Psoriasis: Targets and Therapy

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REVIEW

Telemedicine and e-Health in the Management of Psoriasis: Improving Patient Outcomes – A Narrative Review

Alison Havelin, Philip Hampton

Department of Dermatology, Newcastle Hospitals NHS Trust, Newcastle, UK

Correspondence: Philip Hampton, Email Philip.hampton@nhs.net

Abstract: The role of technology in dermatology is expanding. Telemedicine and eHealth are increasingly being used by doctors and patients in the management of psoriasis. This is a narrative review of the literature relating to the use of digital technology in the management of psoriasis. We divided psoriasis e-health into three areas: mobile phone applications, teledermatology and artificial Intelligence (AI). Literature searches were conducted using the following databases: Pubmed, Google Scholar, Scopus, both app stores using App Annie platform. The following words were used in searches; psoriasis, dermatology, mobile phone application, application, app, smartphone, teledermatology, telemedicine, artificial intelligence, AI, machine learning in various combinations. We defined three key questions, one relating to each of the 3 areas. We then reviewed the relevant papers found in the searches and selected the papers of highest research quality and greatest relevance in order to answer the questions. In addition, for apps, operating systems for IOS and android devices were searched for apps containing the key word "psoriasis" in the title using the app analytic website www.appannie.com on 08/11/21. Research publications linked to these apps were reviewed.

Keywords: psoriasis, dermatology, smartphone, mobile phone application, app, application, teledermatology, telemedicine, artificial intelligence, AI, machine learning

Introduction

Telemedicine, e-health and digital dermatology describes the assessment and management of patients, often remotely, using apps and software platforms to gather information, collect and transfer patient information, calculate disease severity and to inform treatment choices. Whilst much of the focus of tele-dermatology has been on lesion diagnosis, including artificial intelligence-based diagnosis, steady progress has also been made in the application of digital technology to inflammatory skin diseases such as psoriasis.

Digital technologies used to improve the diagnosis and treatment of psoriasis can be divided into 3 main areas; mobile phone applications (Apps), teledermatology and artificial intelligence (AI).

Mobile Phone Applications (Apps)

Health information is increasingly accessible via smartphone applications. In the UK, the share of adults who own a smartphone has increased dramatically. In 2008, smart phone ownership amongst adults in the UK was less than 25%.[1] In 2020, 84% of adults in the UK owned a smartphone.[2] The 2017 US Mobile App report showed that 18–24-year-olds spend two thirds of their digital media time on smartphone apps alone.[3] One review of dermatology related mobile apps identified more than 229 dermatology apps and patients served as the target audience in more than half of them.[4] In one cross sectional study by Wolf et al, of the 557 dermatology patients surveyed who owned a smartphone, 31.8% used at least 1 health related app.[5] The use of smartphones to obtain health related information was associated with younger age (<50 years) and a higher education.[5]

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Teledermatology (TD)

Teledermatology generally refers to apps and software platforms for skin image monitoring and image sharing. Many generic skin monitoring apps exist which can be used by patients to track response to therapy or to share skin image information with a specialist, some are for patient taken images and others for primary care or other specialists to forward images to Dermatology. These products are generally not specific for individual diseases. Store and forward or Live interactive are the two most commonly used modalities of teledermatology. The store and forward method allows a relatively large number of cases to be reviewed in a short period of time. Live interactive consultations allow simultaneous communications between patients and doctors.

Artificial Intelligence (AI)

Artificial intelligence (AI) describes the intelligence shown by a machine. AI software is increasingly deployed to diagnoses skin conditions with rapid progress being made in skin lesion diagnosis. AI is being increasingly used in the field of dermatology. Understanding the role of technology, in shaping the future of healthcare for both providers and recipients is crucial.

Machine learning describes the application of computer algorithms that improve through experience. The outcomes are the result of a learning process rather than being pre-programmed. The main way this has been deployed in image recognition is reinforced learning whereby exposure to labelled images teaches the machine to make a diagnostic decision and then uses past decisions and their outcomes to inform future decisions. Various groups have already developed effective algorithms for lesion diagnosis. In the future Dermatologists could use information from machine learning to help in other areas in addition to lesion diagnosis. For example, to decide whether a patient should continue or switch treatment regimens based on their response after 3 months.[6] In one international online survey of 1271 dermatologists, 85% were aware of AI as an emerging technology in dermatology but only 23% had a good knowledge about it.[31] The greatest potential, reported by the responders, was for dermatoscopic images. 17% of hospital-based dermatologists were fearful of the use of AI in dermatology but the majority agreed it would improve dermatology overall.[31]

To review these areas in more depth we posed 3 main questions in relation to each of these areas focusing on the use of technology in the management of psoriasis.

Methodology and Literature Review

Searches of publicly available research databases including Pubmed, Google Scholar and Scopus were performed using the following combination of terms; psoriasis, dermatology, mobile phone application, smartphone, mobile app, application, teledermatology, telemedicine, artificial intelligence, AI, machine learning. The terms must have been present in the title or abstract. Only articles with abstracts available, published between 2011–2021 and written in English were considered due to the language limitations of the reviewers. The number of articles identified within each database are listed in Supplementary Table 1. In addition, for apps we searched the App Annie website (www.appannie.com) on 10/11/21 for apps containing the word "psoriasis" in IOS and Android operating systems using the search term "psoriasis". (Supplementary Table 2). Studies published on the validity or usability of the apps identified were reviewed.

Two reviewers evaluated the abstracts of all articles and included only those which could best answer our questions, rejecting articles which were irrelevant to the review or of insufficient methodological quality. Articles are only discussed once in this review as there may be cross-over between articles found in searches for "mobile applications" and "teledermatology". If an article is discussed under one section it will not be discussed again under another section.

A narrative review was conducted from the findings of the literature search. The findings were presented by posing 3 key questions and discussing the papers that are most relevant in answering the questions.

Results and Discussion

Mobile Phone Applications

What evidence is there that mobile phone applications provide benefit or have the potential to provide benefit for the diagnosis, management or treatment of psoriasis or for patient education? And what psoriasis apps have been validated for use in clinical practice?

The number of apps containing the word "psoriasis" in their title for IOS and android devices were 23 and 32 respectively. The full list can be found in Supplemental Data Table 2. Very few of the mobile phone apps had any formal research or evaluation linked to them. The relevant research publications linked to mobile phone apps are discussed.

In 2017, Flaten at al performed an analysis into the growth of dermatology related mobile apps.[7] The operating systems Apple, Android and Windows were used to search for relevant apps. Search terms included the word "psoriasis" along with other dermatological conditions. A total of 526 dermatology apps were identified. Most apps fell into the categories of teledermatology, self-surveillance, diagnosis, disease guide and general dermatology reference. The findings were compared with those reported in 2014. There was an increase of 235 apps, indicating an 81% growth in dermatology apps since 2014 and a 231% growth for teledermatology apps. There were 90 self-surveillance and diagnosis apps identified, which was double the figure in 2014. Educational apps grew by 32%. This growth in dermatology related apps was in keeping with the rate of general app growth (83%) on the Apple store.[7] Although this figure would be undoubtedly higher in 2021, the trend shown between 2014 and 2017 is indicative of the changing landscape of dermatology and the shift to mobile technology for both patients and providers.

Banu and Toacse developed a mobile medical application to help physicians diagnose psoriasis using clinical features only.[8] The study identified and compared 6 classification algorithms used to differentiate erythemato-squamous diseases. Erythemato-squamous diseases include psoriasis, seborrheic dermatitis, lichen planus, pityriasis rosea, chronic dermatitis and pityriasis rubra pilaris. The Dermatology dataset of erythemato-squamous diseases was taken from University of California, Irvine (UCI) machine repository. Histopathological features are used in these algorithms. With the help of these 6 algorithms, this study developed a mobile/desktop application which can classify these diseases into 2 groups – psoriasis or non-psoriasis – using clinical features only, with an accuracy of greater than 93%.[8] This mobile application could be used to help physicians differentiate psoriasis from clinically similar conditions.

Svendsen et al conducted a systematic review of eHealth interventions, designed to improve adherence to topical psoriasis treatments.[9] The eHealth technologies explored in this review included telehealth, electronic Health Records, e-learning tools, mobile health, social media, health sector and private companies use of big data. Randomised controlled trials (RCT) only were included. The review found just one RCT by Alinia et al.[10] In this prospective investigator blinded randomised controlled trial, participants were divided in a 1:1 ratio to standard of care or internet-based reporting group. The objective was to assess whether adherence to anti-psoriatic therapy (topical fluocinonide) was improved with the use of an internet-based reporting intervention. 40 participants were included in the study over a 12-month period. Adherence was monitored using Medication Event Monitoring System (MEMS) caps. Greater adherence was seen in the intervention group, compared with the standard of care group (50% vs 35%). This RCT found that internet reporting intervention may improve adherence rates and treatment outcomes for patients with psoriasis.[10] Although this RCT used the internet as a means of reporting outcomes, smart phone applications are considered one of the most affordable and easily accessible of the eHealth technologies available. Svendsen et al, published the first full market analysis of apps containing the word psoriasis.[9] The operating stores BlackBerry, Google Play, iOS, Symbian, and Microsoft Store were searched. In total, 184 apps contained the word psoriasis in the title or description. None of the 184 apps identified had been tested in an RCT to see if they could improve adherence to psoriasis treatments.[9]

Svendsen et al (2018) conducted a randomised controlled trial to evaluate the potential for smart phone apps to improve patient's adherence to psoriasis treatments.[11] Patients received once daily medication (calcipotriol/betamethasone dipropionate foam) and were randomised to no app (n=66) or app intervention (n=68) groups. 122 patients (91%) completed the 22 week follow up. The primary outcome was adherence (med applied >80% of the days during treatment period). The secondary outcome included psoriasis severity (LS-PGA) and quality of life DLQI. More patients in the intervention group were adherent to treatment than those in the non-intervention group at week 4 (65% vs 38%).

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A similar effect was seen at weeks 8 and 26 but not statistically significant. This RCT demonstrated that the study specific app improved short term adherence to foam treatment for psoriasis.[11]

Domogalla et al conducted a randomized controlled intervention study assessing the impact of an educational program combined with a monitoring smart phone application on the mental health of patients with psoriasis.[12] A total of 107 patients were recruited to this study and were randomized to the intervention group or a control group. Participants in the intervention group attended an educational program about psoriasis and had access to their psoriasis app DermaScope Mobile. The app enabled patients to upload photographs of their psoriasis for monitoring purposes and report their health status. Both groups were assessed at face-to-face visits from a skin point of view and completed health questionnaires. 90 patients completed the 24 month follow up period. The intervention group showed a reduction in the Hospital Anxiety and Depression Scale (HADS-D) compared with the control group at weeks 12 and 24, especially participants who had an app usage frequency of <20% (which is equivalent to less than once a month). There was no difference in HADS-D score between patients who used the app more frequently than this or the control group. The app may improve mental health in patients with psoriasis when used once per month. The authors reported that regular usage of the app did not improve HADS-D score suggesting frequent reminders about their psoriasis may contribute to patient's emotional distress.[12]

Trettin et al designed and developed a smartphone application, using participatory design, to support long-term management of patients with psoriasis on biological therapy.[13] Health care professionals, patients, IT designers and researchers all contributed to the app design. The study was conducted at an outpatient department in a University hospital in Denmark. Due to regulations, patients on biological therapy must attend the department every 3 months for monitoring. This can be time consuming for patients who live far from the hospital. The app was developed to replace some of the follow up visits thereby reducing the commute time for patients. Patients contributed to the design of the app ensuring their needs were met, making it a patient focused experience. Multiple work shops were carried out to identify needs of patients and health care practitioners and ensure these were met by features included in the app. This helped ensure satisfaction on both ends. Both parties agreed that when patients completed the pre-consultation preparation feature, which includes a DLQI, the consultation was more patient focused and had a positive impact. The study was a small single centre study and the prototype app *Psoriasis* was tested by a single patient. However, it highlights the importance of including patients in the app design and outlines the key features important to meet all user's needs. It also provides an insight into patient's willingness to use mobile apps as an alternative to face-to-face visits for biologic monitoring purposes.

Pangti et al published the first large scale feasibility study of the use of a mobile health app in patients with skin of colour.[14] A smartphone App was developed using a convolutional neural network-based algorithm to diagnose 40 common dermatological conditions, including psoriasis. The app was tested in the clinical setting and validated on over 5000 patients attending dermatology clinics in India. The results of the app were compared with dermatologists' diagnosis. The app had a high diagnostic accuracy compared with dermatologists and can act as a decision support tool. For psoriasis, the app sensitivity was 68.00 ± 5.06 and specificity 99.18 ± 0.13.[14]

A study (Garzorz-stark et al, 2021) investigated the potential of a new smart phone app to monitor psoriasis disease activity.[15] Patients entered self-PASI, life quality, stress questionnaires and lifestyle factors over 12 months and this was compared with data collected by dermatologists. Patients feedback on use of app was obtained. 12 patients (out of 50) completed the 48-week study consisting of biweekly online smart phone app questionnaires and clinical outpatient visits every 8 weeks. Patient reported disease severity closely resembled PASI performed by a dermatologist. It was observed that a change in BMI or stress level during a 12-month period was followed by an increase in PASI – indicating the app can detect lifestyle changes preceding a shift in PASI. App could potentially serve as an alert system by drawing patients' attention to increasing stress levels or weight gain and prevent a flare. Patient reported benefits of the smart phone app: 50% of users want app supplemented with lifestyle manager to achieve individual lifestyle goals. >80% of study participants gave positive evaluation of smartphone app. Often active -passive relationship between healthcare professionals and patients. Smart phone apps used by patients would bring patients back into the center of disease management. Regular assessment of disease activity by the patient and easy display of disease course and disease related factors via an app would facilitate doctor patient communicationand allows for a more individual medical consultation. Disease related factors in a smart phone app raise awareness and reflection about disease.

Hampton et al assessed the usability of the smart phone app MySkinSelfie in a cohort of patients attending an NHS Dermatology clinic.[16] This smartphone app was developed to improve the quality and accessibility of patient held photographs and to empower patients to take ownership of their condition and of their own clinical photographs. The app allows patients to take photographs, store the photographs in a secure password protected location away from their camera roll. Photographs can easily be obtained for monitoring purposes or compared when next to each other. There is the option for patients to make a comment underneath a photograph. Patients own their data and can select a function on the app to share the photographs with a doctor if they wish. This study recruited 102 patients from the outpatient department. Patients were given written instructions on how to download the app and take photographs. After 3 months, patients were sent a questionnaire about the usability of the app. In total, 32 patients downloaded the app and 21 patients took at least 1 photograph. 19 completed the questionnaire. The conditions of the responders included benign moles, skin cancers, alopecia and inflammatory rashes including psoriasis. The majority of patients found the app easy to use and would recommend it to others. Interestingly, the compare function was noted as being particularly useful to patients.[16]

Moreno-Ramirez et al assessed the reliability of a smartphone application (MDi-Psoriasis) designed to help dermatologists make treatment decisions for patients with moderate to severe psoriasis.[17] The MDi-Psoriasis app uses an algorithm that consists of 60 variables relating to patient demographics, clinical characteristics and medication history. The app analyzes the data and makes treatment recommendations based on currently available guidelines and accepted clinical practice. To test the reliability of the app, 10 experts with at least 5 years' experience working in psoriasis clinics, were asked questions relating to 10 fictitious often complex scenarios involving the treatment of moderate to severe psoriasis. They were asked to comment on the most appropriate treatments, possible treatment options, and least appropriate treatments options for each scenario. The same cases were then input to the MDi-Psoriasis app. A cross sectional analysis of agreement or concordance was conducted comparing the recommendations made between the app and the experts. In total, 1210 evaluations were made and then mean level of absolute agreement between the application and experts was 51.3% and percentage agreement between the first-choice recommendation of experts and MDi-Psoriasis application was 87.3%.[17] The recommendations made by the app were comparable to those of experts suggesting a role for it as a clinical decision aid. The app does not take into account personal preference or doctors experience with a particular medication which often influences treatment decisions. There was variation seen between the experts in response to the cases put forward indicating the complexity involved in managing patients with psoriasis.

The availability of online health related information also has its challenges. Masud et al evaluated dermatology apps targeting patients using a rubic developed by the investigators.[18] The apps educational objectives, content, accuracy, design, and conflict of interest were reviewed. Only 9 (20.5%) of the 44 dermatology apps evaluated were considered adequate as a resource for patient information.[18] Tongdee et al examined the types of dermatology apps that are most popular by analyzing their rankings in the Apple App Store and found that for patients, self-surveillance was the most common type of app ranked whilst for doctors it was reference apps.[19]

Tele-Dermatology

Is Teledermatology Useful for the Remote Management of Psoriasis?

Koller et al (2011) reviewed the use of teledermatology as a monitoring system for patients with psoriasis who are on biologic therapy.[20] The aim was to record the course of the disease during flares, remission and detect adverse events earlier. 20 patients due to commence a biologic therapy were recruited prospectively. Each participant was given a mobile phone with a camera. Participants were reviewed face to face 4 times over a 6-month period. Mobile assessments were held once per week, 2–3 days prior to their injection, where they answered questions about their health, eg fever, night sweats, cough and there was also a comments section to allow for additional information. Participants took photographs of up to 5 pre-defined body parts affected by psoriasis. The physician received the data via a web-browser and sent feedback via SMS. All of the images were assessed by 4 observers trained in PASI assessment. The PASI's obtained via teledermatology were compared with the PASI's recorded in face-to-face visits. 15 participants completed the study. The compliance with the teledermatology monitoring procedure was 76.7%. 95% of the images received were classed as of "good" or "sufficient" quality. The teledermatology PASIs and the in person PASIs showed no significant difference.

However, the same pre-defined areas were examined at each visit whether it was face to face or via teledermatology. 88.2% of patients felt teledermatology was a very good idea and 94% would recommend this form of monitoring to other psoriasis patients.[20]

Hawkins et al conducted an investigator-blinded, randomised, controlled study to assess the efficacy of a web-based application to educate patients with psoriasis about their condition and treatments available.[21] One group of patients were directed towards a patient education website where they were shown an educational video before completing a survey. Patients in the control group were given a link directly to the survey. The main outcome was the difference in psoriasis knowledge between the two groups. The patients who were shown educational materials about psoriasis scored on average 11/14 on the psoriasis knowledge quiz while patients in the control group scored on average 9/14. The participants who received patient education reported a higher satisfaction with their doctor's visit compared to those who received no information about psoriasis. This study showed that web app-based education is an efficient way to improve knowledge, but this study did not demonstrate improvements in medication adherence and lacked the ability to address concerns of psoriasis patients.[21]

In one randomised clinical trial (Armstrong et al 2018) examined the effectiveness of online vs in person care for adults with psoriasis.[22] 296 participants with psoriasis were recruited from dermatology outpatient clinics and divided into two arms to compare in-person consultations versus online consultations over a 12-month period. The primary and secondary end points were the deviation in mean PASI score and BSA affected by psoriasis from baseline between online and in-person groups. The results showed that there was minimal difference in PASI improvement (−0.27) and BSA (−0.05%) between the two groups.[22] The mean decrease in Dermatology Life Quality Index (DLQI) was 1.64 in the online group compared to 1.18 in the in-person group.[22] Teledermatology in managing psoriasis was just as effective as in-person visits.

Singh et al published a case series in 2011 investigating the feasibility of assessing PASI scores remotely. 12 patients with confirmed psoriasis were recruited to this study.[23] Patients had PASI scores performed at face-to-face visits by 2 dermatologists and at the same visit had standardized digital images taken. PASI scores based on the digital images were performed at differential time intervals by 3 dermatologists. Comparison between the face to face PASI scores and telescores revealed good agreement (k= 0.67 and 0.63).[23] This shows PASI scores can be determined using digital images with good accuracy.

Balato et al evaluated the use of text messaging (TM) to improve patient outcomes and adherence to psoriatic treatments.[24] 40 patients were enrolled to this randomized controlled physician blinded prospective pilot study. Participants were randomized in a 1:1 ratio to TM group or control group. The participants in the TM group received 1 text message per day for a 12-week period. Text messages included medication reminders and educational material. The improvement in treatment adherence was statistically significant for the TM group from enrollment to intervention. PASI improvement was greater in the TM group at 12 weeks and there was a reduction in DLQI compared to the control group. There was a better patient-physician relationship in the TM group after the intervention with the control group remaining unchanged. The TM system was helpful for patients and met with a high level of satisfaction.[24]

Zhu et al investigated the feasibility and efficacy of a cloud based interactive patient and physician management of psoriasis using a multimedia application (app).[25] 79 patients were enrolled in the study between May 2015 and July 2016. Participants were randomly divided into the control group and the intervention group. The intervention group were managed using an app on the cloud platform. This platform enabled patients to upload their personal data to their physician and receive management advice in return. This group could also access educational material on psoriasis. The app included questions such as the degree of itching or pain from lesions using a visual analogue scale (VAS), photographs of their skin daily, and psychological questions using the anxiety and depression scale. This data was presented as a trend for health care providers to analyze and understand a patient's experience. The educational tools included text, pictures and videos on topics related to psoriasis and psoriasis management. There was also a function for daily medication reminders. At the end of the study, the PASI, DLQI and self-rating anxiety scale (SAS) scores were significantly lower for the intervention group than the control group suggesting interactive patient-physician management results in improved treatment outcomes for patients with psoriasis.[25]

Young et al assessed the psychological impact of online care versus in-person care for patients with psoriasis in this randomized controlled trial.[26] During the RCT, which included 296 patients who were randomly allocated in a 1:1 ratio to online or in-person care, functional impairment and depression were assessed at 3 monthly intervals using 5-level EuroQol-5 Dimensions (EQ-5D-5L) and Patient Health Questionnaire-9 (PHQ-9). The group receiving online care was equivalent to in-person care in terms of reduction in functional impairment and depressive symptoms in patients with psoriasis.[26]

Frühauf et al conducted a 12-week prospective pilot study to demonstrate the feasibility of teledermatology services for psoriasis patients.[27] Patients commencing on the biologic agent etanercept were enrolled in the study and provided with a smartphone which allowed them to take photographs of their psoriasis. Patients photographed their psoriasis according to the predefined areas as outlined in the PASI or PPPASI. The photographs were sent to teledermatologists at weeks 0, 1, 2 and every 2 weeks thereafter who responded via email with treatment instructions. Two teledermatologists remotely assessed the response to treatment. Patients attended for routine clinic appointments at week 0,1, 6 and 12. Patients who achieved a 50% improvement in their psoriasis based on face-to-face assessments continued on etanercept. 10 patients were included in the study. PASI/PPPASI scores obtained remotely were compared with those obtained at face-to-face visits. There was strong correlation between the face to face and teledermatology outcome, with complete concordance for palmoplantar psoriasis scoring.[27] It can be difficult to assess induration via teledermatology and may be the reason for some variability but in this study the interrater variability was low. Teledermatology is a feasible method for monitoring disease severity in patients with psoriasis. During this study, feedback questionnaires were distributed to the participants and the teledermatologists. There was a high level of acceptance amongst both patients (81% at week 6, 82.9% at week 12) and teledermatologists (74% at week 12). Most patients were satisfied with the use of the teledermatology service rather than in person consultations.[27]

Warshaw et al, published a systematic review of the literature and found that both store and forward and live interactive teledermatology have acceptable diagnostic and concordance compared to clinic dermatology.[28] Interestingly, 76% of patients preferred teledermatology over long wait times for a dermatologist. The time to treatment was shorter for patients assessed by teledermatology. Cost analysis studies are limited but most studies had shown that teledermatology can be cost effective.[28] Mounessa et al conducted a systemic review demonstrating a high level of satisfaction amongst users of teledermatology.[29]

Artificial Intelligence (AI)

Has AI Been Used or Demonstrated the Potential to Effectively Diagnose Psoriasis or Plan Management and Treatment Choices?

Gomolin et al 2020 reviewed the role of AI in dermatology.[30] The authors noted that many studies assessing the use of technology in dermatology are authored by engineering researchers with only a few studies involving dermatologists, which is key for the accurate interpretation and clinical implementation of AI in dermatology. Most of the current dermatological applications of AI focus on the differentiation between benign and malignant skin lesions. Moving away from skin cancer, the potential for AI in dermatology is expanding. Applications have been developed which focus on other areas such as ulcer assessments, psoriasis severity scoring, acne grading and dermatopathology.

Tools have been developed, using image recognition methods, to classify psoriasis severity. The models developed report >90% sensitivity and specificity.

Brito et al performed a literature review and the aim was to identify and critically appraise studies reporting AI algorithms designed to assess PASI in adult patients with plaque psoriasis compared with clinician in-person PASI assessment.[32] 3 studies identified reporting on algorithms for PASI scoring of area, erythema alone and erythema and scale. The studies were small and 2 were not externally validated. No algorithm was validated for scoring all four PASI components, none assessed induration (an on-going challenge for AI-based assessment). Psoriasis severity measures not utilizing induration may be more amenable to AI assessment.

Shrivastava et al (2015) developed a computer aided diagnostic system for the classification of psoriatic lesions. The database used included 540 images of psoriasis and normal healthy skin. The images were analysed according to their

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texture, colour, redness and chaotic features. The system could classify the images into psoriatic lesions and non-psoriatic normal skin with an accuracy of >99%.[33]

Emam et al used data obtained from 681 patients with psoriasis from a Danish registry to examine whether machine learning could help predict long term responses to biologic therapy.[34] Data included patient demographics, disease characteristics such as age at onset, presence of psoriatic arthritis, previous treatments, DLQI and PASI. This information, which is available in the clinical setting, was analyzed using machine learning algorithms, which showed a high level of accuracy in predicting discontinuation of the drug. This study focused on identifying the characteristics which would indicate that a patient has a ≥90% chance of continuing their treatment. The characteristics identified include ≥23 years old at the time of diagnosis, ≤49 years old at the time of treatment, receiving ustekinumab rather than a TNF inhibitor, not diagnosed with psoriatic arthritis, baseline DLQI ≥16, baseline PASI ≥9.4, no previous history of biologic failure and weight ≤98.9kg.[34]

Patrick et al, used statistical genetics and machine learning techniques to assess the risk of psoriatic arthritis (PsA) in patients with psoriasis.[35] As a result of international collaborations, data from over >7000 genotyped psoriatic arthritis and cutaneous only psoriasis patients were studied. Using genetic markers, the authors were able to distinguish psoriasis subtypes including, PsA from cutaneous only psoriasis with an AUC 0.82. Psoriatic arthritis occurs in 30% of psoriasis patients. The use of genetic markers to identify psoriasis patients at highest risk of developing PsA before symptoms of PsA even develop could potentially lead to earlier diagnosis of PsA and have treatment implications.[35]

Conclusions

We posed three main questions to probe the published data on telemedicine and e-health in the management of psoriasis. Firstly, we asked what evidence is there that mobile phone applications provide benefit or have the potential to provide benefit for the diagnosis, management or treatment of psoriasis or for patient education? Within this section, we also assessed whether apps identified for psoriasis were evaluated in clinical studies.

This review has illustrated that mobile apps are being developed to help diagnose psoriasis and differentiate it from other inflammatory conditions.[8,14] Apps may even improve adherence to topical therapies, something that remains a challenge in psoriasis.[11] We should be mindful that patients may not want to be reminded of their condition regularly, therefore an app that does not require frequent use is optimal.[12] Several smartphone apps which claim to help with the diagnosis and management of psoriasis were identified after searching the app stores. The list can be found in the Supplementary Table 1. To the best of our knowledge and within the search limitations, only one of these apps was found to have undergone validation testing (MDi psoriasis).[17] There were only a few apps identified in the literature review that had been clinically tested (MySkinSelfie, Improve 1.0, psoriasis).[13–16] The lack of published data on the majority of apps available for patients with psoriasis makes it challenging for doctors because it is our obligation to direct our patients towards reliable sources of information.

The increased use of smartphones and apps when it comes to managing patients' health is likely to continue, but caution must be practiced when advising technologies that have not been validated in clinical trials. Patient involvement in app development is crucial to the success of the app and user satisfaction.

Next we asked whether teledermatology was useful for the remote management of psoriasis.

There is growing evidence to suggest teledermatology is a useful alternative to in-person clinic visits.[20,22] Remote PASI's can be comparable to in-person PASI assessments.[20,23] In addition to monitoring, teledermatology can help improve adherence by receiving reminders.[28] Improved communication between doctors and patients results in better treatment outcomes. Teledermatology can facilitate more frequent consultations. Limitations include poor image quality and inadequate history which can lead to inefficiencies.[36] Overall, whilst the main focus for teledermatology has been lesion assessment and diagnosis the application of digital technology to psoriasis is expanding and it is likely that technological solutions will soon be applied in clinic to the diagnosis, management and treatment of psoriasis.

Finally we asked whether AI has been used or has demonstrated the potential to effectively diagnose or plan management and treatment choices for psoriasis. The use of Artificial intelligence for psoriasis patients is largely still in the experimental stage but has the potential to revolutionise clinical management. Computer aided diagnostic systems are being developed to improve diagnostic accuracy of psoriasis.[33] Psoriasis has several subtypes, and the clinical presentation can be quite variable. AI could prove helpful when there is diagnostic uncertainty and potentially reduce the need for skin biopsies. The ability to predict patients' responses to treatments represents an exciting advancement in medicine. The future of digital healthcare is rapidly evolving. In dermatology, the evidence points to a shift in the use of technology for predominantly skin cancer/lesion recognition to diagnosis and management of inflammatory conditions, in particular psoriasis. Mobile apps, telemedicine and machine learning algorithms will pave the way towards precision medicine in psoriasis. In the future AI will likely be used to assist physicians with diagnostic and treatment decisions in the clinic setting.

The use of technology in medicine has become more prevalent in recent years. The global pandemic has shone a spotlight on the importance of technology in the delivery of healthcare and organisations with greater digital maturity were able to work more effectively during the global pandemic as the demands for more remote working increased. The urgent need for remote consultations in dermatology has increased the use of teledermatology.

As in other areas of dermatology the application of digital technology to psoriasis needs to consider the risks and benefits. The main risk of remote assessment is data security. Software platforms must comply with the highest levels of digital security including 256 bit encryption of data and multifactor authentication for login access to accounts. Information governance processes and training must always be up to date and high quality. In the UK NHSX, the digital arm of the NHS, is introducing an assessment process for all digital products called DTAC (digital technology assessment criteria) to ensure that all software products approved for the NHS are secure and have high quality clinical governance.

The transmission of images needs to be carefully considered particularly when sharing images of sensitive body sites. When making assessments, the clinician must be sure that they have all the necessary information. Digital medicine for single lesions is relatively straightforward whereas the assessment of a patient with psoriasis requires examination of wider areas. Images of the scalp can often be poor and induration and scaling can also be hard to assess accurately remotely. When using video consultations the issue of chaperoning as in a face to face assessment must be considered.

Generic digital technologies can work well for some disease areas and badly for others. Before embarking on major changes in clinical pathways, proper evaluation of diagnostic accuracy, clinical outcomes, health economic outcomes and patient experiences are needed. Just because a technology enables you to do something does not mean it is necessarily the correct decision to use it. The practice of digital medicine needs the same standards of clinical practice as face-to-face clinical medicine.

Disclosure

The authors report no conflicts of interest in this work.

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