INVESTIGATIVE REPORT

Mobile Teledermatology is a Valid Method to Estimate Prevalence of Melanocytic Naevi in Children

Maria A. KARLSSON[1], Bernt LINDELÖF[1], Carl-Fredrik WAHLGREN[1], Kerstin WIKLUND[2] and Ylva RODVALL[3]

[1]Dermatology and Venereology Unit, Karolinska University Hospital, Department of Medicine Solna, Karolinska Institutet, [2]Karolinska Institutet, and [3]Department of Public Health Sciences, Karolinska Institutet, Stockholm, Sweden

The prevalence of melanocytic naevi in children correlates with sun exposure and may serve as an objective population risk indicator of future melanoma incidence. The aim was to investigate if mobile teledermatology could offer a valid methodology compared with standard manual, face-to-face counting of naevi on the back of children. Ninety-seven children aged 7–16 years were enrolled. One dermatologist performed manual naevi counting and imaging of the child's back using an iPhone 4S comprising a safe-coded mobile application. Two other dermatologists independently counted naevi from the images. Cohen's weighted kappa (κ_w) coefficient demonstrated substantial agreement for both dermatologists: $\kappa_w = 0.69$ (0.57–0.81 [95% confidence intervals]) and $\kappa_w = 0.78$ (0.70–0.86), compared with the manual assessment. Inter-rater reliability was also substantial ($\kappa_w = 0.80$ [0.73–0.87]). Use of mobile teledermatology proved valid for estimating naevi prevalence on the back and could provide a more feasible methodology following trends in sun exposure in children. *Key words: children; naevi; mobile teledermatology; public health.*

Maria A. Karlsson MD. Department of Dermatology, Karolinska University Hospital Solna, Department of Medicine Solna, Karolinska Institutet, SE-171 76 Stockholm, Sweden. E-mail: maria.karlsson@karolinska.se

More than 3 decades of intense public campaigning for better sun protection has not yet given but few indications for a visible reduction of cutaneous malignant melanoma (CMM) incidence (1–3). A less latent variable for validating the effects of sun preventive actions is by studying numbers of common melanocytic naevi (CMN) in children. Previous research has demonstrated that CMN density in children is readily affected by changes in sun protective regimens and can in itself be used as an objective population risk indicator of sun exposure (4–6).

Manual, face-to-face counting of CMN has hitherto been the gold standard when performing population-based studies among children. However, in distant geographic regions or if attempting larger surveys, the manual counting procedure has limitations regarding costs and time-effectiveness.

The use of teledermatology and teledermoscopy for the remote evaluation of skin lesions is a rapidly emerging field of research. By its store-and-forward technology it offers advantages, e.g. abolishing travel costs and lead times for dermatologic evaluations (7). The technique has shown good patient-acceptance (8), accuracy and user-friendliness (9–11). However, the quality of the images can vary and especially mobile applications with automatic diagnostic algorithms linked have been questioned (12, 13). Hitherto, the use of teledermatology among children and adolescents has been scarcely studied (14, 15).

The aim of this study was to investigate the validity and usability of mobile teledermatology for the remote assessment of numbers and size of CMN on the backs of children for the purpose of monitoring trends in sun exposure.

MATERIAL AND METHODS

Study population

Children aged 7 to 16 years, with skin photo type I–IV (16), attending the Paediatric Dermatology outpatient clinic at Karolinska University Hospital, Stockholm between May 2012 and January 2013 were eligible for inclusion. The children and accompanying parents were asked to take part in the study in conjunction to their scheduled doctor's visit. The study was approved by the Regional Ethical Review Board at Karolinska Institutet (2012/225-31/3).

Manual counting and mobile phone imaging of common melanocytic naevi

The manual counting of CMN and digital imaging was performed by the same dermatologist (MAK). The child's back was defined as the area from the nape of the neck, including the shoulders and down to the iliac crest. The International Agency for Research on Cancer (IARC) protocol defining naevus characteristics was followed (17), and CMN of any type were included. The location of each naevus on the back was recorded on an anatomical paper chart and a plastic template was used to define 3 size categories: <2 mm, ≥2 to <6 mm or ≥6 mm. A small sticker with a mm scale was placed adjacent to a naevus approximately 2 mm of size. This naevus represented an "index naevus" used as a size reference facilitating later size assessments from the digital images.

An iPhone 4S comprising an 8.0 megapixel camera downloaded with the mobile application Dermicus was used for the digital imaging (18, 19). Dermicus is a CE marked, interactive telemedicine system developed at Karolinska University Hospital and used for dermatological consultations between primary health care givers and selected dermatologists. The application has a safely coded login system and all images are sent encrypted to a file on an external server certified for high security storage.

Evaluating numbers and size of common melanocytic naevi from digital images

After having completed the clinical examinations, 2 other dermatologists (CFW and BL) independently viewed all digital images, estimated the total number and sizes of CMN and indicated the location of each naevus on an anatomical paper chart. They were blinded to each other's result as well as to the results of the manual counting. To standardise the CMN evaluation process, the images that had not been altered or compressed, were viewed in Microsoft PowerPoint slideshow mode on a 19-inch computer screen. Presence of any other skin eruptions, e.g. excoriations, scars, eczema or acne, was also indicated on the charts.

Statistical methodology

Mean and median numbers of CMN on the back were calculated. To assess the inter-method reliability a Cohen's kappa analysis weighted according to Cicchetti-Allison was performed. The weighted kappa analysis was also used for comparing the inter-rater reliability between the 2 dermatologists counting CMN from digital images. Strength of agreement according to Landis and Koch for value of kappa was set to: ≤ 0 Poor, 0.01–0.20 Slight, 0.21–0.40 Fair, 0.41–0.60 Moderate, 0.61–0.80 Substantial, and 0.81–1.00 Almost perfect agreement.

RESULTS

Of a total of 114 children eligible for inclusion, 109 children and their parents accepted to take part in the study and 5 children declined. In 12 separate cases (11%) the transmission of the digital images from the mobile application to the external server failed. If no errand number was received this rendered exclusion. Final statistical analyses were based on 97 children (41 boys, 56 girls). Median age was 11 years (range 7–16 years). The distribution of skin photo types was I (0%), II (17%), III (55%) and IV (28%).

Counting total numbers of common melanocytic naevi manually versus from digital images

The total mean number of CMN counted by manual procedure were 9.4 (SD 12.5) and for the 2 dermatologists counting CMN from digital images the results were well comparable: 10.6 (SD 12.3) and 9.6 (SD 13.7), respectively (Table I). The inter-method reliability for the total number of CMN showed substantial agreement for both dermatologists when compared with the manual counting: dermatologist 1 ($\kappa_w = 0.69$

Table I. *Crude, mean and median numbers of common melanocytic naevi counted manually versus from digital images by dermatologist 1 and 2 (*n = 97*)*

	Common melanocytic naevi			
	All sizes	<2 mm	≥ 2 to <6 mm	≥ 6 mm
Manual counting (0–90)				
Crude	917 (100%)	490 (53%)	420 (46%)	7 (1%)
Mean (SD)	9.4 (12.5)	5.1 (5.5)	4.3 (8.2)	0.1 (0.4)
Median (IQR)	6.0 (4.0–10.0)	4.0 (2.0–7.0)	2.0 (1.0–4.0)	0.0 (0.0–0.0)
Dermatologist 1 (0–94)				
Crude	1,027 (100%)	299 (29%)	690 (67%)	38 (4%)
Mean (SD)	10.6 (12.3)	3.1 (3.6)	7.1 (10.1)	0.4 (1.0)
Median (IQR)	7.0 (4.0–13.0)	2.0 (1.0–4.0)	5.0 (2.0–8.0)	0.0 (0.0–0.0)
Dermatologist 2 (0–106)				
Crude	931 (100%)	413 (44%)	506 (54%)	12 (1%)
Mean (SD)	9.6 (13.7)	4.3 (7.7)	5.2 (7.2)	0.1 (0.4)
Median (IQR)	6.0 (3.0–11.0)	2.0 (1.0–5.0)	3.0 (2.0–6.0)	0.0 (0.0–0.0)

SD: standard deviation; IQR: interquartile range.

(0.57–0.81 [95% CI]) and dermatologist 2 ($\kappa_w = 0.78$ [0.70–0.86]). Inter-rater reliability was also substantial ($\kappa_w = 0.80$ [0.73–0.87]) between the 2 dermatologists (Table II).

Assessing common melanocytic naevi size manually versus from digital images

Results based on the 3 CMN size categories indicated that the raters allocated CMN sizes somewhat differently (Table I). CMN <2 mm demonstrated fair agreement for dermatologist 1 ($\kappa_w = 0.28$ [0.17–0.38]) and moderate agreement for dermatologist 2 ($\kappa_w = 0.55$ [0.46–0.64]) versus the manual assessment (Table II). For CMN category ≥ 2 to <6 mm, agreement was moderate for dermatologist 1 ($\kappa_w = 0.54$ [0.39–0.70]) and substantial for dermatologist 2 ($\kappa_w = 0.68$ [0.56–0.80]). Inter-rater reliability was moderate for CMN < 2 mm ($\kappa_w = 0.49$ [0.37–0.61]) and substantial for CMN ≥ 2 to <6 mm ($\kappa_w = 0.64$ [0.54–0.75]). The observations of CMN ≥ 6 mm were very few and agreement analysis was therefore not undertaken.

Table II. *Cohen's weighted kappa analyses for common melanocytic naevi (CMN) counted manually versus from digital images by dermatologist 1 and 2*

	κ_w (95% confidence intervals)[a]		
	All sizes	<2 mm	≥ 2 to <6 mm
Manual counting versus	0.69	0.28	0.54
Dermatologist 1	(0.57–0.81)	(0.17–0.38)	(0.39–0.70)
Agreement	Substantial	Fair	Moderate
Manual counting versus	0.78	0.55	0.68
Dermatologist 2	(0.70–0.86)	(0.46–0.64)	(0.56–0.80)
Agreement	Substantial	Moderate	Substantial
Dermatologist 1 versus	0.80	0.49	0.64
Dermatologist 2	(0.73–0.87)	(0.37–0.61)	(0.54–0.75)
Agreement	Substantial	Moderate	Substantial

[a]Cohen's Cicchetti-Allison weighted kappa coefficient.

DISCUSSION

Mobile teledermatology proved to be a feasible and valid method for the remote assessment of CMN on the back of children. Internet-based surveillance of public health will in future likely be more widely utilised and objective parameters, such as CMN in children, may provide candidate biomarkers correlating with sun exposure. The major advantage of using the mobile teledermatology system in this context lies in the safe-coded transmission and storage of images and the potential to attach survey data through the same software platform. The back represents a two-dimensional surface anatomically suitable for photographic imaging and density of CMN on the back correlates well with whole-body CMN counts (20, 21). The back also represents a body site mainly subjected to intermittent sun exposure which associates with both CMN and CMM development (22).

This study was set in a dermatologic clinic and thus comprised children with a higher prevalence of common skin diseases compared with the general population. This enabled evaluation of how different skin conditions influenced the accuracy of CMN identification from images. Both dermatologists commented that eczema with excoriations, acne or extensive numbers of CMN aggravated the counting process. Nonetheless, these cases were not excluded from the analyses and the results still demonstrated a substantial agreement.

The rationale for attempting to estimate CMN size based on images was the potential to link results from any future teledermatological surveys to previous face-to-face studies, most of which comprise CMN ≥ 2 mm. The statistical analyses demonstrated that while agreement between raters for CMN of any size was substantial, a slightly lower agreement was seen for CMN ≥ 2 mm to < 6 mm and even lower agreement for CMN < 2 mm. Results for dermatologist 1 deviated most from the manual CMN size assessment, and a post-study evaluation of the paper charts disclosed that this mainly was due to differences in the size estimations of same CMN. The results could imply that a pre-study validation of manual CMN sizing between all 3 dermatologists potentially would have improved the results. However, the results are in line with English & Armstrong (23) and Aitken et al. (24) who have demonstrated that even when exclusively counting CMN manually, total numbers of CMN consistently yield higher intra-class and inter-class correlation compared with CMN within a certain size category. Also from a utility perspective, the size estimation process when monitoring the digital images was acknowledged as laborious.

As CMN growth by nature is continuous rather than ordinal and in children often borders 2 mm, aiming a cut-off in this size range may risk undermining the temporal benefits of using mobile teledermatology.

In future, the linkage of an automatized standard size template to the mobile application may be a technical development addressing the issue of CMN size.

Use of mobile teledermatology requires a sufficient internet connection which may limit its use in geographic regions with less established wireless network coverage. The mobile application used in this study is continuously maintained to optimise performance, and although the network signal indicated strong, failure when sending the images to the external server was experienced in 11% of cases. No cause could be detected and repeated imaging was not attempted as the clinical visits were limited in time.

In conclusion, this study demonstrated that mobile teledermatology is an easy applicable method providing clinical images of children valid for remote counting of the total number of CMN on the back. The technique needs to be further investigated in out-clinic settings, e.g. by involving medical personnel in health centres or schools. Implemented on a broader population basis mobile teledermatology has the potential to facilitate the surveillance of trends in sun exposure among children.

REFERENCES

1. Erdmann F, Lortet-Tieulent J, Schuz J, Zeeb H, Greinert R, Breitbart EW, et al. International trends in the incidence of malignant melanoma 1953–2008 – are recent generations at higher or lower risk? Int J Cancer 2013; 132: 385–400.
2. Gandini S, Autier P, Boniol M. Reviews on sun exposure and artificial light and melanoma. Prog Biophys Mol Biol 2011; 107: 362–366.
3. Iannacone MR, Youlden DR, Baade PD, Aitken JF, Green AC. Melanoma incidence trends and survival in adolescents and young adults in Queensland, Australia. Int J Cancer 2014 May 8. [Epub ahead of print].
4. Pfahlberg A, Uter W, Kraus C, Wienecke WR, Reulbach U, Kolmel KF, et al. Monitoring of nevus density in children as a method to detect shifts in melanoma risk in the population. Prev Med 2004; 38: 382–387.
5. Karlsson MA, Wahlgren CF, Wiklund K, Rodvall Y. Parental sun-protective regimens and prevalence of common melanocytic naevi among 7-year-old children in Sweden: changes over a 5-year period. Br J Dermatol 2011; 164: 830–837.
6. Smith A, Harrison S, Nowak M, Buettner P, Maclennan R. Changes in the pattern of sun exposure and sun protec-

tion in young children from tropical Australia. J Am Acad Dermatol 2013; 68: 774–783.

7. Wootton R, Bahaadinbeigy K, Hailey D. Estimating travel reduction associated with the use of telemedicine by patients and healthcare professionals: proposal for quantitative synthesis in a systematic review. BMC Health Serv Res 2011; 11: 185.

8. Hsueh MT, Eastman K, McFarland LV, Raugi GJ, Reiber GE. Teledermatology patient satisfaction in the Pacific Northwest. Telemed J E Health 2012; 18: 377–381.

9. Kroemer S, Fruhauf J, Campbell TM, Massone C, Schwantzer G, Soyer HP, et al. Mobile teledermatology for skin tumour screening: diagnostic accuracy of clinical and dermoscopic image tele-evaluation using cellular phones. Br J Dermatol 2011; 164: 973–979.

10. Boyce Z, Gilmore S, Xu C, Soyer HP. The remote assessment of melanocytic skin lesions: a viable alternative to face-to-face consultation. Dermatology 2011; 223: 244–250.

11. Lamel SA, Haldeman KM, Ely H, Kovarik CL, Pak H, Armstrong AW. Application of mobile teledermatology for skin cancer screening. J Am Acad Dermatol 2012; 67: 576–581.

12. Wolf JA, Moreau JF, Akilov O, Patton T, English JC, 3rd, Ho J, et al. Diagnostic inaccuracy of smartphone applications for melanoma detection. JAMA Dermatol 2013; 149: 422–426.

13. Robson Y, Blackford S, Roberts D. Caution in melanoma risk analysis with smartphone application technology. Br J Dermatol 2012; 167: 703–704.

14. Chen TS, Goldyne ME, Mathes EF, Frieden IJ, Gilliam AE. Pediatric teledermatology: observations based on 429 consults. J Am Acad Dermatol 2010; 62: 61–66.

15. Heffner VA, Lyon VB, Brousseau DC, Holland KE, Yen K. Store-and-forward teledermatology versus in-person visits: a comparison in pediatric teledermatology clinic. J Am Acad Dermatol 2009; 60: 956–961.

16. Fitzpatrick TB. The validity and practicality of sun-reactive skin types I through VI. Arch Dermatol 1988; 124: 869–871.

17. English DR MacLennan R, Rivers J, Kelly J, Armstrong BK. Epidemiological studies of melanocytic naevi: protocol for identifying and recording naevi. IARC International report, Lyon France 1990; 90/002.

18. Dermicus [Internet]. Available from: http://apegroup.com/project/dermicus.

19. Carmona AB [Internet]. Available from: http://www.carmona.se/ovriga-tjanster/.

20. Synnerstad I, Nilsson L, Fredrikson M, Rosdahl I. Frequency and distribution pattern of melanocytic naevi in Swedish 8-9-year-old children. Acta Derm Venereol 2004; 84: 271–276.

21. Gallus S, Naldi L, Carli P, La Vecchia C, Italian Group for Epidemiologic Research in D. Nevus count on specific anatomic sites as a predictor of total body count: a survey of 3,406 children from Italy. Am J Epidemiol 2007; 166: 472–478.

22. Dodd AT, Morelli J, Mokrohisky ST, Asdigian N, Byers TE, Crane LA. Melanocytic nevi and sun exposure in a cohort of colorado children: anatomic distribution and site-specific sunburn. Cancer Epidemiology, Biomarkers and Prevention 2007; 16: 2136–2143.

23. English DR, Armstrong BK. Melanocytic nevi in children. II. Observer variation in counting nevi. Am J Epidemiol 1994; 139: 402–407.

24. Aitken JF, Green A, Eldridge A, Green L, Pfitzner J, Battistutta D, et al. Comparability of naevus counts between and within examiners, and comparison with computer image analysis. Br J Cancer 1994; 69: 487–491.