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Logistic regression analysis differentiates high from low computer users by facial skin conditions in a population of Chinese women

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Abstract

In the past few decades, video display terminals (VDTs) and computer use have been associated with various skin symptoms in several published reports. In addition, internet beauty sites report that extended computer use leads to acne or accelerated facial aging. For example, the term "computer face" is used to describe premature aging caused by sitting for long periods of time in front of the screen (http://www.marieclaire.com/beauty/news/a12937/computer-screen-skin-problems/). We wished to determine, using instrumental and expert assessment, if prolonged/extended computer use could be associated with certain skin conditions. This study focused on long-term (10 years or more) office VDT work and was designed to include a wide range of confounding variables. One hundred Chinese women were recruited, 50 in each of two groups characterized as either (a) computer users with 8 or more hours per day, or (b) non-users who use computers 1 h or less per day. All subjects lived in Guangzhou and worked in the same building. Confounders were assessed by survey, and included age, smoking, sun exposure history, exercise, and other factors. Skin conditions, which included acne, sebum, wrinkles, and pigment spots, were assessed by instrumental measurements and blinded dermatologist assessment. Age and skin conditions were subjected to logistic regression analysis to determine major contributors which could separate, or distinguish, the computer group from the non-computer group. From this analysis, the office computer users were found to be statistically significantly associated with a higher incidence of acne, higher sebum levels, and a higher risk of self-reported sensitive skin when compared with the non-computer group. The final model suggests that the major contributors in separating the two groups are acne and pigmented spots (UV and brown). These results indicate that facial skin of women within the Chinese population who use computers for 8 h or more a day may be at higher risk for acne; however, they had lower levels of attributes associated with photoaging, such as lentigines and facial wrinkles. Separate pairwise assessment of other variables such as lifetime cumulative sun exposure, sleep quality, smoking behavior, exercise, and cosmetic product use or procedures showed no significant differences between the two groups. This indicates that the results obtained from objective and subjective measurements were not biased due to these potential confounders, but does not reveal the mechanism for the observed differences in skin conditions between computer/VDT users and non-users.

Background

Many individuals attribute negative skin conditions to electromagnetic frequency radiation (EMF) emitted from their computer devices; however, the existing scientific published literature regarding the effects of electromagnetic fields on human health is contradictory and overall, does not support this opinion. Skin conditions such as atopic dermatitis, sensory hypersensitivity, eczema, have been reported to be related to the use of computers and video display terminals (VDT), but are most probably of multifactorial etiology (Eriksson et al. 1997; Korpinen and Paakkonen 2009; Lyskov et al. 2001; Mortazavi et al. 2007). One report stated that "skin disorders" was a category that was more widely reported by VDT operators than similar, non-users of VDTs; however, there was no specific definition given for "skin disorders" (Knave et al. 1985). Another study reported dermatologic symptoms such as pain, itch, heat sensation, erythema, papules, and pustules were more commonly reported by users of VDTs (Gangi and Johansson 1997). It has also been suggested that there is a small fraction of the population that is intrinsically more sensitive to EMF, leading to contradictory and confusing epidemiological studies. The prevalence of this "electromagnetic hypersensitivity" has been estimated to be from 1.5 to 5% (Korpinen and Paakkonen 2009) even though a large proportion of collected EMF data is below the detection limits of available measurement equipment (Gajsek et al. 2015). More recently, exposure to computer screen blue light has been examined as contributing to health effects via disruption of sleep and circadian rhythm (Tosini et al. 2016). The effects of this blue light are thought to be due to night time or "pre-sleep" exposure, however, as opposed to daytime office work exposure (Oh et al. 2015).

Therefore, although interest in the physiological effect of computers and VDTs has historically been focused on emitted EMF, the adverse health effects, if they exist, most likely are associated with other aspects of computer use, such as blue-light-induced disrupted circadian rhythms and/or exposure to other environmental factors. In addition, there has been limited measurement of specific well-defined objectively assessed skin conditions. One study of 353 office workers did survey certain dermatological conditions such as seborrhoeic eczema, nonspecific erythema, rosacea, lentigo, and acne in a cross-sectional study of office workers (Bergqvist and Wahlberg 1994). We, therefore, wished to examine the relationship between computer-based office work and skin conditions such as premature aging, sensory hypersensitivity and acne by employing objective measurement tools, and accounting for potential confounding variables. To accomplish this, we controlled for location of workplace and age range (35- to 45-year old) and tested two groups of Chinese women who differed, as much as possible, only in daily computer/VDT use. Factors such as sun exposure, age, fatigue and sleep quality, job satisfaction, smoking, alcohol consumption, a diagnosis of atopic dermatitis, and mobile phone use were evaluated. In addition, to monitor potential bias, post-hoc survey questions were asked by telephone to assess attitudes about computer use and health. To control for other potential environmental confounding variables, all women worked in the same building and lived in the surrounding community. The present study focused on determining whether differences exist between the facial skin of adult women who are either workplace users or non-users of computers. This study does not purport to suggest that computers per se are causative for these skin characteristics.

Methods

Subjects

The study was conducted at the Guangzhou Landproof Testing Technology Co. Ltd., Guangzhou, Guangdong, P.R. China. The study protocol and the informed consent form were reviewed and approved by the Guangdong Light Industry Association Institutional Review Board prior to the initiation of the study. Inclusion of subjects into the study was according to the following criteria: subject must be female, from 35- to 45-year old, have worked at her current job for at least 10 years, and not washed her face or applied cosmetics at least 12 h before assessment measurements. Recruitment proceeded until 50 women were enrolled who reported working at computers for 8 h/day or more (including home use), and 50 women were enrolled who reported using a computer <1 h/day (including home use). Subjects were not told that the study had anything to do with computer use in order to reduce recall bias for the survey questions. Hereafter, these two groups are referred to as the computer group (CG) and the non-computer group (NCG), respectively.

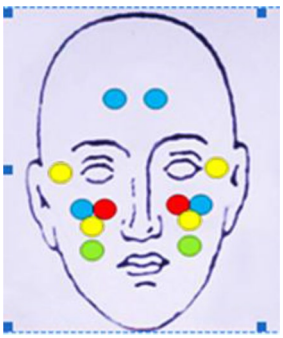
Skin condition and appearance measurements

All measurements and surveys were completed within a 5-day period in July, 2014 after acclimation to 22 ± 1 °C and 50 ± 3% relative humidity for 30 min. Table 1 summarizes the clinical measurements and indicates the instrument used and the location on the face tested. Skin tone, pigment spots, and wrinkles were assessed with the use of the VISIA Complexion Analysis System (Canfield Imaging Systems, Fairfield, NJ). For pigmented skin spots, a score was computed by an algorithm that takes into account the facial area occupied by the spots, the number of spots, and the darkness. Barrier strength was monitored on each cheek using trans-epidermal water loss measured by a Tewameter® TM300 (C + K, Germany). Sebum levels were measured at four sites (two foreheads, each cheek) with a Sebumeter® Derma Unit SSC 3 (Courage + Khazaka, Germany). Skin elasticity was measured at four sites (two peri-ocular and both cheeks) with a dual MPA 580 cutometer (Courage + Khazaka, Germany) and skin hydration was assessed with a Corneometer® (Courage + Khazaka, Germany) for both cheeks. Each data point is the average of three readings at each site. Acne severity was assessed by a board-certified dermatologist visual evaluation according to the protocol described in Rook's Textbook of Dermatology (Simpson and Cunliffe 2004). Skin sensitivity was assessed using a modification of the Frosch Kligman method (Frosch and Kligman 1977) in which 10% lactic acid or normal saline was applied in a blinded fashion to right and left nasolabial folds. After 2.5 and 5 min, subjects reported the intensity of any sting, burn, and itch sensation by giving a score ranging from 0 to 3. Sun exposure history, smoking and alcohol consumption, the quality and quantity of sleep, fatigue, self-perceived skin qualities, and job satisfaction were assessed with a written questionnaire.

Modeling and statistical analysis

Individual non-parametric or parametric pairwise comparison (Statistica v12, Statsoft) was performed for each of the measured skin condition end points to identify the significance of any differences in variables between the two groups (CG and NCG). The values separately obtained from left and right sides of the face were averaged—see Table 2.

Table 1 Analysis of facial skin characteristics

	Parameter/factors	Method	Evaluation sites
1	Skin spots	VISIA (Canfield Scientific. Inc., USA)	Entire face
2	Stratum Corneum waterloss	Tewameter® TM300	Nasolabial cheeks
3	Skin sebum	Sebumeter® Derma Unit SSC 3	Both cheeks and two sites on forehead
4	Skin elasticity	MPA 580-Cutometer®	Two lateral orbital sites Both medial cheeks
5	Skin hydration	Corneometer®	Two sites lateral to each nasolabial fold
6	Acne	Visual evaluation	Entire face
7	Sting test	10% lactic acid solution versus normal saline	Nasolabial folds
8	Stratum Corneum waterloss	Red	
9	Skin sebum	Blue	
10	Skin elasticity	Yellow	
11	Skin hydration	Green	

Clinical measurement categories (parameter/factors) are listed for parameters in rows 1 through 7. Clinical endpoints listed in rows 8 through 11 were performed at facial sites associated with colored dots under "Methods" section and which are portrayed in the schematic face to the right of rows 8–11

The choice of method for statistical comparisons was determined by the normality of the data of each group and/or homogeneity of their variances.

The next statistical strategy employed methods to identify specific factors that may contribute to the separation of the two groups. Hence, the data from the objective measurements and subjective data from the questionnaire referred to in Table 2 were collectively analyzed using multivariate techniques. Twenty-eight variables categorized as binary, continuous, and ranking types were used in the analyses. Stepwise logistic regression was performed to associate measured descriptor variables to the dependent variable (CG or NCG). Subsequently, factor analysis with Varimax rotation (for example see Fig. 1) was performed to extract uncorrelated factors and determine any hidden structures (latent construct) of the data, if present. Also, factor analysis was used to decrease dimensionality of the data by grouping together related variables. This also increases the predictability of the model by removing any multicollinearity of the collected variables, which increases the predictability of the model. The extracted latent factors were then subjected to another stepwise logistic regression to determine the final model that predicts CG from NCG. An example of the principal component analysis with Varimax rotation is shown in Fig. 1 for key skin measurements.

Subjective survey questions were analyzed using the SPSS17.0 software package in which the Wilcoxon method or *T* test was used.

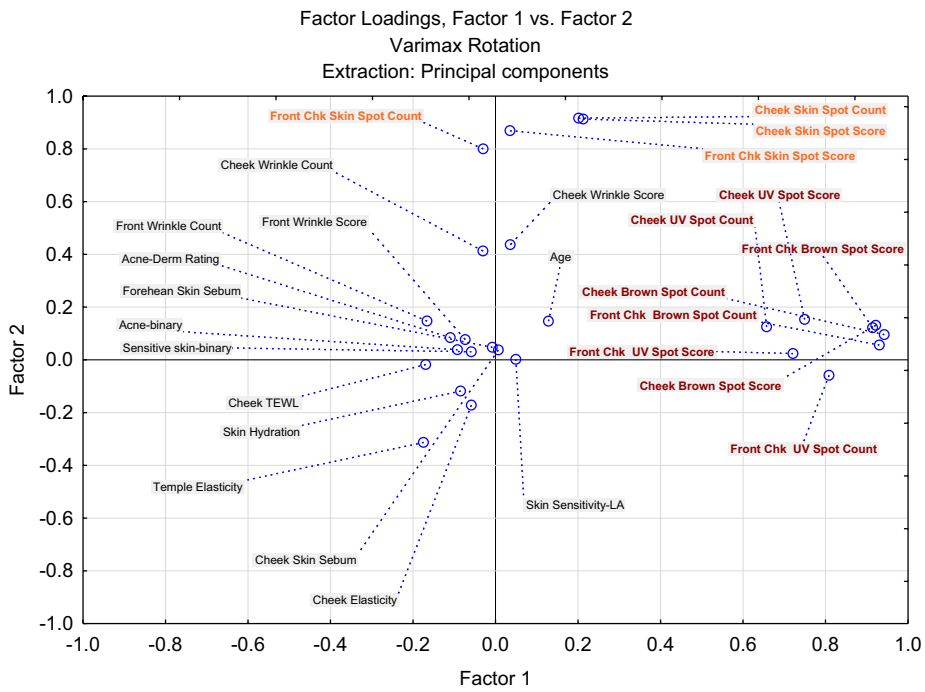


Fig. 1 The first and second factors after Varimax Rotation. In this graph, the first factor shows high association with variables related to UV and Brown Spots (in *bold red*). This indicates that these two measures of skin features on the face are similar. On the other hand, the second factor shows high association with variables related to skin spots (*bold orange*). Since the axes of the graphs are orthogonal, this suggests that this measure of skin features is different from the UV and Brown spots

Results

Age and lifestyle variables

The answers to the questionnaire were analyzed and no difference between the two groups was observed in levels of job satisfaction, childhood and adolescent sun exposure, including number of sunburns, cosmetic procedures (botox, fillers, lasers, peels, etc.), smoking, drinking, sleep quantity, sleepiness, tiredness, or fatigue. There was no difference between the two groups in the answer to "How often do you apply sunscreen (SPF 15 or higher) to your face?" and "At the present time, how long on average are you exposed to sun every day?" There was no difference in the reported incidence of persistent redness, flushing, and blushing. There was also no difference in the use of acne medications. Subjects in the two groups did not differ in their self-perception of facial age, or appearance, or in their level of satisfaction with their appearance and health. The CG had a higher proportion of subjects that believed themselves to have acne or sensitive skin, which is shown by the designation "Sensitive skin-Binary" and "Acne-Binary" in Table 2. Questions about fatigue and sleep were considered as surrogates for disruptions in circadian rhythm for this study.

Interestingly, the majority of all women in the study said that computer use has effects on health and facial skin in the post-hoc survey, without a significant difference between the two groups in their response when asked post-hoc: "Do you think that sitting in front of the computer is unhealthy?" and "Do you think that long hours in front of the computer may affect your facial skin?". In response to the first question, the NCG and CG

Table 2 Descriptive statistical information for facial measurements

Variable	CG Mean (SD) or Median (IQR)* n = 50	NCG mean (SD) or Median (IQR)* n = 50	Data type	*P* value
Age	39 (4)*	41 (4)*	Continuous	*0.0117*
Sensitive skin-binary (Yes or No)	34/50	25/50	Binary	***0.0673***
Acne-binary (Yes or No)	20/50	6/50	Binary	*0.0014*
Front Chk skin spot count	127.20 (27.55)	130.04 (23.70)	Continuous	0.5818
Front Chk skin spot score	2.59 (0.61)	2.72 (0.59)	Continuous	0.2653
Front Chk UV spot count	415.00 (120.00)*	458.50 (91.00)*	Continuous	*0.0054*
Front Chk UV spot score	4.75 (3.14)*	6.30 (2.57)*	Continuous	*0.0070*
Front Chk brown spot count	130.12 (71.16)	165.08 (72.83)	Continuous	*0.0170*
Front Chk brown spot score	1.39 (0.86)	1.83 (0.92)	Continuous	*0.0141*
Cheek skin spot count	44.50 (22.00)*	49.00(16.50)*	Continuous	0.3592
Cheek skin spot score	1.31 (0.61)*	1.46 (0.51)*	Continuous	0.1242
Cheek UV spot count	292.50 (80.00)*	321.50 (45.50)*	Continuous	*0.0452*
Cheek UV spot score	6.89 (3.34)*	8.30 (2.60)*	Continuous	*0.0023*
Cheek brown spot count	106.39 (57.59)	131.13 (54.71)	Continuous	*0.0300*
Cheek brown spot score	1.95 (1.23)	2.59 (1.21)	Continuous	*0.0100*
Front wrinkle count	48.5 (21.00)*	52.50 (23.00)*	Continuous	0.2344
Front wrinkle score	10.60 (4.48)	11.69 (3.97)	Continuous	0.2031
Cheek wrinkle count	9.00 (7.00)*	10.75 (6.50)*	Continuous	0.1090
Cheek wrinkle score	1.19 (0.91)	1.45 (1.11)	Continuous	*0.0248*
Cheek TEWL	12.93 (3.33)	13.55 (4.27)	Continuous	0.4196
Forehead skin sebum	59.25 (52.00)*	50.75 (27.00)*	Continuous	0.1121
Cheek skin sebum	26.50 (36.50)*	21.00 (29.50)*	Continuous	0.2071
Temple elasticity	0.73 (0.10)*	0.70 (0.13)*	Continuous	*0.0367*
Cheek elasticity	0.65 (0.09)*	0.63 (0.09)*	Continuous	0.2626
Skin hydration	72.89 (10.52)	68.46 (12.15)	Continuous	***0.0543***
Acne (dermatologist rating)	0.00 (1.00)*	0.00 (0.00)*	Ranking	*0.0146*
Skin sensitivity (lactic acid)	2.00 (2.00)*	1.50 (2.00)*	Ranking	0.2822

The skin condition variables measured in this study for the "computer group" (CG) and the "non-computer group" (NCG) are listed in the left column, with the associated statistical analysis data characteristics. Results of parametric analysis are given by mean ± standard deviation (SD). Results of non-parametric data analysis are given by median ± interquartile range (IQR) and indicated by *. The types of queries collected are indicated as either continuous, binary, or ranking. Significance is shown in italic (<0.05) or bold italic (approaching 0.05)

thought that sitting in front of the computer is either extremely unhealthy (38 and 53% respectively) or somewhat unhealthy (57 and 42%). Similarly, 50% of the NCG thought that computer use significantly affects facial skin (42% said it somewhat affects), and 67% of the CG responded with "significantly affects" and 42% said that it "somewhat affects" facial skin. These results correspond to those published for a previous study which assessed whether subjects' knowledge about the purpose of a study on VDU exposure affected their response to questionnaires on skin complaints (Berg and Axelson 1990).

Instrumental and dermatologist evaluations

A summary of the statistics of the instrumental and dermatologist evaluations are given in Table 2. The last column gives the p values from the parametric and non-parametric (asterisked) pairwise comparisons between the two groups. Several variables were

Table 3 Logistic regression coefficients of the raw measured variables for computer group

Variable	Log-odds ratio coefficients	*P* value
Subjective sensitive skin-binary (not sensitive)	−0.494	0.0470
AVG LR Chk wrinkle score	−0.944	0.0064
Acne	1.487	0.0100
Cheek dark spot count	−0.006	0.0175
Cheek skin sebum	0.031	0.0143

Significant log-odds ratio coefficients are shown for the computer group (CG) subjective questionnaire (no applied lactic acid): sensitive skin, the cheek wrinkle score from the average for left and right cheeks, the front cheek dark spot count (number of dark spots) and the sebum levels on the cheeks

characterized by significant *p* values, age, acne-binary (yes/no), spots on the front cheeks (UV/brown), spots on the side cheeks (UV/brown), cheek wrinkle score, temple elasticity, and acne (dermatologist rating). These results suggested that NCG had significantly greater spots (UV/brown) and wrinkles on the cheek than did the CG. In addition, in a pairwise comparison, the average age of NCG was greater than CG. CG had significantly greater temple elasticity and higher acne severity than did NCG. It is worth noting that the skin sensitivity-binary (yes/no) and skin hydration were marginally ($p < 0.10$) greater in CG than in NCG.

Two passes of logistic regression analyses were performed. The first pass was performed on the raw data, which are identified as "correlated" as many of them are highly correlated to other variables. The second pass of logistic regression was performed on the latent factors extracted from the factor analysis of the raw data, and they are referred to as "non-correlated" because each factor is orthogonal from all the others.

The first pass of logistic regression on the raw variables gave a goodness-of-fit Cox–Snell R^2 value of 0.270. Table 3 lists the significant variables with their log-odds ratio coefficient values that are a measure of each variable's contribution to the predictability of being in the computer user group. These results indicate, in rank order for their contribution to the model from high to low, that having acne, sensitive skin, less wrinkles, high sebum, and fewer UV spots are predictors of belonging to the CG. For example, the ranking variable, acne, with a log-odds-ratio of 1.487; it suggests that for every one unit increase in acne score, the odds of being in CG increases by more than 300%. The binary variable "Sensitive Skin Binary (not sensitive)" has a log-odds ratio coefficient of −0.494,

Table 4 Latent factors and percent variance

Latent factor	% variance
UV/Brown spots	21.7
"Dark" spots	13.5
Sebum	11.0
Acne (dermatologist rating and self-perception)	8.2
Wrinkles	8.8
Sensitivity (lactic acid sensitivity ≥2 and affirmative survey answer)	7.1
TEWL	4.7

Each latent factor extracted from factor analysis is shown in the leftmost column with the associated percent variance in the right column

Table 5 Logistic regression coefficients for computer group (CG) using the latent factors

Variable	Log-odds ratio coefficient for the CG	*P* value
Spots (UV, brown)	−0.545	0.0169
Acne	0.950	0.0004

Pigment spots are associated with the non-computer group (NCG). Acne is associated with the computer group (CG)

which translates to an odds-ratio of 0.61. This implies that for every ten people with sensitive skin, about six of them belong to CG.

The second pass of logistic regression was performed on latent factors extracted from factor analysis. Table 4 shows the percent variance in the data attributable to each of the latent factors listed in the left column. Performing modeling on latent factors prevents the overfitting of the model due to multicollinearity of the predictors in the raw data. From the factor analysis, it was found that there was no hidden structure in the data, grouping only those variables that were highly correlated. Seven latent factors were kept that accounted for 74% of the variance in the data. These are UV/brown spots (21.7%), skin spots (13.5%), sebum (11%), sensitivity (7.1%), acne (8.2%), wrinkles (8.8%), and TEWL (4.7%). This new set of data with reduced dimensionality represented an orthogonal dataset, and therefore the factors in the dataset (listed above and in Table 3) were not correlated with each other. From the factor loadings, it was further determined that age had no correlation with the latent factors associated with facial spots, sebum, and sensitivity and had low correlation with the latent factors associated with acne, wrinkles, and TEWL. It should be noted that the age range of the total subject population was relatively narrow; between 35- and 45-year old. The average age of all subjects in the study was 40.02 (Table 2), with an average for the CG of 39.26 $\pm$ 2.9 SD and for the NCG of 40.78 $\pm$ 2.7 SD. Fig. 1 shows the first and second factors after Varimax Rotation. In this graph, the first factor shows high association with variables related to UV and Brown Spots (in bold red). This indicates that these two measures of skin features on the face are similar. On the other hand, the second factor shows high association with variables related to skin spots (bold orange). Since the axes of the graphs are orthogonal, this suggests that this measure of skin features is different from the UV and Brown spots.

The final model gave a goodness-of-fit of Cox–Snell R^2 value of 0.19. The two significant factors that contribute most to the difference between the two groups are UV/brown spots and acne, as shown in Table 5. In the initial analysis, spots were differentiated by lighting conditions from which the image was taken. Skin spots were calculated from one of the VISIA's "Standard" lighting conditions, UV spots from ultraviolet lighting, and brown spots from cross-polarized lighting. The factor analysis suggested that the UV and brown spots were the same, and thereafter the term "spots", or "dark spots" was used. In the final model, the log-odds-ratio coefficient of −0.545 for spots suggests that for every unit decrease in spots, the odds of being in CG increases by 72%. For acne, the log-odds-ratio value of 0.950 indicates a 158% increase in the odds ratio for CG for every 1 unit increase in acne.

Based on the analysis of both correlated and uncorrelated data, membership in the CG can be predicted by the presence of acne and fewer dark spots (UV spots, brown spots) in this Chinese population. The CG had significantly higher acne values ($p = 0.0004$) and

lower dark spot values ($p = 0.016$). Therefore, these two factors serve as descriptors to discriminate between the CG and NCG. It should be again noted that the subjects in the present study were adults between 35 and 45 years of age, and the average incidence of acne fell within values previously reported for that age group in China (Shen et al. 2012). In addition, in both first and second logistic regression analyses, the age factor was not a contributing factor that predicted the two groups for both correlated (raw data) and non-correlated (latent factors) data.

Using pairwise comparison, other lifestyle, attitudinal, or behavioral characteristics measured in this study showed no difference between the two groups, including reported use of acne medication or cosmetic products for acne. There was no difference between the groups in their use of cosmetic procedures, including botox injections, resurfacing procedures, laser treatments, or dermal fillers. There was no difference in reported job satisfaction or in diagnosed atopic dermatitis or rosacea. In both groups, there was very limited use of cosmetic cleansers (other than "soap"), make-up removers, astringents/toners/fresheners, moisturizers, nighttime moisturizers, anti-wrinkle/anti-aging treatments, eye treatments, facial masks, facial exfoliators/scrubs, masks, and facial lightening/whitening products). As assessed by a written survey that asked about time spent in walking, sitting, and standing, exercise did not differ significantly between the two groups. Subjects' body mass indexes (BMI) were calculated and the average BMI for the CG was 22.02 ± 0.5 and for the NCG was 22.4 ± 0.7 ($p = 0.47$) and was not related to the presence of acne.

Conclusions and discussion

We wished to determine whether long-term workplace computer/VDT use could be associated with facial skin issues such as acne, hypersensitivity, and signs of accelerated aging by comparing women who were characterized by (a) computer use or (b) no computer use. We were able to recruit 100 Chinese women who fit the criteria between the ages of 35 and 45 and we measured both subjective and objective endpoints. Although there is public concern that extended computer use leads to general health risks (Baliatsas et al. 2015), substantiation of objectively measured effects on specific facial skin damage endpoints is lacking. Through this study, we wished to, first, show whether measurable adverse effects could be associated with daily extended office work-related computer/VDT use, and second, if these effects could be explained by factors other than computer/VDT use, such as sleep disruption, stress, exercise, or other lifestyle differences. In this study, subjects' exposure to EMF was predicted to differ only with respect to computer use, if at all, as all subjects worked in the same building and live in the same area, such that the exposure to high-voltage overhead power lines was the same for all subjects and the survey did not reveal any differences in mobile phone use.

In summary, 8 or more hours per day of computer use was found to be statistically significantly associated with more severe acne and higher levels of sebum, but correlated with lower values for facial wrinkles and pigmented spots. In addition, subjects who were computer users were found to have a higher risk of sensory hypersensitivity when subjectively reported but not when tested with the "lactic acid sting test". Other factors such as sleep quality/quantity and sun exposure, that could influence the occurrence and severity of acne, skin aging, and skin hypersensitivity, were assessed and not found to correlate. It should be noted that none of the other lifestyle, attitudinal, or behavioral

characteristics measured in this study were different between the two groups. These included use of acne medication or cosmetic products for acne, and there was no difference between the groups in their use of cosmetic procedures, including botox injections, resurfacing procedures, laser treatments, or dermal fillers. There was no difference in reported job satisfaction or in diagnosed atopic dermatitis or rosacea. There was limited use of cosmetic anti-aging or whitening products, possibly due to the relatively young age of the subjects. As assessed by a written survey, exercise did not appear to differ significantly between the two groups; however, individual wearable monitoring devices may have been able to detect a difference between subjects in the CG versus the NCG which then could be analyzed with regard to acne. Therefore, long periods of inactivity may be a possible confounder that could not be fully accounted for with the experimental protocol employed. Related to this, no difference was detected in BMI between the two groups.

It was particularly important to assess sleep in this study, as recent reports suggest that computer screen-generated light in the blue range can impact human health via several related pathways and in multiple organs (Tosini et al. 2016; Kayaba et al. 2014; Beaven and Ekstrom 2013) or may have no effect (O'Hagan et al. 2016). For example, one study showed that the blue light of LED-backlit computer screens significantly suppressed melatonin production in human subjects (Sroykham and Wongsawat 2013). In addition, a recent report suggested that there exists a relationship between sleep quality and facial sebum levels in women with acne vulgaris (Bilgic et al. 2016). In another study unrelated to computer use, Caucasian women who were good sleepers had significantly lower intrinsic skin aging scores that poor sleepers (Oyetakin-White et al. 2015). Because it has been suggested that high computer use can lead to sleep disturbances, in the current study questions related to sleep quality were given to all subjects. There was no difference in reported sleep quantity, quality, or in the perception of fatigue between the CG and NCG. In addition, the self-reported skin type (combination, oily, dry), the occurrence of flushing/blushing, the satisfaction with how the subject's skin/face looks, or how healthy the subject's face and complexion were self-perceived were not associated with computer use.

One skin characteristic that is often reported to be associated with VDT use is the "sensitive skin syndrome" in which subjects are more likely to react to lactic acid with itching, burning, and stinging. Complaints of tightness, stinging, burning, and itching sensations as well as erythema and facial dryness have been previously reported for video display workers (Eriksson et al. 1997) Overall, VDT workers report skin symptoms more frequently than non-VDT office employees, and the term "electromagnetic hypersensitivity" has been coined to describe people who experience health symptoms in the vicinity of electromagnetic fields (EMFs) and who regard them as causal for their complaints (Tuengler and von Klitzing 2013). The fraction of the population with electromagnetic hypersensitivity has been estimated to be as high as 9%, and projected to be up to 50% by the year 2017 (Hallberg and Oberfeld 2006). Previous reports that computer users to have relatively hypersensitive skin was supported here only in terms of the subjective survey results, not as assessed by the lactic acid sting test.

There is some evidence in previous studies to suggest that job-associated computer use is accompanied by a higher frequency of "skin disorders", including rashes (Knave

et al. 1985). For example, Liden and Wahlberg (1985a) reported that subjects with rosacea, seborrhoeic dermatitis, and acne were over-represented in a VDT-exposed group in one study, and in another published study they reported that there was a higher frequency of diagnosed seborrheic dermatitis, acne, rosacea, and perioral dermatitis among exposed subjects when compared with control subjects (Liden and Wahlberg 1985b). They further review additional studies in which dermatologic examination rules out contact allergy, increased photosensitivity, and in which symptoms were "clearly related to time at work". Interestingly, even though the level of EMF and LFEMF emitted from VDTs is considered below harmful levels and often below the limits of detection, in one study with acute provocation (2–4 h) seated close to but facing away from an "ordinary PC", investigators claimed that mast cells increased in the upper dermis within 24 h (Johansson et al. 2001). This phenomenon was found in 5 out of 13 subjects, leading to a hypothesis that some fraction of humans is hypersensitive to VDT and particularly prone to "screen dermatitis". It should be noted that one study of university students that used a questionnaire to probe symptoms such as headache, fatigue, difficulties in concentration, vertigo/dizziness, attention disorders, nervousness, palpitation, low back pain, myalgia, and tinnitus found no significant differences in the prevalence of these symptoms between VDT users and those who did not use VDTs.

Some observed physiological sequelae of work with video display terminals are relatively easy to explain, such as eye and shoulder, neck and back musculoskeletal discomfort. Other perceived consequences of long hours at a computer are not as easily explained. The mechanism for increased sebum and acne, the perception of sensory hypersensitivity, lower wrinkling, and pigment spots is not clear. A more complete psychological or behavioral evaluation of stress might reveal differences which correlate with sebum and acne, but would be unlikely to also correlate with lower wrinkling and pigment spots. Furthermore, a psychological cause is also not supported by the post-hoc answers to questions about the subjects' perceived dangers of computer use. A reasonable explanation for the lower wrinkling and spots would be a small but long-term difference in sun exposure, which may not have been accurately assessed by the survey used in this study. One study reported that Langerhans' cells were depleted in "screen dermatitis" (Gangi and Johansson 1997), but we did not confirm this by biopsies or antigen sensitization assays in the present work. Another group suggested, after collecting data from 3877 subjects, that the evidence did not support a direct physiological impact of VDT work on the skin, but rather than any effects were due to psychological stimuli (Liden and Berg 1991). Bergqvist and Wahlberg (1994) reported no associations between EMF levels and skin disease or symptoms but indicated instead that there were other factors that did associate with skin symptoms, such as perceived work load, inability to take rest breaks, and a low relative humidity. We did not uncover explanatory mechanisms for the observations made, but strongly suggest that additional investigations should be made because of the current findings and the public's perception that extended computer use adversely affects certain aspects of skin physiology. For example, a recent advice website, http://www.glamour.com/lipstick/blogs/girls-in-the-beauty-department/2013/03/change-your-life-beauty-tip-th-6 suggested that hair falling onto the face during computer use was a cause of increased risk of acne. In an editorial in the JAAD, Berg and Liden proposed the hypothesis (never verified) that an electrostatic field

causes a deposition of volatile and particle-bound air pollutants on the skin, leading to toxic irritation (Berg and Liden 1987).

Properly designed double-blind provocation protocols may lead to a deeper understanding of acute effects—but have been difficult to achieve for many reasons, including the possibility that the percentage of the population susceptible to this is low. In addition, important endpoints measured such as acne, dark spots, and wrinkles are not "acute"-type phenomena. In contrast, skin sensory sensitivity may be more amenable to acute challenge protocols. The present study was designed to examine skin conditions in women who had worked for at least 10 years in office-related computer work. To our knowledge, this is the first observational report to suggest a link between extended office-related computer/VDT use and an increased risk of acne and perceived facial hypersensitivity. There is clearly the possibility that these associations are due to office environmental and work condition issues.

Abbreviations

VDTs: video display terminals; UV: ultraviolet; EMF: electromagnetic frequency radiation; CG: computer group; NCG: non-computer group; TEWL: transepidermal water loss; BMI: body mass index.

Authors' contributions

MSM conceived of this study, performed the necessary literature research, designed the experimental protocol, and drafted the manuscript. JDC performed the statistical analysis and associated interpretation of data. JT, BWD, GL and XX performed the clinical studies, including recruitment of subjects, and data collection, and also contributed dermatological expertise. All authors read and approved of the final manuscript.

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Competing interests

This study was financially supported by the Clinique Laboratories, LLC. No treatment modality or product was tested and no patents or patent applications are associated with this report. MSM, JDC and BWD are full-time employees of the Estee Lauder Companies, Inc.

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