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Smartphone applications for melanoma detection by community, patient and generalist clinician users: a review*

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Summary

Smartphone health applications ('apps') are widely available but experts remain cautious about their utility and safety. We reviewed currently available apps for the detection of melanoma (July 2014), aimed at general community, patient and generalist clinician users. A proforma was used to extract and assess each app that met the inclusion criteria, and we undertook content analysis to evaluate their content and the evidence applied in their development. Thirty-nine apps were identified with the majority available only for Apple users. Over half (n = 22) provided information or education about melanoma, ultraviolet radiation exposure prevention advice, and skin self-examination strategies, mainly using the ABCDE (A, Asymmetry; B, Border; C, Colour; D, Diameter; E, Evolving) method. Half (n = 19) helped users take and store images of their skin lesions either for review by a dermatologist or for self-monitoring to identify change, an important predictor of melanoma; a similar number (n = 18) used reminders to help users monitor their skin lesions. A few (n = 9) offered expert review of images. Four apps provided a risk assessment to patients about the probability that a lesion was malignant or benign, and one app calculated users' future risk of melanoma. None of the apps appeared to have been validated for diagnostic accuracy or utility using established research methods. Smartphone apps for detecting melanoma by nonspecialist users have a range of functions including information, education, classification, risk assessment and monitoring change. Despite their potential usefulness, and while clinicians may choose to use apps that provide information to educate their patients, apps for melanoma detection require further validation of their utility and safety.

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What's already known about this topic?

- Earlier detection of melanoma would allow timely treatment and could improve outcomes.
- Although smartphone applications ('apps') are recognized as having potentially wide use in dermatology and oncology, experts have expressed caution concerning their diagnostic utility and safety.

What does this study add?

- We identified almost 40 smartphone apps available to detect or prevent melanoma by nonspecialist users including previously unaffected individuals, patients previously diagnosed with skin cancer, and generalist clinicians.
- Most apps gave advice or education about melanoma, ultraviolet radiation exposure preventive advice, and skin self-examination strategies; half of the apps enabled patients to capture and store images of their skin lesions either for review by a dermatologist or for self-monitoring to identify change, an important predictor of melanoma; only four apps provided a risk assessment about a skin lesion.

- There was little evidence of clinical or research-based input into the design of these apps or of evaluation of their utility, so clinicians should be cautious about supporting the use of such apps to detect melanoma.

Smartphones are rapidly evolving from being solely devices for communication and entertainment to include specialized applications ('apps') that are intimately involved in many aspects of daily life. A vast range of health apps is now available to assist users (> 13 000 in a 2012 report), for example to monitor their pulse and blood pressure, or to track their food intake and exercise undertaken to manage weight loss. Furthermore, two out of three U.S. clinicians already use smartphone health apps in their practice to manage a range of conditions.[1] Some apps have been evaluated, such as those to assist in managing diabetes[2] and pain,[3] and to aid monitoring of anticoagulation therapy[4] and epilepsy,[5] but such evaluation is not common among apps aimed at general community users, probably due to the rapid evolution and commercial drivers of this field. While smartphones have been hailed as 'new clinical tools in oncology',[1] many experts remain cautious about the utility of the thousands of apps currently available, either free or at a small charge, for the prevention, detection and management of cancer.[6,7] It has also been suggested that apps for detecting cancers tend to lack scientific and specialty input,[8] and the use of technology to deliver cancer follow-up has only begun to be studied for safety and utility: a recently published systematic review found only two randomized studies that had used smartphone technology.[9]

A number of dermatology-specific apps have been developed which aim to help previously unaffected individuals or those previously diagnosed with a skin cancer to decide if they should seek medical review for a skin lesion,[10,11] and to assist nonspecialist clinicians such as general practitioners (GPs) to make decisions about whether to reassure the patient that their lesion is benign or to refer for specialist assessment.[10] However, a recent comparison of the accuracy of four smartphone apps in assessing melanoma risk demonstrated wide variation in performance and utility.[7] Furthermore, smartphone apps for the identification or management of cancer including melanoma have not been subject to any sort of validation or regulatory controls in the U.S.A., the U.K. or elsewhere. Therefore, while they have the potential to improve patient and nonspecialist clinician assessment and patient–clinician communication about potential skin cancer there is the risk that these apps could actually harm users. The advice could be inaccurate or misleading, apps could be used as a substitute for a clinical consultation, and they could even delay melanoma diagnosis.[12] This risk is particularly concerning for melanoma compared with other cancers as the majority are detected by the patient rather than their clinician, and the time taken to present to a clinician from first noticing a skin change or symptom is longer than for all other cancers except those of the head and neck.[13]

In this paper we report a review of currently available smartphone apps for the detection of melanoma aimed at general community, patient or generalist clinician users, evaluating their content and the evidence applied in their development.

Methods

In July 2014 we searched the online stores of the two most popular smartphone providers (Apple[14] and Android,[15] which together provide more than 90% of cancer-related apps[6]), for health apps that suggested any kind of support for previously unaffected individuals, or those previously diagnosed with a skin cancer, to detect melanoma. Our search terms included 'skin cancer', 'mole' and 'melanoma'. We assessed the descriptions of each app identified by the searches, and included in this review all apps that stated an aim to help to detect melanoma. We excluded all apps that aimed to provide entertainment, cosmetics advice or general medical information alone. We also excluded those designed only for use by skin cancer specialists (dermatologists and plastic surgeons) including apps which use a dermoscopy attachment to the phone, but included any aimed specifically at generalist clinicians. We also excluded apps that were not available in English.

We developed a proforma specifically for this review, and one researcher (A.P.K.) extracted data about all the apps that met the inclusion criteria. The proforma was completed based only on the online descriptions; no apps were downloaded for data extraction purposes. All included apps were evaluated for their operating systems (Apple, Android, both), whether they were derived from research and/or validated, and the year of the latest update. The included apps were also evaluated for (i) general information about melanoma and/or skin cancer, ultraviolet radiation (UVR) and sun exposure preventive advice, and skin self-examination strategies; (ii) risk factor assessment; (iii) cataloguing and/or classifying using 'image analysis', defined as a comparison between the lesion and a stored image or an algorithm to assess the image, or the forwarding of images to a dermatologist; and (iv) monitoring changes in moles over time.

Content analysis and critical appraisal were then performed independently by two researchers (A.P.K. and F.M.W.) to analyse the findings and refine the categories. The emerging categories were discussed and critiqued by all the experienced

researchers, whose differing perspectives and expertise facilitated a robust and critical interpretation of assigned themes, and discussion and resolution of any differences by consensus.

Results

We identified 39 unique smartphone apps that met our inclusion criteria (Tables 1 and 2). Most are available for Apple Inc. devices only (26, 66·7%), with eight available for Android devices only (20·5%), and just five available for both platforms (12·8%).

Properties of available smartphone apps

Table 1 demonstrates the 39 smartphone apps currently available (July 2014) for previously unaffected individuals or those previously diagnosed with a skin cancer in the online stores of the two main application providers. Most of the apps (n = 28) were available to download for free, with the remaining apps having an added cost to download (range £0·69–£4·99).

Table 2 shows the properties and functions of these apps. The commonest function was to provide general information about melanoma and/or skin cancer (n = 22). Nineteen apps catalogued and classified lesions by capturing images, and applying integral algorithms, and 18 apps aimed to monitor skin lesions.

Information about melanoma and/or skin cancer was provided in a number of ways including access to online libraries. The ABCDE method (A, Asymmetry; B, Border; C, Colour; D, Diameter; E, Evolving) was most commonly used to provide education about skin self-examination and self-assessment of moles (n = 12).[16] Most of the apps provided more than one type of function. For example, the Mollie's Fund app provided information on skin self-examination, the ABCDE method, and how to protect from UVR exposure; and the UMSkinCheck app provided information about the ABCDE method, the commonest types of skin lesions, and how to protect against UVR exposure. Four apps (Dermatology Planet, iDoc24, Skin Cancer, Skin of Mine) also offered guidance on how to find a dermatologist in the U.S.A. One app (UMSkinCheck) stated it was specifically designed for non-Hispanic white U.S. citizens.

Cataloguing and classifying lesions was mainly undertaken by comparing the users' own photographic images obtained by the smartphone against a set of exemplar images, such as in Embarrassing Bodies – My MoleChecker. Some apps contained integral algorithms for photographic analysis such as pattern recognition and real-time computer image analysis technology in Doctor Mole and SpotMole, enabling the user to take a photographic image of the mole for assessment of each of the ABCDE criteria, and reporting changes in the features of the mole compared with previous photographic images. One app, Melanoma Visual Risk Calculator, used a Visual Analogue Scale (VAS) to compare the user's skin lesion against the ABCDE criteria. It was noteworthy that seven apps (Mole Detective, Mole Monitor, Skin of Mine, Skin Prevention – Photo Body Map, Skin Scanner, Skin Vision, SkinXM) provided limited or no information on how the photographic images were processed and analysed to provide advice on likelihood of melanoma. Apps from Apple Inc. are available for iPhones, iPads and iPod touch with software 3.1.3 and later, and apps from Android for all Android phones with software 1.6 and up. A minority of apps (n = 9), such as Dermlink.md and Mole Check App, offered prompt expert review of images taken by the user. These were often accompanied by advice on making an appointment with a dermatologist, and functioned only in the U.S.

Using smartphone apps to monitor skin lesions was undertaken via the storage of photographic images of their skin lesions. Users were encouraged to track the evolution of individual lesions by comparing serial images over time. While some such as Doctor Mole and Skin Prevention used simple comparisons with stored images, others used more sophisticated algorithms, such as Skin Analytics, which claimed to use 'real time vision technology'. Some, such as the Doctor Mole app, provided feedback to patients based on the ABCDE method; others, such as the Embarrassing Bodies – My MoleChecker and the Mole Detective apps allowed users to set reminders to take another photograph for comparison after a selected time. These apps also suggested that users could share the images during consultations with their dermatologist or family physician.

Only four apps provided tools to assess a skin lesion for likelihood of melanoma. The Doctor Mole and Skin Doctor apps used a computerized algorithm based on the ABCDE method, and the Melanoma Visual Risk Calculator provided a risk approximation based on patients' responses to a VAS. iSkin claimed to gather information about a mole and then calculate risk of melanoma, but provided no further information about the method involved.

A single app offered assessment of a person's baseline risk factor: UMSkinCheck used eight risk factors (region, sex, race, age, complexion, tanning, small moles and freckling) to calculate 5-year absolute risk for melanoma. However, there was no information about the model used to underpin this calculation.

Development and performance of apps

Even though several of the apps incorporated the ABCDE method, only one app acknowledged any research and developmental processes; the Melanoma Visual Risk Calculator was based on the diagnostic value of the ABCDE criteria for patient users.[17] Clinician involvement in the development of apps was clearly stated in only four apps. None of the apps were reported to have been validated.

Version updates

Among the apps, the range of latest updates was 2009–14, with 17 updated in 2013–14, nine in 2012, seven in 2011,

Table 1 Smartphone applications for melanoma detection by nonspecialist users including previously unaffected individuals, patients previously diagnosed with skin cancer, and generalist clinicians

	Name	Owner/developer	Country of origin	Type	Cost	Provider	Latest update (year)	Notes (from application descriptions in the online stores only)
1	ABCDEs of melanoma	Mouhammad Aouthmany	U.S.A.	Cl.	Free	Android	2013	Provides information on the ABCDE method, and a game aiming to identify abnormal moles
2	Dermatology Planet	Edizioni Scripta Manent snc	Italy	Co.	Free	Apple	2013	Provides daily news and skin cancer information, and helps U.S. user to identify a dermatologist; available for patient and provider use
3	Dermlink.md	Dermlink Inc.	U.S.A.	Co.	Free	Apple	2013	Allows user to take a photographic image of a mole and send to a U.S. dermatologist; the user receives a diagnosis within 24 h
4	Doctor Mole – Skin Cancer App	RevoSoft/Mark Shippen	Australia	Co.	£3·99	Both	2014 App; 2013 Android	Provides information on the ABCDE method. Contains a risk calculator (based on ABCDE method) with real-time computer vision technology aiming to assess changes in moles. Enables setting of reminders to monitor moles
5	Embarrassing Bodies – My MoleChecker	Channel 4	U.K.	Co.	Free	Apple	2012	Tracks moles by taking and storing photographic images and comparing them with standard images. Contains a 'mole gallery', self-examination videos, and enables setting of reminders to monitor moles
6	Embarrassing Bodies – My SelfChecker	Channel 4	U.K.	Co.	Free	Apple	2012	Provides information on skin self-examinations among other self-checks. Enables setting of reminder to monitor moles together with self-check videos, information about skin checks and the ABCDE method
7	FotoSkin	Wake App Health SL	Spain	Co.	Free	Apple	2014	Allows user to monitor their skin using a photographic register, and to show the images to their health professional. Also offers information about skin conditions, skin protection, and preventing skin cancer

Table 1 (continued)

	Name	Owner/developer	Country of origin	Type	Cost	Provider	Latest update (year)	Notes (from application descriptions in the online stores only)
8	iDoc24 – Ask the dermatologist today!	iDoc24 AB	Sweden	Co.	Free	Apple	2014	Allows user to send photographic image plus personal and lesion information (age, sex, description, duration, changes in appearance, size, location, symptoms) to anonymous dermatologist service with reply within 24 h. Also provides information about skin conditions, and helps to identify a dermatologist
9	iSkin	David Klotz; 2009 Mobile Otis	U.S.A.	Co.	£0·69	Apple	2009	Requires information from the user about their mole and calculates risk of melanoma. If high risk, urges user to seek medical help. It also provides a list of their responses for the user to discuss with their clinician
10	LoveMySkin – Mole map for skin cancer prevention	Steven Romej	U.S.A.	Co.	£0·69	Apple	2011	Provides a photographic image of the user's body to mark spots that the user wishes to monitor. Also provides information on the ABCDE method
11	Melanoma iABCD rule	Mindexs	Brazil	Co.	Free	Apple	2012	Provides information about the ABCDE method and on how to differentiate a malignant from a benign mole
12	Melanoma Visual Risk Calculator	Sigve Dhondup Holmen MD	Norway	Cl.	Free	Apple	2011	Provides a VAS[a] for each of the ABCDE criteria; user can then assess their lesion and receive melanoma risk information
13	Melanoma Watch	Stroika	U.K.	Co.	Free	Apple	2010	Guides user to learn the difference between malignant and benign moles. Compares the user's moles with stored images. Provides information about moles and the ABCDE method
14	Mole Check App	Botomap Inc.	U.S.A.	Co.	Free	Apple	2014	Allows a photographic image to be taken and assessed by a dermatologist. Requires a fee to submit image

Table 1 (continued)

	Name	Owner/developer	Country of origin	Type	Cost	Provider	Latest update (year)	Notes (from application descriptions in the online stores only)
15	Mole Checker	Stroika	U.K.	Co.	Free	Apple	2010	Guides user to learn the difference between malignant and benign moles, and how to self-examine, with information about ABCDE method. Compares moles with stored photographic images
16	Mole Checker	Harry Arden	U.K.	Co.	Free	Android	2011	Guides user to learn skin self-examination. Contains the same description as the 'Melanoma Watch' application
17	Mole Detective	Lascarow Healthcare Technologies Ltd	U.K.	Co.	£3·04	Android	2012	Allows a photographic image to be taken and stored, and analyses using the ABCDE method, giving melanoma risk information. Compares pictures over time, and enables user to set reminders to monitor their moles
18	Mole Monitor	Pro-Cal Powertrain Development	U.K.	Co.	£4·99	Apple	2014	Analyses and monitors mole images using an algorithm. Images are compared with previous ones uploaded and the user is provided with a report, which the health provider can refer to
19	MoleQuest	ProjectProject Pty Ltd	U.S.A.	Co.	Free	Apple	2013	The user captures two images and answers a few 'Yes/No' questions. Responses and photographic images are forwarded to a dermatologist for reviewing. The user is provided with a report with recommendations by the dermatologist
20	MoleTrac	Depthmine Software	U.S.A.	Co.	£0·69	Apple	2011	A photographic diary aiming to educate the user to track changes in moles. Requires information on characteristics such as size, colour and thickness
21	Mollie's Fund	MCS Advertising. Mollie Biggane Melanoma Foundation	U.S.A.	Ch.	Free	Both	2011 App; 2013 Android	Provides information about ABCDE method, skin self-monitoring and sun protection. Enables user to keep track of their self-exams with Monthly Skin Check logs

Table 1 (continued)

	Name	Owner/developer	Country of origin	Type	Cost	Provider	Latest update (year)	Notes (from application descriptions in the online stores only)
22	nēvus	Shonik IDEAS	U.S.A.	Co.	£1·99	Both	2012 App; 2013 Android	Allows user to track their moles by using a Skin Record. Provides information about sun protection, tips and product recommendations from dermatologists, and information on abnormal moles OnlineDermClinic.com LLC U.S.A.
23	OnlineDerm Clinic	OnlineDermClinic.com LLC	U.S.A.	Co.	Free	Both	2014	Allows user to take photographic images and answer a few skin-related questions. Information and image are forwarded to a U.S.A. dermatologist for response within 48 h.
24	Skin Analytics	Skin Analytics Development	U.K.	Co.	Free	Both	2014	Allows user to take and compare photographic images over time. It also requires information such as living location, but it is not explained how this information is used
25	Skin Cancer	Andrew Kaufman, MD	U.S.A.	Cl.	Free	Apple	2014	Provides information about types of skin cancers and their treatment. Allows user to upload photographic images, and enables user to identify a dermatologist and request an appointment
26	Skin Cancer Information	Anima	U.S.A.	Co.	Free	Android	2011	Provides information ranging from symptom management to skin cancer diagnosis and available treatments
27	Skin Doctor	Ibrahim Salim Alhalabi	U.S.A.	Co.	Free	Android	2014	Compares uploaded photographic images with stored images to evaluate melanoma risk, using an algorithm based on the ABCDE method
28	Skin Mole Analysis	Opticom Data Research	Canada	Co.	Free	Android	2012	Provides access to an online database of moles and their risk analysis. Provides information about a device called MoleSense, and allows user to upload a photographic image and receive a dermatologist's report within a week
29	Skin of Mine	Medical Image Mining Laboratories	U.S.A.	Co.	Free	Apple	2011	Analyses and tracks photographic images, and refers user to a licensed dermatologist in certain U.S. states

Table 1 (continued)

	Name	Owner/developer	Country of origin	Type	Cost	Provider	Latest update (year)	Notes (from application descriptions in the online stores only)
30	Skin Prevention – Photo Body Map for Melanoma and Skin Cancer Early Detection	Dimension S.r.l.	Italy	Co.	£4·99	Apple	2014	Allows user to upload photographic images to monitor skin changes by comparisons with previous images. It is described as promoted by the International Society of Dermatoscopy
31	Skin Scanner	Intelligent Life Solutions	Portugal	Co.	£0·69	Apple	2012	Scans mole area in order to monitor the moles. It then provides information on moles that need observation and skin counselling. Enables user to set reminders to monitor their moles. Permits forwarding of photographic images to the user's dermatologist
32	SkinTagger	Coriumedic Systems LLC	U.S.A.	Co.	Free	Apple	2014	Annotates corresponding site of lesion on a model to facilitate tracking of changes. Contains information about ABCDE method
33	SkinVision	SkinVision B.V.	Netherlands	Co.	£0·69	Apple	2014	Creates instant analyses of mole photographic images and provides information on how to improve skin health and determine personal UVR exposure to prevent melanoma
34	SkinXM	AlternateUniverse Technologies	U.S.A.	Co.	£2·99	Apple	2012	Allows user to monitor their moles using image analysis tools to compare images for changes
35	SpotCheck 2	SpotCheck Applications Inc.	U.S.A.	Co.	Free	Apple	2013	Provides information and images to differentiate between a malignant or benign mole, based on ABCDE method. Provides access to dermatologist review of photographic images within 24 h. Not available in England
36	SpotMole	Cristian Munteanu	Spain	Co.	Free	Android	2014	Detects signs of melanoma using image processing and pattern recognition techniques
37	Track-A-Mole	Peak Mobile Designs LLC	U.S.A.	Co.	Free	Android	2011	Creates slideshow projects for user's moles. Enables user to set monthly reminders to monitor their moles. Contains information about ABCDE method

Table 1 (continued)

	Name	Owner/developer	Country of origin	Type	Cost	Provider	Latest update (year)	Notes (from application descriptions in the online stores only)
38	UMSkinCheck	University of Michigan	U.S.A.	Un.	Free	Apple	2012	Allows user to complete and store a full-body photographic survey, set up self-exam prompt, track detected lesions, and fill out a melanoma risk calculator. Provides information about ABCDE method, images of common skin lesions, sun safety and sunscreen. Provides a risk calculator for 5-year absolute melanoma risk. Area-specific to the U.S.A. and only for non-Hispanic whites
39	YourSkinDiary	Buiss Ultimo GmbH. Danné Montague-King	Australia	Co.	Free	Apple	2012	Allows user to capture photographic images and tracks changes. Contains UV index level information of the user's area

ABCDE (A, Asymmetry; B, Border; C, Colour; D, Diameter; E, Evolving); Ch., charity; Cl., clinical; Co., commercial; Un., university; UV, ultraviolet; UVR, UV radiation; VAS, visual analogue scale. [a]A VAS is a psychometric response scale, which indirectly measures variables that cannot be directly measured.

two in 2010 and one in 2009. Three apps (Doctor Mole – Skin Cancer app, Mollie's Fund, nēvus) had their Apple and Android versions updated in different years.

Discussion

This review has identified smartphone apps for detecting melanoma by nonspecialist users including previously unaffected individuals, patients previously diagnosed with skin cancer, and generalist clinicians. We have evaluated the content of the apps with respect to general information about melanoma and/or skin cancer, UVR and sun exposure preventive advice, skin self-examination strategies, assessment of current and future melanoma risk, personal or expert image analysis to classify lesions, and lesion monitoring over time. We have identified 39 smartphone apps with the majority available only for Apple users. One-third of these apps provided information only. A similar number enabled patients to capture and store images of their skin lesions either for review by a dermatologist or for self-monitoring to identify change, an important predictor of melanoma. Four apps provided a risk assessment to patients about the probability that a lesion was malignant or benign, and only one app incorporated a validated risk model giving individuals information about their future risk of melanoma. None of the apps appeared to have been validated for diagnostic accuracy or utility using established research methods. There was limited information about whether the apps were developed with clinician involvement, and some apps had not been updated for more than 3 years.

While a recent systematic review of smartphone apps for the prevention, detection and management of cancer in general concluded that there has been 'a lot of action, but not in the right direction', as they tend not to incorporate technological innovation,[6] we have identified a range of uses of smartphone technology for melanoma detection. For example, image analysis allows for self-monitoring, and the use of reminders and alerts promote the added use of monitoring skin changes over time. Furthermore, the technology can use a 'teledermatology' model, and send the image for expert review and advice. Nevertheless, one-third of the apps that we identified only promoted awareness of cancer symptoms or solar protection, with no potential for interaction or specialist overview, despite the strong evidence suggesting that the provision of information alone is not an effective intervention to improve patient self-management of chronic disease in primary care.[6,18] Adding self-monitoring techniques could be more effective than information-provision alone.[19] Moreover, as communication with clinicians may improve adherence to e-healthcare interventions,[20] apps that facilitate communication with skin specialists may have utility, particularly for individuals previously diagnosed with a skin cancer.

Almost a quarter of the apps used a teledermatology model to send the image for expert review. Evaluations of remote

Table 2 Properties of smartphone applications for melanoma detection by nonspecialist users including previously unaffected individuals, patients previously diagnosed with skin cancer, and generalist clinicians

		Information and/or education				Cataloging/classifying		
	Name	Melanoma/ skin cancer	UVR/sun exposure advice	Skin self-examination	Risk factor assessment	Image analysis[a]	Dermatologists review	Monitoring/ tracking
1	ABCDEs of melanoma	•		•				
2	Dermatology Planet	•						
3	Dermlink.md						•	
4	Doctor Mole – Skin Cancer App[b]	•		•	•	•		•
5	Embarrassing Bodies – My MoleChecker[b]	•		•		•		•
6	Embarrassing Bodies – My SelfChecker	•		•				•
7	FotoSkin	•	•	•		•		•
8	iDoc24 – Ask the dermatologist today!	•					•	
9	iSkin				•			
10	LoveMySkin – Mole map for skin cancer prevention	•		•				•
11	Melanoma iABCD rule	•		•				
12	Melanoma Visual Risk Calculator[f]				•	•		
13	Melanoma Watch[g]	•		•		•		
14	Mole Check App						•	
15	Mole Checker (by Stroika)[g]	•		•		•		
16	Mole Checker (by Harry Arden)	•		•				
17	Mole Detective[h]					•		•
18	Mole Monitor[b]					•		•
19	MoleQuest						•	
20	MoleTrac							•
21	Mollie's Fund	•	•	•				
22	nēvus	•	•					•
23	OnlineDermClinic						•	
24	Skin Analytics							•
25	Skin Cancer	•						
26	Skin Cancer Information	•						
27	Skin Doctor[h]					•		•
28	Skin Mole Analysis[i]	•		•		•	•	
29	Skin of Mine[f]					•	•	•
30	Skin Prevention – Photo Body Map for Melanoma and Skin Cancer Early Detection[c]					•		•
31	Skin Scanner[c]					•	•	•
32	SkinTagger	•						•
33	Skin Vision[b]	•	•			•		
34	SkinXM[d]					•		•
35	SpotCheck 2[c]	•		•			•	
36	SpotMole[i]					•		
37	Track-A-Mole	•		•				•
38	UMSkinCheck[e]	•	•	•	•	•		•
39	YourSkinDiary[f]		•			•		•
	Total	22	6	15	4	18	9	19

ABCDE (A, Asymmetry; B, Border; C, Colour; D, Diameter; E, Evolving); UVR, ultraviolet radiation. [a]Defined as comparison between lesion and a stored image; [b]requires iOS 6·0 or later; [c]requires iOS 5·1 or later; [d]requires iOS 5·0 or later; [e]requires iOS 4·3 or later; [f]requires iOS 4·0 or later; [g]requires iOS 3·1·3 or later; [h]requires Android 2·2 and up; [i]requires Android 2·1 and up; [j]requires Android 1·6 and up.

assessment of clinical photographs and/or dermoscopic images have given good diagnostic values (up to 98% sensitivity), suggesting the likely reliability of this method in smartphone apps assuming adequate image quality.[21–24] Most evaluations describe dermatologists or plastic surgeons as experts, but a fully qualified dermatologist may not need to support skin

apps, and there could be roles for generalist clinicians and allied health professionals, particularly if using a dermoscope attached to a phone.[25] Fewer apps used automated image analysis for skin self-examination. While this is clearly feasible,[26] there is less clear evidence around its diagnostic accuracy or utility. Indeed, a recent report highlighted the diagnostic inaccuracies of four smartphone apps for melanoma detection, with wide variations in sensitivity and specificity to detect malignant skin lesions.[7]

Twelve apps made use of the ABCDE method[27] to inform and educate users. The Doctor Mole and Skin Doctor apps also used a computerized algorithm based on the ABCDE method to help people assess the risk of melanoma directly for a specific lesion. Most apps that we identified were developed in the U.S.A. where the ABCDE method is widely used, even though there is evidence that the revised 'Glasgow' 7-point checklist has higher sensitivity for diagnosing cutaneous melanoma when compared with the ABCDE method.[28] Future apps could consider incorporating and validating the 7-point checklist for melanoma detection, particularly for use in the U.K. population where it was developed and recently validated in a primary care population.[29] Two apps were not included in the review as they were marketed for doctor's use only. iDoc24 Pro was the 'professional' version of iDoc24, aiming to 'help clinicians assess whether to refer a patient to a dermatologist', and Melanoma Risk Assessment Tool (Apple; last updated 2011) used the patient's personal and medical history and the result of a back and shoulders examination to calculate an estimate of a patient's absolute melanoma risk.

We found that some apps have not been updated for more than 3 years. Even when updated recently, there was no discussion around whether the updates were based on new evidence, and we were not able to distinguish whether commercial or other apps were updated most regularly. We also found surprisingly scanty scientific evidence about the development or evaluation of the smartphone apps included in our review; only one app provided a single reference to a peer-reviewed publication. Reviews of smartphone apps for dermatology in general,[7,11] and for colorectal cancer,[8] have reported similar findings. There seems to be a profound mismatch between the promise of the app developers on the one hand and evidence of clinical validity and utility on the other hand, as demonstrated in this study. This is of concern for two reasons: firstly, it is important to establish the safety, including accuracy and utility, of these apps, particularly as the market is unregulated; secondly, clinicians may be benefiting financially from both the sale of the apps and the teledermatology role, and this should be disclosed.

Strengths and limitations

Previous reviews of smartphone apps focused mainly on those developed by Apple Inc.[3,30] This review extends knowledge to apps for melanoma detection developed by Google. This is the first review that evaluates the content of smartphone apps available for melanoma detection for previously unaffected individuals or those previously diagnosed with a skin cancer, and generalist clinicians. It is also the first review to outline the content of available apps, whether they are derived from research evidence, and whether they have been validated.

We recognize that there are limitations to this review. It was restricted to the descriptions available from the online stores; more information may have been available after purchasing or using the apps, but this was not undertaken in order to ensure equity across the review. Moreover, we felt that users should be able to make an informed choice about the apps by reading their description in the online stores. We reviewed apps only available in English; therefore we may have failed to identify any apps published in other languages. In reality this is unlikely as the U.S.A. and U.K. were the main countries publishing these apps, with a few also coming from Western Europe and South America. Finally, we only reviewed apps applicable to Apple and Android phones as we knew that more than 90% of apps are available via these two platforms. It is likely that small platforms would use the same apps – as some were available via both of the major platforms – and we are therefore confident that few are missing.

Clinical and policy implications

A recent systematic review mapping mobile health research over the last decade identified 117 publications, but concluded that few included large or rigorous evaluation of the novel technologies.[31] Another recent review has also identified patients as having a stronger desire to be informed about underpinning scientific evidence than commercial stakeholders.[32] Our review has shown little evidence of clinical- or research-based input; therefore, more research is needed to evaluate their content, validity and utility to support detection of melanoma in previously unaffected individuals and those previously diagnosed with a skin cancer. A particular priority should be to evaluate how skin self-monitoring could help people appraise their skin changes and make appropriate help-seeking decisions. Without a more explicit research base, clinicians should be cautious about supporting the use of such apps to detect melanoma earlier, although they may choose to use apps for education and/or information alone. It is noteworthy that although the U.S. Food and Drug Administration (FDA) does not currently regulate the mobile health industry, there are plans to do so in a similar way to regulation for medical devices;[33] the European Medicines Agency has signalled similar intentions.[34] Further evidence on clinical validity and utility are likely to be required for these regulators.

Nevertheless, these apps continue to have great potential.[35] Ideally, evidence is needed on the diagnostic accuracy of these tools in the hands of intended users compared with a reference standard diagnosis. If shown to be accurate, trials of their clinical utility would be needed to assess their cost-effectiveness in promoting earlier diagnosis and reducing consultations for benign lesions. Evidence-based smartphone apps could

then contribute towards minimizing the diagnostic delay experienced by people with melanoma, which may be significantly associated with mortality.[36]

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