, et al. Rhinology future debates 2018, a EUFOREA report. *Rhinology.* 2020;58(4):384-393.
48. Hellings PW, Fokkens WJ, Bachert C, et al. Positioning the principles of precision medicine in care pathways for allergic rhinitis and chronic rhinosinusitis - a EUFOREA-ARIA-EPOS-AIRWAYS ICP statement. *Allergy.* 2017;72(9):1297-1305.
49. Commission E. GREEN PAPER on mobile Health (mHealth). [Internet] Available from: <https://europeaeu/digital-single-market/en/news/green-paper-mobile-health-mhealth> [Internet].
50. Stephani V, Opoku D, Quentin W. A systematic review of randomized controlled trials of mHealth interventions against non-communicable diseases in developing countries. *BMC Publ Health.* 2016;16:572.
51. Beratarrechea A, Lee AG, Willner JM, Jahangir E, Ciapponi A, Rubinstein A. The impact of mobile health interventions on chronic disease outcomes in developing countries: a systematic review. *Telemed J e Health.* 2014;20(1):75-82.