

Original Article

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Smartphone app to screen individuals with scabies symptoms

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ABSTRACT

INTRODUCTION. Patients with scabies are often misdiagnosed before being attended by a dermatologist. The aim of this study was to use a smartphone app to screen individuals from the general population with scabies symptoms.

METHODS. Subjects who suspected that they had scabies were recruited online and downloaded a app tailored for this study. A questionnaire on symptoms was completed and photos of the skin were uploaded from within the app. Two physicians, a board-certified dermatologist and a resident dermatologist, evaluated the requests by categorising the scabies risk of each case, and categorisation triggered an auto-generated response describing the level of scabies and letting the participant know whether to contact a general practitioner or not.

RESULTS. Within 15 days of advertisement, 228 requests were sent (71% women); mean age 24 years (standard deviation: \pm 10.0). Itch was experienced by 90% (n = 208) and rash by 76% (n = 174). The rash was distributed bilaterally in 79% (n = 138). The areas of rash localisation were: arms (63%), hands (56%), legs (55%), abdomen (52%), inner thigh (45%), chest (26%), genitals (24%), head and neck (17%) and axilla (16%). 5% of all cases evaluated by either the senior or junior physician were evaluated as having a high risk of scabies.

CONCLUSION. In a very short time, the app received a high number of requests from individuals worrying about scabies; 5% of the incoming requests were categorised as carrying a high risk of having scabies. Mobile apps are a helpful tool to screen for scabies in primary care settings.

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Scabies is a contagious skin condition caused by infestation by the mite *Sarcoptes scabiei var. hominis*. After 4-6 weeks, patients develop an allergic reaction to mite proteins, eggs and faeces, causing intense itch and rash. Transmission occurs when adult mites pass between humans by skin-to-skin contact [1]. Young children, elderly and immunocompromised individuals carry an increased risk [2]. The estimated worldwide annual prevalence of scabies is 300 million cases [3].

The general practitioner (GP) is the first point of healthcare contact in Denmark. A study by Anderson et al. [4] showed that 45% of patients diagnosed with scabies had been misdiagnosed by another healthcare provider before being assessed by a dermatologist. Lack of GP expertise may result in failure to recognize scabies, resulting in delayed diagnosis and inadequate treatment of infested individuals and their contacts. A delay in

diagnosis and treatment may increase the number of people infested, prolong chains of infestation, and, potentially, cause outbreaks.

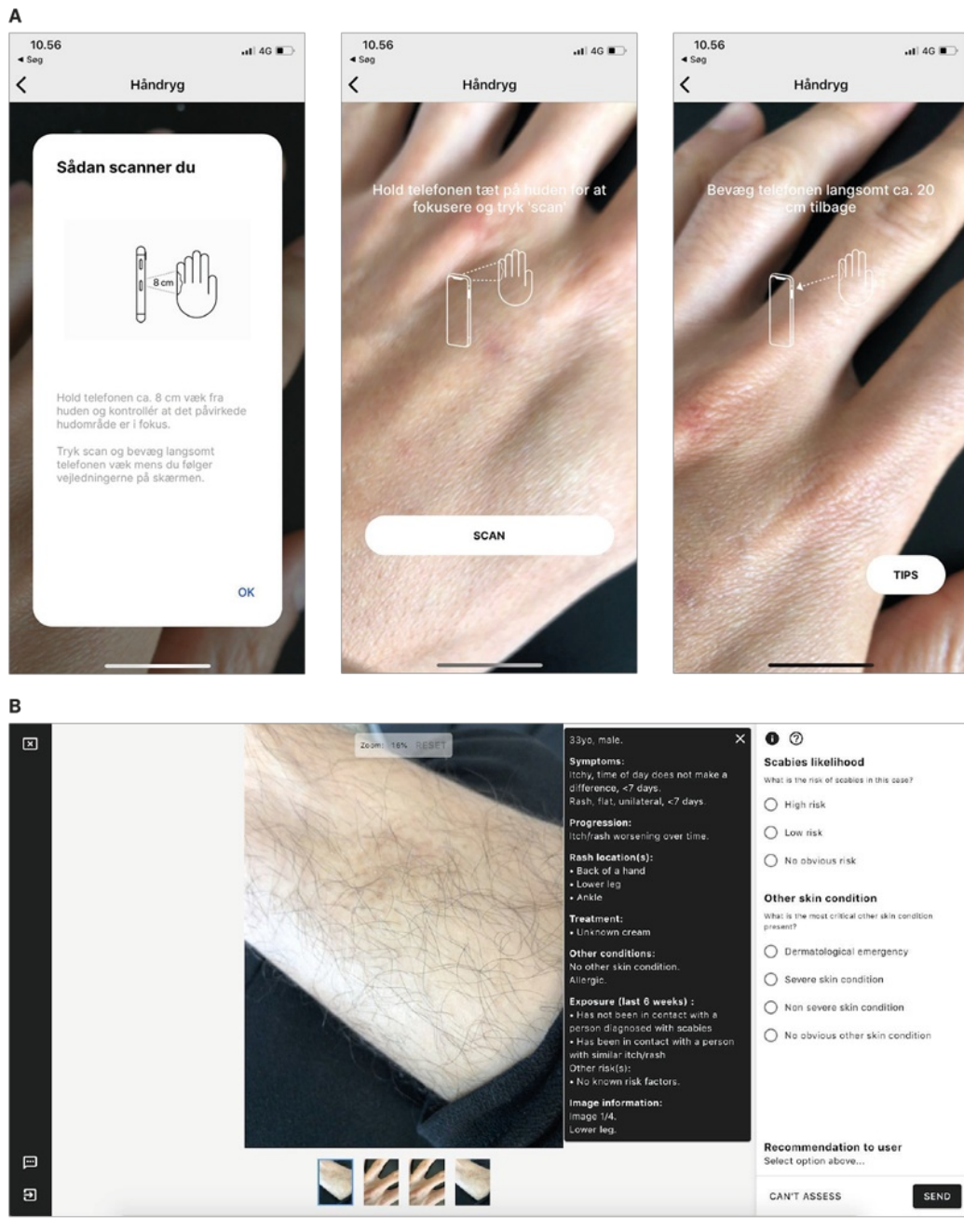
The aim of this study was to use a smartphone application (app) to evaluate the risk of scabies among individuals from the general population who had scabies symptoms.

METHODS

Enrolment

Individuals above 18 years of age with an itchy rash living in Denmark were recruited online through advertisements on Google search. The advertisement was displayed to individuals searching online for scabies, itch and rash and stated “If you are worried that you might have scabies, you can have your symptoms assessed. Get clarity about the cause of your itching and learn what to do about it. Get a free medical evaluation of your symptoms”. Other advertisements with slight variations in wording were also used. The advertisement directed the individuals to a landing page that helped them download a smartphone app tailored for this study (HUDSVAR). Users were able to create an account using an e-mail address, a phone number, or they could create an anonymous account without providing any further personal information [5]. To send a request, users first needed to complete a questionnaire, including age, gender, a description of symptoms, duration of symptoms, progression of symptoms, location of rash, use of treatment and possible exposure to scabies within the past six weeks. After completing the questionnaire, patients were requested to take photos of the affected skin. Using a feature in the app, patients were able to zoom in and out and focus to get a clear photo of the skin (**Figure 1**). Users were allowed to upload several photos. Once the questionnaire had been completed and photos had been uploaded, patients were able to submit their the request.

FIGURE 1 Photo feature of the scabies app. **A.** Patient's view. **B.** Physicians' evaluation dashboard.



Evaluation of incoming requests

Two medical physicians, a board-certified dermatologist and a resident dermatologist, all from the Department of Dermatology, Copenhagen University Hospital-Bispebjerg, Denmark, assessed all the incoming requests within two working days. The assessors used a password to log on to a personal dashboard allowing them to evaluate requests from a desktop or a laptop. All photos were displayed on the left side of the screen. The physicians had the opportunity to scroll through the photos, zoom in and out and review the photos. Information provided by the patients was displayed on the right side of the screen. The physicians were able to see the photos and the information provided by the patients simultaneously (Figure 1).

The physicians then had the opportunity to categorise the patients as having a high, low or no apparent risk of scabies. A high risk was defined as a typical rash and/or having a rash on a body location common for scabies (hands, wrists, genitals or widespread) and/or having an intense itch with worsening at night. Low risk was defined as presence of both typical and atypical scabies symptoms, whereas no apparent risk was defined as clear skin or symptoms suggesting another or no skin condition. The categorisation auto-generated standardised response to the patient recommending that they contact the GP to establish a treatment plan, get further examination or informing them that contact the GP was not needed. Along with the standardised reply, the patients were encouraged to read several educational articles about scabies, treatment of scabies, itching or other articles, depending on their risk assessment.

If other serious skin conditions besides scabies were observed on the photos, the physicians also had the option to pass this information on to the patient by classifying the case as a dermatological emergency, severe condition, non-severe condition or no obvious condition. This action also triggered an auto-generated reply to the patients recommending that they consult their GP. The patient received the evaluation only from the first assessor and not from both evaluations.

Statistics

Baseline variables were reported as means and standard deviations for continuous variables and as frequencies and percentages for categorical variables. Pearson's χ^2 test was used for categorical variables and t-test for continuous variables. A p value below 0.05 was considered statistically significant. Value of agreement and Cohen's kappa were calculated to evaluate agreement between the two evaluators. F1 score, recall, precision, and accuracy were calculated for no apparent risk and low risk, respectively, versus high risk. A stepwise logistic regression analysis was conducted for risk of scabies with the variables of age, gender, itch and rash. All analyses were performed using the statistical software SPSS statistics version 25.

Trial registration: none.

RESULTS

The study started on 3 January 2021 and ran for a month. The advertisements were live online for 15 days from 3 January to 18 January 2021. During these 15 days, the advertisement had been seen by 16,789 individuals (7,653 women, 3,248 men and 5,888 unknown) of whom 2,759 (16.5%) (1,342 women, 585 men, and 832 unknown) clicked through.

Characteristics of the subjects who used the app

A total of 228 requests (71% women) were received. On average, eight photos were submitted by each subject. The mean age of the subjects was 24 years (standard deviation: ± 10.0 , range: 18-99 years) (< 20 years: 54% (n = 122); 20-30 years: 30% (n = 69), 30-40 years: 7% (n = 16), 40-50 years: 7% (n = 16), > 50 years: 2% (n = 5)). In total, 128 individuals (56.1%) had an Apple device, 14 (6.1%) had a Samsung device and six (2.6%) had a HUAWEI device (Table 1). Around 85% of the users sent a request within ten minutes of opening the app, the medium time spent completing questionnaire was one minute and 43 seconds, and 84% accessed at least one of the recommended information articles. The three most accessed articles were "What factors can affect your itch?" recording 114 clicks, "How to cope with itching?" recording 91 clicks and "What are the symptoms of scabies" recording 88 clicks.

TABLE 1 Questionnaire responses among 228 cases from the background population worrying about scabies (N = 228, mean age: 24.2 (± 10.7) yrs).

	n (%)		n (%)
<i>Gender</i>		<i>Progression in itch/rash</i>	
Male	65 (28.5)	Improving	17 (7.5)
Female	163 (71.5)	Worsening	73 (32.0)
<i>Device brand</i>		Fluctuation	81 (35.5)
Apple	128 (56.1)	None	47 (20.6)
HUAWEI	6 (2.6)	<i>Contact with a person with similar symptoms in the past 6 wks</i>	
Samsung	14 (6.1)	Yes	31 (13.6)
OnePlus	1 (0.4)	No	135 (59.2)
Unknown	79 (34.6)	<i>Contact with a patient with scabies in the past 6 wks</i>	
<i>Itch</i>		Yes	52 (23.2)
Yes	208 (91.2)	No	165 (72.4)
No	20 (8.8)	<i>Exposure 6 wks prior to itch</i>	
<i>Duration of itch:</i>		Communal living	6 (2.6)
Hours	13 (6.2)	Job	8 (3.5)
Days	87 (41.8)	Visitors	37 (16.2)
Weeks	68 (32.6)	Travelling	1 (0.4)
Months	40 (19.2)	Hospitalised	1 (0.4)
<i>Fluctuation day/night</i>		Individuals with no risk	72 (31.5)
Worsening at night	115 (50.4)	<i>Other skin conditions</i>	
Worsening at daytime	25 (11.0)	Acne	4 (1.7)
No fluctuation	68 (29.8)	Atopic dermatitis	8 (3.5)
<i>Rash</i>		Psoriasis	1 (0.4)
Yes	174 (76.3)	Unspecific dermatitis	1 (0.4)
No	54 (23.7)	Urticaria	1 (0.4)
<i>Duration of rash:</i>		Scabies	12 (5.2)
Hours	17 (9.7)	No other skin conditions	201 (88.2)
Days	71 (40.8)	<i>Allergy</i>	
Weeks	59 (33.9)	Yes	58 (25.4)
Months	27 (15.5)	No	170 (74.6)
<i>Rash distribution:</i>		<i>Treatment</i>	
Unilateral	36 (20.6)	Treatment for scabies	42 (18.4)
Bilateral	138 (79.3)	Corticosteroid creme	12 (5.3)
<i>Rash location:</i>		Other treatment	49 (21.5)
Head and neck	31 (17.8)	No treatment	100 (43.9)
Chest	46 (26.4)		
Abdomen	92 (52.8)		
Back	60 (34.5)		
Axillae	29 (16.7)		
Arms	111 (63.8)		
Hands and wrists	98 (56.3)		
Buttocks	58 (33.3)		
Genitals	43 (24.7)		
Thigh, inner	79 (45.4)		
Legs	96 (55.2)		
Feet and ankles	58 (33.3)		
<i>Palpable rash:</i>			
Yes	99 (56.8)		
No	75 (43.1)		

The app was used in the entire country (Denmark) and not only by individuals living immediately around the hospital employing the evaluating physicians located in the Capital Region; 58.2% of the users were from the Capital Region of Denmark, 4.40% from the North Denmark Region, 13.6% from the Region of South Denmark, 14.7% from the Central Denmark Region and 9.16% from Zealand.

Itch and rash

Around 90% (n = 208) of the cases experienced itch, 17% of whom experienced an itch for months before sending a request in the app. 18% of the cases had used topical scabies treatment before submitting a request. 50% experienced a worsening of their itch at night, and 30% did not have any fluctuation of their itch. Rash was

experienced by 76% of the patients, and the rash was distributed bilaterally in 79%. Areas of rash localisation were arms (63%), hands (56%), legs (55%), abdomen (52%), inner thigh (45%), chest (26%), genitals (24%), head and neck (17%) and axilla (16%) (Table 1).

Evaluations

Twenty-eight cases were evaluated by only one physician as they exceeded the duration of the study period. Moreover, 72 cases were excluded; three due to poor image quality and 69 had not included any images, leaving 128 cases for evaluation by both physicians. On average, the senior physician used 27 seconds and the junior physician used one minute and 14 seconds to evaluate a case. 5% of the cases evaluated by both physicians were evaluated as high risk, 22% as low risk and 73% as no apparent risk of scabies. The agreement between the two physicians regarding high risk of scabies versus all other groups was 92.2% corresponding to a Cohen's kappa coefficient of 0.25 (95% confidence interval (CI): 0.05-0.56), $p = 0.001$. The senior physician evaluated four (3%) as high risk, 26 (20%) as low risk and 98 (77%) as no apparent risk of scabies. The junior physician evaluated ten (8%) as high risk, 30 (23%) as low risk and 88 (69%) as no apparent risk of scabies (Table 2). Out of all 256 evaluated cases (128 cases evaluated by each physician), a total of 14 cases (5%) were evaluated as high risk by either the senior or junior physician (ten by the junior and four by the senior physician). No cases were assessed as dermatological emergency, but in one case the participant was assessed to have a severe skin condition. For no apparent risk and low risk, respectively, versus high risk (which the app was built to detect), the accuracy was 0.92, the precision was 0.94, recall was 0.98 and the F1 score was 0.96.

TABLE 2 Evaluation of incoming scabies requests by a senior and a junior physician. The values are n.

Junior physician	Senior physician			total
	no apparent risk	low risk	high risk	
No apparent risk	75	12	1	88
Low risk	19	10	1	30
High risk	4	4	2	10
Total	98	26	4	128

Cases that were evaluated as having no apparent risk of scabies were characterised by significantly fewer contacts with an individual with scabies (7% versus 52% and 69%, $p < 0.001$) than individuals who were judged to have a low risk or high risk. No difference was observed in age, gender and presence of itch or rash between cases judged to have low risk or high risk.

The intraclass correlation coefficients for agreement between the two physicians evaluating the cases as no apparent risk, low risk and high risk of scabies was 0.51 (95% CI: 0.32-0.66).

Furthermore, no statistically significant association was observed between risk of scabies and age, gender, itch or rash.

DISCUSSION

In this online study of 228 cases from the background population worrying about scabies, 90% had an itch and 76% had a rash. These cases were most commonly localised on the upper body including arms, hands, abdomen, legs and inner thigh. Only around 5% were categorised as having a high risk of scabies and around two thirds were categorised as having no apparent risk of scabies. The app made it feasible to screen individuals with scabies symptoms very quickly. Furthermore, the screening tool was produced during a national scabies epidemic to reduce the workload of the GPs and office-based dermatologists, and to give the patients an instant evaluation to guide the right patients to the doctor while minimising healthcare costs and serving as a valid supplement during busy periods.

A traditional in-clinic consultation with a GP or a dermatologist takes at least 10-20 minutes. In this study, the primary evaluation time was reduced remarkably with the senior dermatologist using an average of 27 seconds to evaluate each case and the junior resident using one minute and 14 seconds. A study conducted by Norman et al. [6] showed that with expertise, a correct diagnosis is associated with a decrease in response time. That study also showed that the accuracy of dermatological diagnoses rose with five levels of expertise from 21% for medical students to 87% for dermatologists. Furthermore, the junior physician displayed a tendency towards evaluating more cases as having high risk than the senior physician who deemed more cases not to have a high risk. This was deemed to be due to lack of experience or a concern for giving a false negative diagnosis. A majority of the cases was evaluated to not have a high risk of scabies. This underpins the idea of using the app as a screening tool to guide patients with scabies-like symptoms, providing them with a rapid evaluation and probably reducing the number of consultations in primary care.

50% of the patients experienced worsening of itch at night, which is in line with the literature [7, 8]. Typical itch locations in patients with scabies are not well described though many studies have described the most common locations of rash or scabies lesions [9, 10]. However, itch may be localised to the site of visible scabies lesions or generalised to other body parts. The scabies lesions are often very itchy, but in some individuals they may not be itchy at all [11]. This may be the case for lesions located to the genital areas. Scabies lesions are often described around the genital areas [12]. However, in our study genital area lesions were less common.

Our study has some important strengths and limitations. All evaluations were conducted in real time while the patients were experiencing the symptoms, reducing the risk of recall bias. Some important limitations include the overrepresentation of women, which means that we cannot generalise our findings. Furthermore, the mean age of the included patients was 24 years, thus not representing the older population. Apps like the one used in this study will be very useful in the future to reduce the increasing burden on dermatologists. We also expect that more apps will appear with built-in machine learning and artificial intelligence technologies that may be used to screen dermatologic patients, which may potentially further reduce healthcare workloads.

CONCLUSION

In conclusion, a high demand was recorded for instant clarity of itch and rash symptoms. In two weeks, we received more than 200 requests from patients worrying about having scabies in a small country with 5.8 million citizens. Many patients had had itch and rash, and the most common localisation of rash was the upper body, including arms, hands, abdomen, and legs and inner thigh. 5% were categorised as having high risk of scabies, and the agreement between the two physicians on high risk of scabies was 92.2%. During busy periods and periods of national epidemics, a screening tool like the one used in this study may be needed to ease physicians' workload. Therefore, such apps should be tested and validated so that they may supplement in-clinic visits.

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Conflicts of interest Potential conflicts of interest have been declared. Disclosure forms provided by the authors are available with the article at ugeskriftet.dk/dmj

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