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Identifying people at higher risk of melanoma across the U.K.: a primary-care-based electronic survey*

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Summary

Background Melanoma incidence is rising rapidly worldwide among white populations. Defining higher-risk populations using risk prediction models may help targeted screening and early detection approaches.

Objectives To assess the feasibility of identifying people at higher risk of melanoma using the Williams self-assessed clinical risk estimation model in U.K. primary care.

Methods We recruited participants from the waiting rooms of 22 general practices covering a total population of > 240 000 in three U.K. regions: Eastern England, North East Scotland and North Wales. Participants completed an electronic questionnaire using tablet computers. The main outcome was the mean melanoma risk score using the Williams melanoma risk model.

Results Of 9004 people approached, 7742 (86%) completed the electronic questionnaire. The mean melanoma risk score for the 7566 eligible participants was 17·15 ± 8·51, with small regional differences [lower in England compared with Scotland ($P = 0·001$) and Wales ($P < 0·001$), mainly due to greater freckling and childhood sunburn among Scottish and Welsh participants]. After weighting to the age and sex distribution, different potential cut-offs would allow between 4% and 20% of the population to be identified as higher risk, and those groups would contain 30% and 60%, respectively of those likely to develop melanoma.

Conclusions Collecting data on the melanoma risk profile of the general population in U.K. primary care is both feasible and acceptable for patients in a general practice setting, and provides opportunities for new methods of real-time risk assessment and risk stratified cancer interventions.

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Conflicts of interest

None declared.

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What's already known about this topic?

- Programmes to identify people at higher risk of melanoma and offer them preventive advice about sun protection, skin awareness, early consultation or surveillance are of increasing interest to healthcare providers in the U.K. and internationally.
- Numerous models exist for predicting future risk of melanoma, with little difference between models suitable for self-assessment and those requiring a healthcare professional; none has been calibrated for the U.K. population.

What does this study add?

- Collecting data on the melanoma risk profile of the general population in U.K. primary care is both feasible and acceptable.

- This provides an opportunity for new methods of real-time risk assessment in primary care.
- Using the Williams model produces a distribution of risk in the population attending general practices that allows identification of subgroups at different levels of risk.
- As regional differences were small, a single approach could be implemented.

Melanoma is the leading cause of skin cancer deaths in the U.K., with incidence rates having increased between 2000 and 2009 by 55% and continuing to rise.[1,2] Identifying people at higher risk of melanoma can help early diagnosis and prevention, and in turn mortality.[3,4] Screening programmes to identify those at higher risk of melanoma and offer them preventive advice about sun protection and skin awareness and early consultation or surveillance are, therefore, of increasing interest to policy and healthcare providers.

Currently, mass screening is not recommended in the U.K. because of difficulties in identifying the target population,[5] as well as due to concerns about the low incidence of melanoma and therefore the time and resources required to identify a relatively small number of people with the disease.[6] Additionally, while the SCREEN project in northern Germany has suggested that population screening is feasible and may have an impact on diagnosis and 5-year mortality, it led to an increase in biopsies,[7,8] and there has been insufficient evidence for the cost-effectiveness of routine screening of the general population using a total body skin examination.[9] Previous studies, however, suggest that selective, targeted screening might be more cost-effective as the cost falls dramatically when screening is targeted to higher-risk populations, defined variously by age, family history or phenotypic characteristics.[10–14] A stratified approach is currently recommended for Australian primary care physicians, who are advised to perform skin examinations every 3–12 months in people who have multiple atypical or dysplastic naevi or a first-degree relative with melanoma.[15]

The overall impact of stratified screening for melanoma, however, depends on easily and accurately identifying a high-risk group.[16] Such identification may be improved by the use of risk prediction models. Our recent systematic review identified 25 risk models for predicting future risk of melanoma.[17] Twelve of those are suitable for self-assessment (defined as not including any of the following factors: dysplastic or atypical naevi, actinic lentigines, total body naevus count, genetic analysis requiring samples, or specialized equipment such as dermoscopy or colorimetry). Many had performance measures comparable with those for other cancers, including breast cancer[18] and colon cancer,[19] and there was little difference between those scores suitable for self-assessment and those requiring a healthcare professional. The review did not identify any risk models calibrated for the U.K. population and none was more than moderately predictive. Of those suitable for self-assessment, only one, developed from a U.S. case–control study by Williams *et al.*,[20] had been validated outside the development population. It is a self-assessed clinical risk estimation model not requiring full-body skin examination that, in a validation population, had an area under the receiver operator characteristic curve of 0·70 [95% confidence interval (CI) 0·64–0·77] and was able to identify 15% of the population in whom 50% of melanomas would be expected to develop. The Williams score can therefore be used to determine population risk of melanoma and enable stratified screening based on individual risk. The aim of this study was to assess the feasibility of identifying people at higher risk of melanoma using the Williams self-assessed clinical risk estimation model, the 'Williams model'[20] in U.K. primary care.

Methods

Study population and data collection

Ethical approval was gained from the West Midlands Research Ethics Committee (13/WM/0405). Participants were recruited from general practices in Eastern England (n = 10), North East Scotland (n = 6) and North Wales (n = 6) between February 2014 and March 2015. Patients and companions aged ≥ 20 years were approached in general practice waiting rooms by trained researchers at different times of day and different days of the week; posters were also placed in the waiting rooms to advertise the study. Those willing to take part were invited to complete an electronic questionnaire using tablet computers. The sex and reason for not wishing to participate was recorded for each person choosing not to take part.

Tablet computer-administered electronic questionnaire

The electronic questionnaire consisted of two sections: the Williams model and additional demographic variables. The questions for the Williams model were phrased as originally reported[20] and included: sex, age, natural hair colour at the age of 15 years, number of raised moles on both arms, density of freckles on both arms before the age of 20 years, number of severe sunburns up to the age of 18 years and prior nonmelanoma skin cancer (basal cell cancer and squamous cell cancer). Participants were also asked whether they had had melanoma. Age was collected in six age bands (20–34, 35–44, 45–54, 55–64, 65–74 and ≥ 75 years). The questions and

Table 1 Williams model melanoma risk score calculation (range 0–67)[20]

Risk factor	Score
Sex	
Male	7
Female	0
Age (years)	
35–44	0
45–54	5
55–64	8
65–74	11
Natural hair colour at age 15 years	
Dark brown/black	0
Light brown	4
Blond	5
Red	8
Number of severe sunburns aged 2–18 years	
None	0
1–4	1
5–9	4
10 or more	7
Prior nonmelanoma skin cancer	
No	0
Yes	13
Number of raised moles on both arms	
None	0
1	3
2	5
3 or more	11
Density of freckles on arms before age 20 years	
None	0
A few	4
Several	6
A lot	10

possible responses for the other risk factors are shown in Table 1. Photographic images were included of raised moles and freckles alongside those questions to facilitate completion of the questionnaire by each participant independently. The demographic section included questions on ethnic group, education level and employment status.

Statistical analyses

The risk score for each participant was calculated using the points scoring system developed by Williams *et al.*[20] We then computed the mean risk score and standard deviation for the entire sample and for each of the three regions separately, and compared the mean risk in each of the three regions using linear regression adjusting for the age and sex of participants. We proceeded to calculate the proportion of participants who would be identified as high risk using each of the four risk score cut-offs used by Williams *et al.*:[20] 25, 28, 30 and 34. We repeated this, weighted to the age and sex distribution of the registered practice populations, to obtain estimates of the proportion of the population who would be classified as high risk if the entire practice population had been questioned. To estimate the positive predictive value (PPV) and negative predictive value (NPV) for each cut-off we assumed that the Williams model would perform equally in the U.K. population as in the published validation study. We used the sensitivity and specificity reported by Williams *et al.* for each of the four risk score cut-offs and the published national data for 2011 crude melanoma incidence to estimate 5-year PPVs and 5-year NPVs. All analyses were performed using Stata version 12 (StataCorp, College Station, TX, U.S.A.).

Results

General practices

The 10 Eastern England practices had between 4229 and 20 279 registered patients and covered a total population of 112 651 patients; most were urban (n = 7). The six in North East Scotland were mostly rural or semirural (n = 5) with between 1845 and 20 976 registered patients covering a total population of 68 010, and the six in North Wales were mostly urban or semiurban (n = 5) with between 5801 and 15 409 registered patients covering a total population of 60 096 (Table 2).

Participant recruitment

The total person-time spent recruiting was 1009 h, with the time in each practice ranging from 15 to 93 h and the mean time per participant ranging from 2·1 to 18·5 min (mean 8·2 ± 5·0). This variation was largely due to differences in patient flow within practices. Factors facilitating quicker recruitment included: larger practice size; a greater number of doctors in the practice at the time; larger waiting rooms with more space to approach patients; and longer waiting times for appointments. Conversely, recruitment was difficult at times when large numbers of patients were arriving for very short appointments, such as blood tests or flu vaccinations, as many were called in before they had time to complete the questionnaire. Overall, 9004 people (3·7% of the registered population) were approached and 7742 completed the electronic questionnaire (86%) (Fig. 1); 275 people agreed to take part but were called for their appointment before completing the electronic questionnaire (3%), and 1063 people (12%) declined to participate. The total number recruited from the Eastern England practices was higher than in North East Scotland or North Wales (4140 compared with 1509 and 2093, respectively) but acceptance rates were similar in all three regions (Eastern England 85·3%, North East Scotland 86·8%, North Wales 86·7%). Reasons for not wishing to participate varied: over half either provided no reason or indicated no interest in the study (n = 593, 55·8%) with other common reasons including poor English (n = 86, 8·1%), no time (n = 72, 6·8%), and not having glasses with them (n = 59, 5·6%).

Table 2 Characteristics of general practices

Practice type	Practice population[a]	Cancer prevalence[b]	Deprivation (IMD quintile)[c]	Number recruited
Eastern England				
Urban	20 279	2·1	3	422
Urban	17 657	2·8	2	392
Urban	11 396	3·0	3	395
Rural	11 129	2·1	1	436
Rural	10 517	1·8	1	300
Rural	10 408	2·1	2	396
Urban	9549	2·2	1	433
Urban	9115	2·2	2	458
Urban	8372	2·4	3	396
Urban	4229	2·7	4	409
North East Scotland				
Semirural	20 976	2·1	2	431
Semirural	15 726	2·2	3	326
Semirural	12 222	2·8	1	150
Urban	11 062	1·9	5	368
Rural	6179	2·4	2	122
Rural	1845	1·6	1	83
North Wales				
Semiurban	15 409	2·4	2	387
Urban	13 068	2·4	3	384
Urban	9935	2·8	4	195
Rural	8331	2·8	2	502
Semiurban	7552	0·6	4	236
Semiurban	5801	2·2	2	342

[a]At time of recruitment. [b]Prevalence data in the Quality and Outcomes Framework: percentage of patients with a diagnosis of cancer, excluding nonmelanotic skin cancer. England and Wales 2013–2014[34] and Scotland 2012–2013.[35] [c]Index of Multiple Deprivation (IMD) quintiles computed using the practice postcode and published values for IMD where 1 is the least deprived.

Participants

We excluded 177 (2·3%) participants (Eastern England 100, North East Scotland 29, North Wales 47) who had a history of melanoma. Therefore, 7566 participants are included in further analyses. Table 3 shows the details of these 7566 participants by the three regions, with comparison where possible to the total patients registered in the practices. The majority were white (British and others, 96·5%), reflecting the regional populations.[21,22] Our sample contained proportionately fewer male and older participants than that of registered patients in the practices. Most were retired (30·1%) or working full time (35·9%), and education levels were similar to those in the 2011 Office of National Statistics, with over a quarter having an undergraduate degree (10·4%), or postgraduate degree or professional qualification (16·7%).

Distribution of melanoma risk factors and scores

Table 4 shows the mean risk score in each of the three regions and for the entire study population along with a breakdown of the proportion with each risk factor. The mean risk score for all 7566 participants was 17·15 ± 8·51 and was similar in each of the three regions (Eastern England: mean 16·79 ± 8·47; North East Scotland: mean 17·87 ± 8·41; North Wales: mean 17·37 ± 8·60). This difference in mean scores between North East Scotland and Eastern England of 1·10 (95% CI 0·59–1·61) reduced to 0·67 (95% CI 0·26–1·09, $P = 0·001$) after adjusting for age and sex; the corresponding difference between North Wales and Eastern England increased from 0·60 (95% CI 0·14–1·05) to 0·80 (95% CI 0·43–1·18, $P < 0·001$) after adjusting for age and sex. These differences were mostly explained by increased density of freckles on both arms before the age of 20 years and a greater number of severe sunburns aged 2–18 years reported by participants in both North East Scotland and North Wales; the difference between North East Scotland and North Wales was not significant ($P = 0·58$).

Figure 2 shows the distribution (unweighted) of melanoma risk scores in each of the three regions and the entire study population, overlaid with the four cut-off points used in the Williams model. Table 5 shows the percentage of study participants above each of the four cut-off points used in the Williams model, along with the estimated percentage of the registered practice population at all the included practices (estimated by weighting to age and sex distribution of practice populations) above each cut-off. Estimated PPVs and NPVs are also given for each cut-off in the three regions using the values for the relative risk, sensitivity and specificity reported in the Williams paper and assuming that the model is transferable to the U.K. population.[20] These suggest that, for example, using the lowest cut-off of 25 would classify approximately 17·7% of the practice populations in Eastern England as higher risk. This group would contain approximately 61% of the people predicted to be diagnosed with a melanoma at any time in the future and approximately 3·1% of this group would be expected to develop melanoma in the following 5 years. These values are similar for Northeast Scotland and North Wales but a slightly greater proportion of the population would be classified as high risk in both regions than in Eastern England at all thresholds (Table 5).

Discussion

To our knowledge this is the first study to use tablet computers to collect data specifically on risk of cancer in primary care. We have shown that collecting data on the risk profile of the general population in U.K. primary care is both feasible and acceptable. This provides an opportunity for new methods of real-time risk assessment in primary care for melanoma and for other cancers. We have also shown that using the Williams model[20] produces a distribution of risk in the population attending general practices that allows identification of subgroups at different levels of risk. Although this distribution varied slightly between the three U.K. regions included in this study, the differences were small and, from a policy

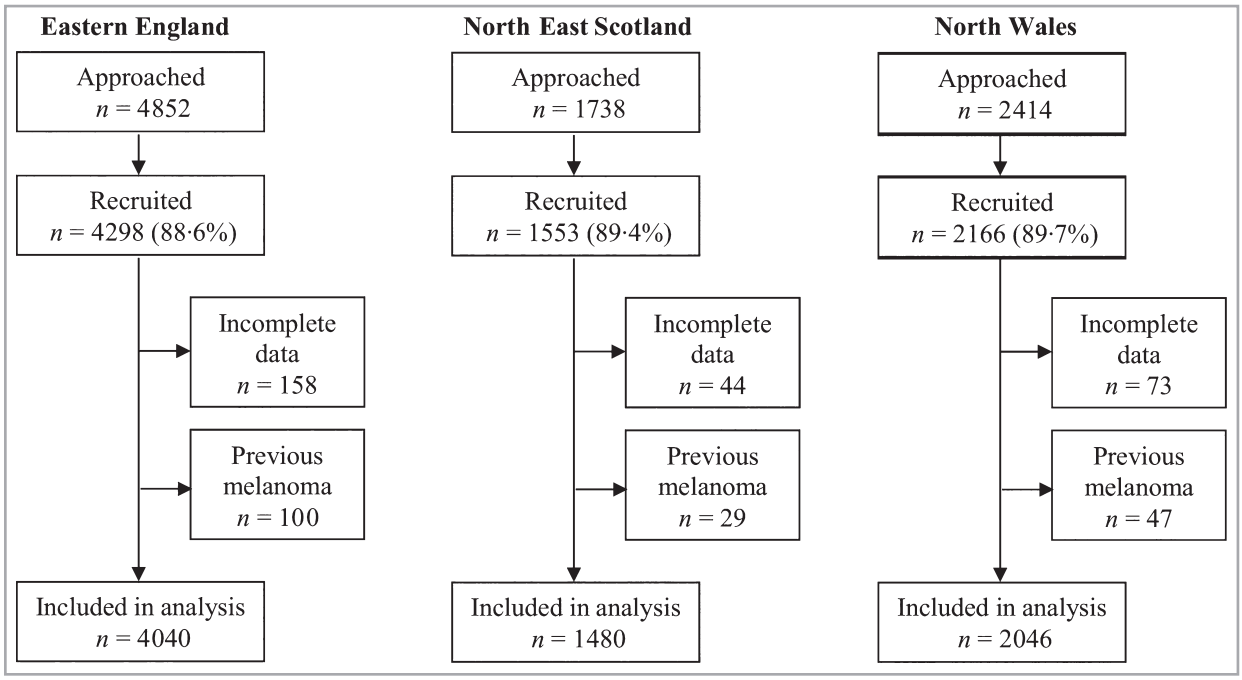

Fig 1. Recruitment flowchart.

perspective, suggest that a single risk stratifying approach could be implemented across the whole U.K. in the future.

The main strength of this study is the method of collecting data. Almost 90% of patients approached while attending routine general practice agreed to take part, and we were able to easily recruit 7742 participants from three regions across the U.K. with an average total researcher time per participant of < 10 min. Furthermore, we were able to collect data from a large sample representing a general practice population of almost a quarter of a million people, and drawn from three distinct regions across the U.K.

This data collection method, however, has its limitations. Firstly, the recruited sample is drawn from those attending general practice, so we acknowledge that we may not have accessed individuals who are reluctant to visit their doctors, and that some selective approaching of potential participants was inevitable. Older people and women will tend to be overrepresented as they attend general practice more often than younger people and men;[23] women are also more likely to be in the practice accompanying young children or more elderly people. To account for this we repeated our analysis with our sample weighted to the practice-registered populations. This requires the assumption that the risk of developing melanoma in the patients not attending the practice is the same as those of the same age and sex who did attend the practice during the recruitment period. We think this assumption is reasonable as most primary care consultations are not related to melanoma or its risk factors. Our sample is also predominantly white (British and others), which limits the generalizability of our findings to other ethnic groups, many of whom would be at lower risk of melanoma. The ethnic distribution of our sample does, however, reflect the regional populations in the three areas, where over 90% are white British, and are likely to be targeted in a risk-stratified melanoma screening programme.

Other limitations include that this was a cross-sectional study with no follow-up. The absence of melanoma outcomes means we are unable to assess the performance of the Williams model in this U.K. population. The estimated 5-year PPVs and NPVs are therefore based on the sensitivity and specificity of the different risk score cut-off values reported from the original paper by Williams *et al.*[20] We acknowledge that the model was self-validated on a fairly small dataset from Washington State, U.S.A., where the cases were all white and aged between 35 and 74. The performance measures reported by Williams *et al.* at the different thresholds are, therefore, estimates calculated from this sample and not the whole population. The model has also not been calibrated for the U.K. population. The age-standardized incidence of melanoma is lower in the U.K. than in the U.S.A. (17·3 per 100 000 for England in 2011,[6] compared with 22·9 per 100 000 in the U.S.A. in 2011[24]), so the sensitivity may be slightly higher and the specificity slightly lower due to spectrum effect. We also excluded patients with previous melanoma, while national incidence data include all new cases of melanoma. The Williams model does not contain some expected risk factors such as family history of skin cancer and skin colour. Our review found that family history was absent in many models: it was considered in 18 of the models but only remained in the final score in six.[17] Finally, most of the questions were asking either about the past and so subject to recall bias, or required participants to count raised moles. However, the same biases

Table 3 Sociodemographic characteristics of participants

Characteristic	Eastern England, n (%)	North East Scotland, n (%)	North Wales, n (%)	Total, n (%)	Population > 20 years registered at all practices, n (%)
Sex					
Male	1399 (34·6)	517 (34·9)	775 (37·9)	2691 (35·6)	91 593 (49·5)
Female	2641 (65·4)	963 (65·1)	1271 (62·1)	4875 (64·4)	93 560 (50·5)
Age (years)					
20–35	916 (22·7)	298 (20·1)	567 (27·7)	1781 (23·5)	43 286 (23·4)
35–44	692 (17·1)	218 (14·7)	335 (16·4)	1245 (16·5)	32 500 (17·5)
45–54	671 (16·6)	238 (16·1)	351 (17·2)	1260 (16·7)	35 804 (19·3)
55–64	611 (15·1)	264 (17·8)	325 (15·9)	1200 (15·9)	29 245 (15·8)
65–74	630 (15·6)	260 (17·6)	317 (15·5)	1207 (16·0)	24 374 (13·2)
≥ 75	520 (12·9)	202 (13·6)	151 (7·4)	873 (11·5)	19 944 (10·8)
Ethnic group					
White British	3620 (89·6)	1372 (92·7)	1945 (95·1)	6937 (91·7)	–
White other	224 (5·5)	75 (5·1)	63 (3·1)	362 (4·8)	–
Mixed	27 (0·7)	9 (6·1)	5 (0·2)	41 (0·5)	–
Asian or Asian British	87 (2·2)	9 (6·1)	12 (0·6)	108 (1·4)	–
Black or black British	35 (0·9)	5 (0·3)	7 (0·3)	47 (0·6)	–
Chinese	12 (0·3)	2 (0·1)	5 (0·2)	19 (0·3)	–
Other ethnic group	35 (0·9)	8 (0·5)	9 (0·4)	52 (0·7)	–
Education					
None	719 (17·8)	295 (19·9)	349 (17·1)	1363 (18·0)	–
GCSE, O-level or CSE	975 (24·1)	285 (19·2)	528 (25·8)	1788 (23·6)	–
Vocational	684 (16·9)	293 (19·8)	387 (18·9)	1364 (18·0)	–
A-level or equivalent	570 (14·1)	162 (10·9)	271 (13·2)	1003 (13·3)	–
Undergraduate degree	386 (9·6)	190 (12·8)	210 (10·3)	786 (10·4)	–
Postgraduate degree or professional qualification	706 (17·5)	255 (17·2)	301 (14·7)	1262 (16·7)	–
Employment status					
Retired	1276 (31·6)	481 (32·5)	517 (25·3)	2274 (30·1)	–
Unemployed, seeking work	99 (2·5)	29 (2·0)	63 (3·1)	191 (2·5)	–
Unemployed, unable to work	63 (1·6)	23 (1·6)	72 (3·5)	158 (2·1)	–
Student	67 (1·7)	54 (3·6)	64 (3·1)	185 (2·4)	–
Working part time	778 (19·3)	288 (19·5)	331 (16·2)	1397 (18·5)	–
Working full time	1393 (34·5)	472 (31·9)	849 (41·5)	2714 (35·9)	–
Home carer/homemaker	308 (7·6)	97 (6·6)	100 (4·9)	505 (6·7)	–
Permanently sick or disabled	56 (1·3)	36 (2·4)	50 (2·4)	142 (1·9)	–

GCSE, General Certificate of Secondary Education; CSE, Certificate of Secondary Education.

would be true for the original Williams model, which performed well in an external validation cohort and in this study we additionally included photographs of moles and freckles to help participants distinguish between them, which, if anything, would be expected to improve the performance of the model.

Only one similar study has been conducted for melanoma risk,[25] where patients at 16 English general practices completed a paper questionnaire based on a risk score developed by Mackie.[26] While this is, therefore, the first study to use tablet computers to collect melanoma or any other cancer-specific risk factor information in general practice waiting rooms, tablet computers have been used in this setting previously. One collected general health risk information from patients attending an Aboriginal Community Controlled Health Service in Australia,[27] and two U.K. vignette-based studies have recently investigated ethnic differences in preferences for prostate cancer investigation,[28] and for investigation for possible lung, colorectal and pancreatic cancer:[29] both had high (> 70%) recruitment rates. This study therefore supports the increasing interest in making the most of the 'waiting room wait', both for clinical practice and research. It also identifies a number of factors to be considered when recruiting participants from primary care waiting rooms, in particular the need to consider the layout of the waiting room and patient flow through each practice and, where possible, select times when there are more appointments with general practitioners and fewer for very short consultations such as blood tests or flu vaccinations. However, as we did in this study, it remains important to sample at different times during the day to provide the opportunity to recruit a range of patient groups. For example, working individuals may favour early and late

Table 4 Risk factor profile of participants

Risk factor	Point score	Eastern England, n (%)	North East Scotland, n (%)	North Wales, n (%)	All, n (%)
Sex					
Male	7	1399 (34·6)	517 (34·9)	775 (37·9)	2691 (35·6)
Female	0	2641 (65·4)	963 (65·1)	1271 (62·1)	4875 (64·4)
Age (years)					
< 44	0	1608 (39·8)	516 (34·9)	902 (44·0)	3026 (40·0)
45–54	5	671 (16·6)	238 (16·1)	351 (17·2)	1260 (16·7)
55–64	8	611 (15·1)	264 (17·8)	325 (15·9)	1200 (15·9)
≥ 65	11	1150 (28·5)	462 (31·2)	468 (22·9)	2080 (27·5)
Natural hair colour at age 15 years					
Dark brown/black	0	1518 (37·6)	579 (39·1)	811 (39·6)	2908 (38·4)
Light brown	4	1634 (40·4)	574 (38·8)	830 (40·6)	3038 (40·2)
Blond	5	718 (17·8)	230 (15·5)	306 (15·0)	1254 (16·6)
Red	8	170 (4·2)	97 (6·6)	99 (4·8)	366 (4·8)
Number of severe sunburns aged 2–18 years					
None	0	2111 (52·2)	698 (47·2)	892 (43·6)	3701 (48·9)
1–4	1	1623 (40·2)	609 (41·1)	964 (47·1)	3196 (42·2)
5–9	4	197 (4·9)	94 (6·4)	121 (5·9)	412 (5·4)
10 or more	7	109 (2·7)	79 (5·3)	69 (3·4)	257 (3·4)
Prior nonmelanoma skin cancer					
No	0	3930 (97·3)	1457 (98·4)	1996 (97·6)	7383 (97·6)
Yes	13	110 (2·7)	23 (1·6)	50 (2·4)	183 (2·4)
Number of raised moles on both arms					
None	0	2654 (65·7)	1020 (68·9)	1298 (63·4)	4972 (65·7)
1	3	618 (15·3)	163 (11·0)	279 (13·6)	1060 (14·0)
2	5	312 (7·7)	123 (8·3)	202 (9·9)	637 (8·4)
3 or more	11	456 (11·3)	174 (11·8)	267 (13·1)	897 (11·9)
Density of freckles on arms before age 20 years					
None	0	1793 (44·4)	591 (40·0)	707 (34·6)	3091 (40·9)
A few	4	1309 (32·4)	481 (32·5)	792 (38·7)	2582 (34·1)
Several	6	518 (12·8)	159 (10·7)	261 (12·8)	938 (12·4)
A lot	10	420 (10·4)	249 (16·8)	286 (14·0)	955 (12·6)
Total score: mean (±SD)		16·8 (8·5)	17·9 (8·4)	17·4 (8·6)	17·1 (8·5)

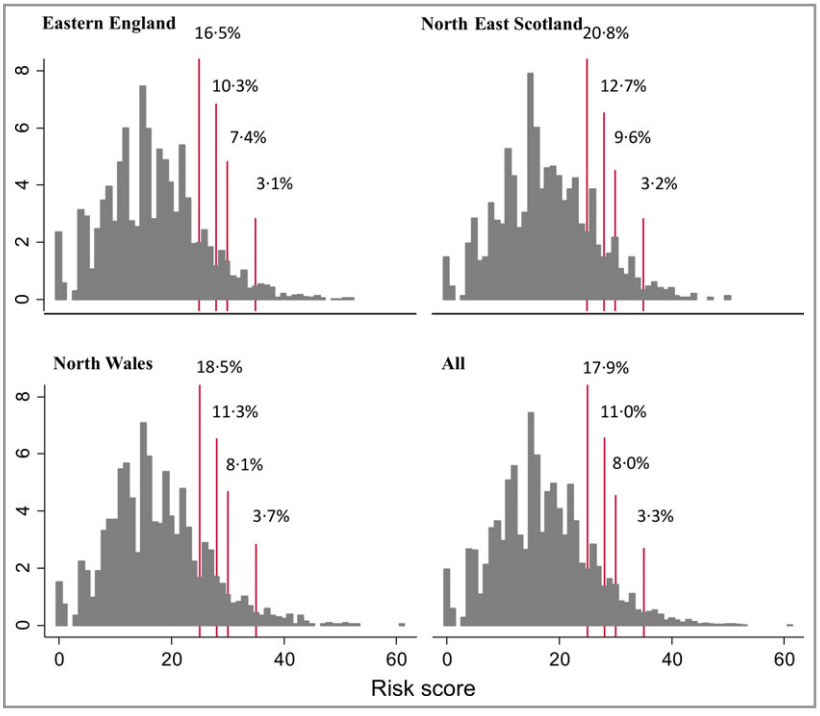

Fig 2. Distribution of risk scores. Vertical lines mark the four different score cut-offs (25, 28, 30 and 34) of the Williams model[20] melanoma risk score with the percentage of participants above each threshold alongside.

Table 5 The population above various risk score cut-offs of the Williams model melanoma risk score[20] along with the estimated positive predictive values (PPVs) and negative predictive values (NPVs)

Region	Williams risk score cut-off	Sample above cut-off (%)	Practice population above cut-off (%)[a]	Estimated 5-year PPV (%)[b]	Estimated 5-year NPV (%)[c]
Eastern England	25	16·5	17·7	3·1	99·5
	28	10·3	11·0	3·4	99·4
	30	7·4	7·9	4·3	99·3
	34	3·1	3·5	5·7	99·2
North East Scotland	25	20·8	22·4	3·4	99·4
	28	12·7	12·9	3·7	99·3
	30	9·6	9·8	4·7	99·3
	34	3·2	3·6	6·2	99·1
North Wales	25	18·5	19·3	3·7	99·4
	28	11·3	12·2	3·9	99·3
	30	8·1	8·5	4·8	99·2
	34	3·7	4·9	6·3	99·1
All	25	17·9	19·4	–	–
	28	11·0	11·8	–	–
	30	8·0	8·6	–	–
	34	3·3	3·9	–	–

[a]Weighted for the age and sex of the registered population in each participating practice. [b]Estimated 5-year PPV: the estimated proportion of the population considered higher risk who would be diagnosed with melanoma in the next 5 years, assuming the same performance of the Williams model as reported in Williams *et al.* 2011 and a prevalence of newly diagnosed cases of 104·5 per 100 000 for England (the 2011 crude incidence of melanoma in England from data from the Office of National Statistics multiplied by 5), 119 per 100 000 for Wales (the 2011 crude incidence of melanoma in Wales from the Welsh Cancer Intelligence and Surveillance Unit) and 114·5 per 100 000 for Scotland (the 2011 crude incidence of melanoma in Scotland from the Cancer Information Programme, Information Services Division Scotland). [c]Estimated 5-year NPV – the estimated proportion of the population considered low risk who would not be diagnosed with melanoma in the next 5 years, assuming the same performance of the Williams model as reported in Williams *et al.*[20] and a prevalence of newly diagnosed cases of 104·5 per 100 000 for England (the 2011 crude incidence of melanoma in England from data from the Office of National Statistics multiplied by 5), 119 per 100 000 for Wales (the 2011 crude of melanoma in Wales from the Welsh Cancer Intelligence and Surveillance Unit) and 114·5 per 100 000 for Scotland (the 2011 crude incidence of melanoma in Scotland from the Cancer Information Programme, Information Services Division Scotland).

appointments, older patients may favour appointments in the middle of the day and parents with children may favour after school appointments.

This study also provides useful evidence for the planning and development of future screening and educational programmes in the U.K. for people at higher risk of melanoma. It shows that collecting information on risk factors in general practices across the U.K. is feasible and acceptable to patients, and that use of a melanoma risk model allows stratification of the population into different risk groups. The small differences in risk profiles between the three U.K. regions are also consistent with U.K. melanoma incidence rates, which show only small and nonstatistically significant differences,[30] and suggest that a single approach could be introduced across the U.K.

Identifying those at higher risk in this way, therefore, could allow screening, surveillance or education programmes to be targeted at those most likely to benefit, including specific advice and support via primary care. In particular, the risk stratification could be used to determine the interval for surveillance, with those at higher risk being recommended to have more frequent screening. This is of particular relevance to conditions like melanoma where the overall incidence is low but the benefits of prevention or identifying people with disease earlier are substantial. The low incidence means interventions at the whole population level have considerable implications in terms of healthcare costs to benefit only a small number for whom early detection could improve treatment options, reduce morbidity and mortality, and both physical and psychological consequences to the large numbers who are unlikely to ever develop the condition.[31]

The proportion of the population in the higher-risk group depends on the choice of risk cut-off point. As with all screening there is a trade-off between sensitivity and specificity. A cut-off with higher sensitivity will increase the proportion of those likely to go on to develop melanoma being identified as higher risk, but at the expense of a lower specificity and a larger proportion of the population classified as higher risk. Using the four cut-off points of the Williams model in this study would identify between 4% and 20% of the population as candidates for a targeted intervention, and those groups would contain between approximately 30% and 60% respectively, of those likely to develop melanoma. This is not dissimilar to the 8·7% of the population identified as 'worryingly high risk' or 'very increased risk' in the study by Jackson *et al.*[25] While such strategies are likely to increase local referral rates and dermatology workload, and there is a U.K. shortage

of dermatologists, a recent review suggests that melanoma early detection programmes might be cost-effective[14] if targeted at high-risk populations such as older men[32] or those with a family history of melanoma.[12] It is likely that identifying higher-risk individuals using a risk score would be more cost-effective, but further studies are needed to confirm this and to determine the most cost-effective intervals for surveillance amongst those at different levels of risk.

The finding that collecting risk information in waiting rooms in general practices across the U.K. using tablet computers was both feasible and acceptable to patients also has implications beyond screening for melanoma. In addition to completing risk assessment questionnaires, patients could also: identify consultation goals and enable doctors to better tailor appointments; be provided with educational material; and complete decision aids.[33] The acceptability of a self-completed tool also suggests that similar approaches could be used more widely in settings outside the waiting room, such as in pharmacies or secondary care, as well as potentially via web-based applications.

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