Acta Derm Venereol 2004; 84: 422–427

Taylor & Francis
healthsciences

INVESTIGATIVE REPORT

Comparison of Clinical and Computerized Image Analyses in the Assessment of Skin Ageing in Smokers and Non-smokers

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Tobacco smoke and UV radiation are extrinsic risk factors for accelerated skin ageing. In this study the effects of smoking on wrinkling and ageing were assessed in males living in Northern Finland, where cumulative sun exposure is low. Smoking habits, age and facial wrinkling were estimated from facial photographs of 41 smokers and 48 non-smokers by eight panellists, using a blinded standardized assessment. Wrinkling of 26 smokers and 31 non-smokers was also assessed by computerized image analysis. The panellists identified 68% of the smokers correctly as being smokers and the smokers were estimated as being an average of 2.1 years older than their age by the panellists, whereas the non-smokers were estimated as being an average of 0.7 years younger than their age ($p < 0.05$). No significant difference in skin wrinkling was found between the groups by either clinical assessment or by computerized image analysis. In conclusion, even in the absence of increased wrinkling, the smokers looked older than their age and a majority of them could be identified as smokers by their facial features alone. ***Key words: smoking; skin; ageing; wrinkles; computerized image analysis.***

(Accepted April 13, 2004.)

Acta Derm Venereol 2004; 84: 422–427.

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Skin ageing is due to intrinsic ageing, where genetic factors play a major role, and extrinsic ageing, in which sun exposure is a well known factor, with distinct clinical and histological features (1, 2). Tobacco smoke is another potential extrinsic factor contributing to skin ageing, but surprisingly little is known of the effects of smoking on skin. Tobacco smoke extract alters the function of human skin fibroblasts and affects the extracellular matrix turnover *in vitro* (3) and *in vivo* (4), which could accelerate skin ageing in smokers.

'Smoker's face' was described as early as the 1970s and 1980s (5, 6). Daniell (5) reported increased facial wrinkling in smokers in 1971 and developed a scoring system for the severity of facial wrinkling. The skin of smokers was characterized as having prominent wrinkles in the temporal and perioral regions and a yellowish grey pallor as opposite to the pink skin colour of non-smokers. Model (6) defined 'smoker's face' as having one or more of the following features: a) facial lines or wrinkles, especially in the perioral and crow's foot regions, b) prominence of the bony contours and sinking of the cheeks, c) an atrophic, greyish appearance of the skin, and d) skin complexion varying from a slightly orange colour to purple and red. Smoker's face was present in 46% of the current smokers, 8% of the ex-smokers and none of the non-smokers in the study population. Recently, larger and more carefully designed epidemiological studies have shown that the prevalence of premature wrinkling is independently associated with sun exposure and pack-years of smoking (7–9). Furthermore, smoking is associated with visibly evident premature skin elastosis in both men and women with a history of smoking and with increased facial telangiectasia in male smokers (10). Some studies suggest that the impact of smoking on wrinkling is minimal compared to sun exposure (11–13), whereas others have found that cigarette smoking but not sun exposure is a powerful predictor of skin ageing in older people (14).

The setting and quality of the studies that have addressed the association between smoking and skin wrinkling vary considerably. The definitions of smokers and non-smokers, the climatic conditions and the usage of blinding techniques are not uniform, which may affect the results. Our study was performed to investigate the effects of smoking on appearance in a well defined cohort of smokers and non-smokers who live in a region where yearly sun exposure is scant and the confounding effect of UV exposure on skin ageing is therefore small. We also wanted to assess the usefulness of computerized image analysis as an additional tool for the evaluation of wrinkling.

MATERIALS AND METHODS

Subjects

Eighty-nine Finnish men from Northern Finland were enrolled into the study. All study subjects gave written informed consent. The study protocol was approved by the ethical committee of the Medical Faculty of the University of Oulu. Non-smokers were defined as men who had never been

 ISSN 0001-5555
DOI: 10.1080/00015550410014969

habitual smokers. All smokers were current daily smokers, who had been smoking for an average of 33 years (range 15–56), and the mean number of cigarettes smoked per day was 19 (range 5–40). Pack-years of smoking averaged 30 years. Pack-years of smoking were calculated by multiplying the number of years smoked by the number of packs smoked per day. Of the smokers, 38 were cigarette smokers, two were pipe smokers and one smoked cigars. All pipe and cigar smokers were previous cigarette smokers and were therefore likely to have inhaled tobacco smoke in amounts comparable to cigarette smokers (15). The smoking status of both the smokers and the non-smokers was confirmed by assays of urinary cotinine and other nicotine metabolites, using a commercial double-antibody nicotine metabolite kit (Diagnostic Corporation, Los Angeles, CA, USA). The exclusion criteria consisted of diagnosed diabetes, psoriasis, rheumatoid arthritis, and other diseases requiring long-term corticosteroid treatment.

Sun exposure during the Finnish summer months (from 1 June until the end of August) was recorded as no sun exposure or 1–2 weeks, 3–4 weeks, 5–8 weeks or 9–12 weeks of exposure. The subjects were asked to estimate how many weeks of sun exposure they usually had during that period. High (at least 5 weeks) and low (<5 weeks) sun exposure during the Finnish summer months did not differ between the groups ($p=0.24$). The frequencies of holidays in southern countries and outdoor occupations were also similar in the groups of smokers and non-smokers ($p>0.1$).

Assessment of facial photographs

Facial photographs were available of 89 participants for clinical evaluation of wrinkles. A professional photographer at the studio of Oulu University Hospital took the photographs. The camera used was a Canon EOS 650 with a Canon EF Zoom Macro objective, 35–105 mm, 1:3.5–4.5. A macro setting of 105 mm and a 1:8 ratio to life size was used for the frontal pictures. A Canon T 500 close-up lens, in a 1:4 ratio to life size, was used for the close-up of the temple region. Two Pro 5 1200 Ws studio flashes were used, with a fixed angle of 40°.

A panel of eight members, including three dermatologists, three residents specializing in dermatology and two medical students, performed the standardized assessment of facial wrinkling, smoking status and age of 41 current smokers and 48 never-smokers. One to two panellists at a time were shown the slides of the study subjects at a fixed distance of 2 metres. Two slides of each study subject were shown. The first slide presented a frontal view of the face and the second a close-up of the temple region. The panellists wrote down an estimate of each person's age and smoking status and gave him a wrinkle score based on the scoring system proposed by Daniell (5). Daniell's score was explained to every panel member before starting the task. Clinical examples referring to the Daniell's score are shown in Fig. 1. The scale was graded from I to VI in the following manner. Grade I: facial skin essentially unwrinkled; two or three short (<1.5 cm) shallow lines may be present in the temple region. Grade II: several, usually two to six, significant wrinkles up to 3 cm long may be seen on the temples. Grade III: several prominent wrinkles 3–4 cm in length on the temples together with smaller wrinkles. Increased wrinkling on the forehead but not on the cheeks. Grade IV: wrinkles extend from the temples toward the forehead and the cheek, usually 5 cm or more, or if exceptionally deep, 4 cm in length. Wrinkles extend over the zygomatic ridge. Grade V: wrinkles extend superiorly and inferiorly from the temples and are prominent on the forehead and the cheeks. Grade VI: essentially wrinkled. Profound wrinkling over most of the face.

Computerized image analysis system

Facial photos of 26 smokers and 31 non-smokers were assessed by computerized image analysis. For the computer analyses, the original digitized images were first preprocessed, which included cropping (Fig. 2) and colour feature counting. The preprocessed images were then analysed with self-developed algorithms, which detect the wrinkles from the image by using a line matching technique and then count the percentage area of wrinkle involvement. The final wrinkle percentage of each patient was calculated as an average of the two cropped images. In order to minimize false matches during the final wrinkle assessment, the images were cropped in such a way that only the significant parts of the face were included in the analysis, while such areas as the eyes and eyebrows were rejected. The need to maintain comparability between the results of different patients was the reason for standardizing the cropping of the images. The image in the RGB (red, green, blue) model is based on three independent primary colours, and the value of each component strongly depends on the light intensity of the image. In the present study, the RGB system (normalized colours: red, green, blue) was used, which minimizes errors caused by irregular light intensity in the image. Normalized blue colour (b) was counted from the original colour image with the formula $b=B:(R+G+B)$, where R, G and B have been normalized to be in the range of 0–1.

The final wrinkle assessment is based on a line pattern matching technique, where the cropped gray-scale image is scanned to detect local line patterns. When a local line pattern is found, the algorithm makes a connected components analysis relative to its neighbouring pixels and, depending on previously given parameters, either approves or rejects them as part of the wrinkle. The manually given parameters are threshold, length and minimum size. Threshold is a gray-scale value that determines whether a pixel is part of a wrinkle or normal skin. Length is the minimum length of a local line pattern. Minimum size is the smallest number of pixels in an approved connected component. After wrinkle assessment of the image, the software calculates the percentage area of wrinkle involvement.

Statistical analyses

Statistical analyses were performed with the SPSS 10.1 for Windows software. For calculation of means, independent-samples t-test was used for variables with normal distribution and Mann–Whitney test was used for variables with skewed distributions. Pearson's correlation coefficient was used to evaluate the correlation between the clinical wrinkle scores and the results of computerized image analysis. Cross-tabulation and chi square were used to evaluate categorical variables. Fisher's exact t-test was applied when comparing the panellists' estimation of the ages of the smokers and non-smokers. Confidence intervals were observed when assessing the ability of the panellists to differentiate between smokers and non-smokers and when assessing the estimated age in relation to real age. A p value of <0.05 was considered statistically significant.

RESULTS

The panellists identified 68% of the smokers correctly as smokers, whereas 40% of the non-smokers were

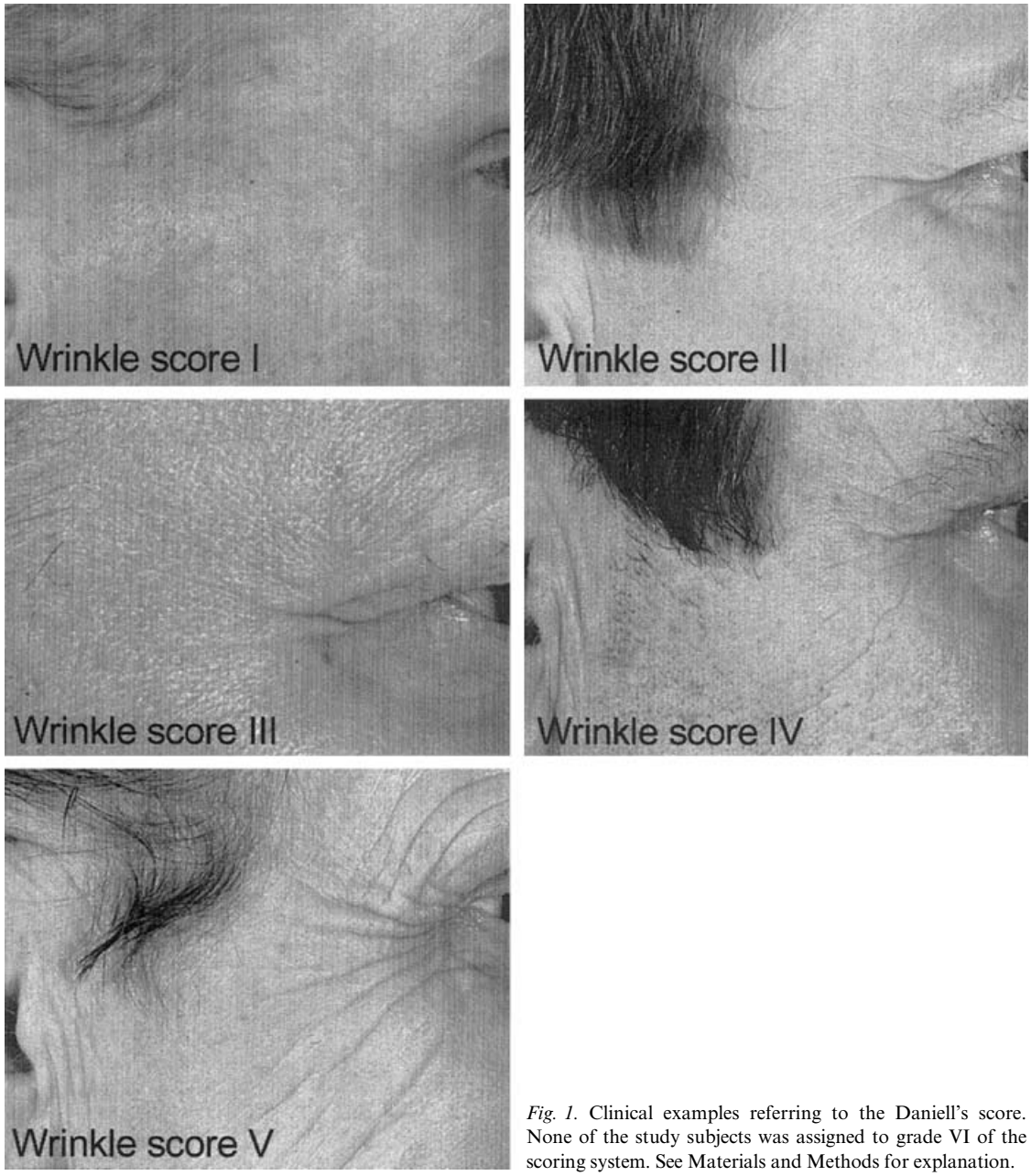

Fig. 1. Clinical examples referring to the Daniell's score. None of the study subjects was assigned to grade VI of the scoring system. See Materials and Methods for explanation.

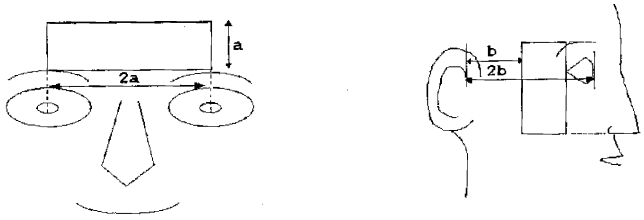

Fig. 2. Cropping of forehead and temple images for computerized image analyses. Anatomical sites were used as landmarks for defining the area under evaluation. In the assessment of the forehead skin, the cropping was performed using mid eye on both sides as cut points for width (2a) and the height was always half of the width (a). In the assessment of the temple skin, the distance from the ear to the eye (2b), divided by two was used to mark the lateral border of the assessment area. The height of the area under evaluation reached from the eyebrow level to the tip of the nose.

falsely estimated to be smokers (Table I). The 95% confidence interval (95% CI) for the difference of 0.68 versus 0.40 was 0.09 – 0.49, which is statistically significant. The smokers tended to be estimated as older than their real age, whereas the non-smokers were often estimated as younger than their age (Table I). The smokers were estimated to be an average of 2.1 years older than their age, whereas the non-smokers were estimated to be an average of 0.7 years younger than their age ($p = 0.005$; 95% CI of the difference 0.88 – 4.69). Based on the confidence intervals, smokers look up to 4.7 years older than non-smokers. However, the clinically assigned wrinkle scores or the percentages of wrinkles obtained by computerized image analyses did not differ significantly between the smokers and the

Table I. *Blinded assessment of the smoking status and age of the study subjects (n=89) by a panel of eight persons*

Panel member	Percentage of smokers ($n=41$) recognized correctly	Percentage of non-smokers ($n=48$) recognized correctly	Percentage of smokers estimated as older/younger than their age	Percentage of non-smokers estimated as older/younger than their age
Dermatologist	59	60	68/29	48/50
Dermatologist	68	56	61/34	46/42
Dermatologist	56	71	66/29	38/56
Resident	78	56	61/29	38/52
Resident	71	75	46/51	13/85
Resident	66	50	63/32	52/44
Student	76	56	76/22	50/42
Student	71	56	66/32	42/46
Mean values	68	60	63/32	41/52

Table II. *Scoring of facial wrinkling (shown as percentages) according to Daniell's score by a panel of eight persons*

	Smokers ($n=41$)		Non-smokers ($n=48$)	
	Wrinkle score I–II	Wrinkle score III–V	Wrinkle score I–II	Wrinkle score III–V
Dermatologist	32	68	19	81
Dermatologist	54	46	48	52
Dermatologist	41	59	42	58
Resident	90	10	94	6
Resident	56	44	71	29
Resident	37	63	31	69
Student	39	61	29	71
Student	44	56	31	69
Mean	49	51	46	54

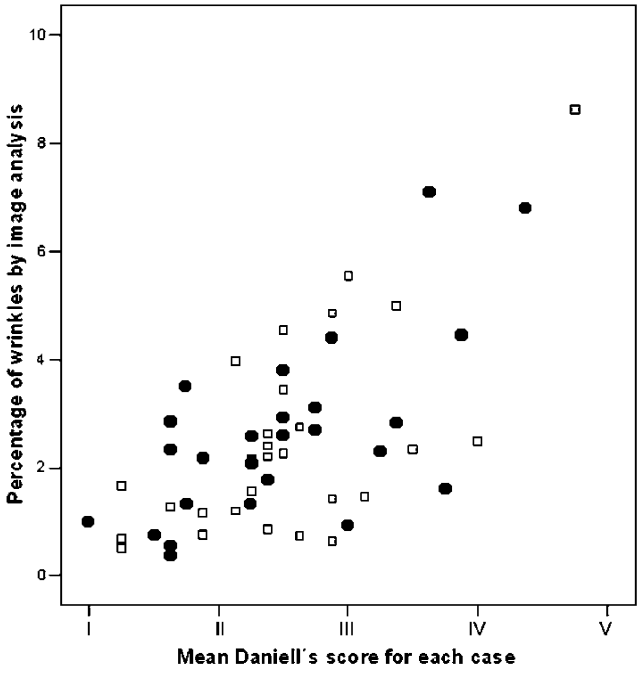

Fig. 3. Correlation between the subjects' mean individual Daniell's scores by the eight panelists and percentages of wrinkles by computerized image analyses. Non-smokers, □; smokers, ●.

non-smokers in this study. Daniell's scores of I–II were assigned to 49% of the smokers and 46% of the non-smokers, and scores above III were assigned to 51% of the smokers and 54% of the non-smokers (Table II). The mean percentage of wrinkles by computerized image analysis was 2.6% for the smokers and 2.3% for the non-smokers ($p=0.35$). On the whole, the clinical wrinkle scores correlated with the percentages of wrinkles obtained by computerized image analyses ($r=0.63$, $p<0.001$, Fig. 3). There was a tendency towards higher Daniell's scores in the smokers with higher pack-year values ($r=0.53$, $p<0.001$), whereas the correlation between pack-years and the percentages of wrinkles obtained by image analysis was weaker ($r=0.37$, $p=0.06$). Wrinkle scores did not differ significantly in the groups of high (at least 5 weeks) versus low (<5 weeks) sun exposure ($p=0.113$), nor did the wrinkle percentages by image analysis ($p=0.089$).

DISCUSSION

In this blinded, standardized assessment of facial wrinkling, neither clinical nor computerized wrinkle assessments revealed statistically significant differences between smokers and non-smokers. However, our

study showed that smokers looked older than their age and could be differentiated from non-smokers even in the absence of increased facial wrinkling. Based on the confidence intervals, smokers look up to 4.7 years older than non-smokers. Interestingly, despite the similar wrinkle scores assigned to the smokers and non-smokers in our study, 68% of the smokers were correctly identified by the panellists as smokers, and 60% of the non-smokers were correctly identified as non-smokers, which is more than has been previously estimated. Model (6) found that only 50% of smokers could be differentiated from non-smokers by their facial features alone. However, it seems evident that facial features other than wrinkles help a person to differentiate a smoker from a non-smoker, as suggested by Model in 1985 (6). More recently, such features as premature grey hair and baldness (16) as well as telangiectasia and visible skin elastosis (10) have been reported as being more frequent in the skin of smokers. In our own previous study, we did not find significant differences in the elasticity of skin or in the number or width of elastic fibres in smokers compared to non-smokers (17).

The definitions of smokers and non-smokers vary considerably from one study to another, as do the settings and study designs. This makes the interpretation and comparison of results from different studies difficult. Our study was conducted in Northern Finland, where the climate and yearly sun exposure differ considerably from the conditions of many of the previous studies. Despite the small number of study subjects ($n=89$), our study has the advantage of evaluating a fairly homogeneous group of age- and sex-matched individuals of Finnish origin who did not differ with respect to the amount of previous sun exposure. Smoking status was confirmed with maximum reliability. The slight difference in the mean ages of the smokers and non-smokers was not statistically significant and is unlikely to explain the lack of increased wrinkling in the smokers in our study. In a large study by Ernster et al. (7), wrinkling was found to be so uncommon among subjects aged <40 that they excluded subjects younger than 40 years from their analysis. In our study, 95% of the subjects were over 40 years of age, and only 5% were under 40, the mean age of the participants being 52 years.

Kadunce and his group (8) found that heavy cigarette smokers were 4.7 times more likely to be wrinkled than non-smokers, and when excessive sun exposure and smoking occurred together, the risk for acquiring excessive wrinkles was multifold. According to Ernster et al. (7), the relative risk of moderate to severe wrinkling for current smokers compared to never-smokers was 2.3 among men and 3.1 among women aged 40 years or more, after controlling for age, sun exposure and body mass index. Since smoking and sun exposure have been observed to mutually potentiate each other's effects on skin ageing, smokers living in regions with intensive sun exposure may be more prone to acquiring wrinkles than those living in countries with less sun exposure, and this may explain the contradictory findings. Our results concerning skin wrinkling support the evidence of the previous studies (12, 13), which questioned the significance of smoking as a causative agent for facial wrinkling. Recently, a large multicentre epidemiological study of 12,735 adults aged between 45 and 60 years was conducted in France, in order to evaluate the risk factors for photo-ageing, and smoking was found to have a slight impact on photo-ageing among women (12). O'Hare et al. (13) had three dermatologists review facial photographs of 82 smokers and 118 non-smokers and concluded that, despite the significant correlation between smoking and facial wrinkling, the role of smoking as a cause of wrinkles is small. The smoking status of the study subjects was also evaluated. The positive predictive value of the guesses based on the three facial views of 200 subjects was 0.62, while the negative predictive value was 0.52. A false positive smoking status was predicted for 23% of the non-smokers and a false negative non-smoking status for 19% of the smokers. This study was well arranged and controlled, and the authors criticized some earlier studies for insufficient blinding (13). Despite the fact that our study supports the evidence that smoking does not necessarily cause increased wrinkling, our results are in line with the previous evidence (7–9) suggesting that smoking does contribute to premature skin ageing. It seems that there are more changes in the skin of smokers than just visible wrinkles, especially in regions with limited yearly sun exposure. Studies of skin replicas, with the help of image analysis as well as biochemical studies of the skin connective tissue proteins, can give more insight into the pathomechanism of skin ageing due to smoking.

In an American survey of public awareness of the association between smoking and skin ageing, almost one quarter of smokers believed that some or most smokers would quit if they knew that smoking increases facial ageing (18). This encourages us to rigorously inform smokers about the adverse effects of smoking on skin, especially when combined with excessive sun exposure.

ACKNOWLEDGEMENTS

We acknowledge Oulu University Hospital, the Finnish Medical Foundation and the Finnish Society of Dermatologists for grants supporting the study. We thank the staff of the photographic laboratory at Oulu University Hospital for the expertise in the field of photography. Virpi Pelto MSc(Tech) is acknowledged for making the final computerized image analyses for the test material. Mrs Soili Manninen is acknowledged for expert secretarial assistance. There is no conflict of interest.

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