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ORIGINAL CONTRIBUTION

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A new method for skin aging evaluation of Chinese women

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Abstract

Background: With the development of cosmetic industry in China, an aging evaluation method of Chinese women is in great need.

Aims: The aim of this study is to establish a skin aging assessment method using convenient portable machine Antera 3D.

Methods: The quantitative approach was developed by capturing 11 areas of the face, and overall, 48 parameters were extracted for aging evaluation. Later, 297 subjects were recruited to take facial image and life style questionnaire. Evaluation of age was accomplished by establishing prediction method with detected skin traits.

Results: The age prediction model was built by using the evaluated facial traits, and a R square of 0.6 is achieved by comparing to the chronological age. The crow's feet, cheek skin pigmentation, forehead skin tone, and wrinkles around the month are critical factors in evaluating Chinese women skin aging. In addition, we also explored life styles associated with important skin aging traits.

Conclusion: The method developed in this research provides reliable alternative in aging study of Chinese women.

KEYWORDS
age prediction model, aging standard, Chinese women, skin aging, skin test

1 | INTRODUCTION

With the development of Chinese cosmetics industry and related aging research, there is a growing demand for skin aging evaluation method for Chinese women. There are two major types, the descriptive and photographic scale method.[1] In descriptive method, expert such as dermatologist is required to assess the severity of multiple skin traits based on established guideline. For instance, in SCINEXA aging standard, 5 intrinsic items and 18 extrinsic items were evaluated by dermatologist into 4 classification: 0 (none), 1 (mild), 2 (moderate), and 3 (severe).[2] The photographic scale is composed of a set of facial characteristic photographs, usually scoring from 1 to 10, and evaluation can be accomplished by comparing to these scales. For instance, a series of standard photographs were established for upper face,[3] mid face,[4] lower face,[5] and global face[6] for aging reference. Both methods have the strength and limitations. Although the descriptive method provides specific information, application scenarios are relatively limited since well-trained expert is always required. The photographic method is easier to apply but most are used in wrinkle study. An easy-to-apply and comprehensive method is needed.

Recently, due to the development of skin instrumental device, more and more studies applied imaging system to analyze skin. One advantage is most instrument contains UV and polarized light source, which enable it captures much more information of individual comparing the manual method.[7] In addition, the installed software provides quantification of skin traits. For instance, skin pigmentation is important factor in aging.

VISIA has been successfully applied to study hyperpigmentation in Japanese women with different ages.[8] It was also used in wrinkle study in different scenarios.[9,10] Antera 3D, another skin analyzer, with multidirectional illumination obtained by LEDs, reported to be more accurate than VISIA in wrinkle and enlarged pore assessment.[11]

The ethnic difference of facial characteristics also makes it difficult to apply existed method to Chinese women. Asian and Caucasian have unique facial traits in skin pigmentation,[12] PH,[13] sensitivity,[14-16] and wrinkle.[17] For instance, in aging process occurrence of skin aging manifest is very ethnic specific. In general, Caucasians develop more pronounced wrinkles earlier, whereas Asians develop more pronounced pigment spots earlier.[18,19] Even in Asians, women from different countries showed distinct aging traits. It was reported that Chinese women had significantly more severe wrinkles in area round eyes comparing to Japanese counterpart.[20] With population as large as 1.4 billion, surprisingly standards of Chinese is very rare in previous study.[1] Therefore, an aging quantification method specifically for Chinese women is necessary in skin aging industry and research.

In this study, we use Antera 3D, a multi-light source portable device, to establish the aging standard in Chinese women. In total, 297 subjects were tested, and 48 parameters were captured in each subject. We established the age-predicting algorithm for age estimation with parameters provided by the machine. We also evaluate the factors affect skin aging.

2 | MATERIALS AND METHODS

2.1 | Study design

The flowchart of the study is illustrated in Figure 1. The standard operating procedure (SOP) was developed for quantification of Chinese women skin aging traits. To verify the reproducibility of the SOP, selected subjects were analyzed by different testers to confirm inter-rater variation. Later, over 200 subjects were recruited. Multiple images were captured on each individual and analyzed by established SOP. Questionnaires about life styles were also asked to fill for later study. With all the collected data, the age prediction model was built and effect of exposome was evaluated.

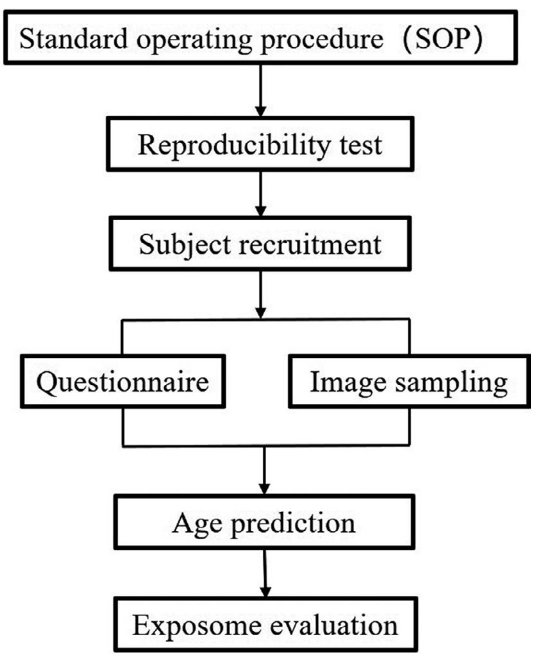

FIGURE 1 Study flowchart diagram

2.2 | SOP development

We captured 11 areas on the face, including forehead, glabellum, periorbital, eye corner, face, and mouth images using Antera 3D instrument. The areas are illustrated in Figure 2. The acquired images were converted into melanin concentration images, hemoglobin relative variation images, wrinkle images, and skin color images for further quantitative analysis.

Biophysical parameters derived from using the ANTERA 3D® device includes wrinkles and sagging, number of wrinkles, depth of wrinkles, length of wrinkles, skin pigmentation, concentration of melanin, distribution (heterogeneity) of melanin, superficial vascular component, concentration of hemoglobin, distribution (heterogeneity) of hemoglobin, facial furrows analysis, and nasogenian furrow analysis. The phenotypes of all subjects involved in the study are represented by 48 variables that are shown in Table S1. To validate and control inter-rater difference, images of 17 subjects were captured and analyzed by 3 different testers independently. Then, results were compared to evaluate the inter-rater repeatability.

2.3 | Subjects

Two hundred and ninety-seven (297) healthy volunteers were recruited for participation to the study in Shanghai. Subjects who were currently participating in another clinical study, pregnant or nursing, or receiving concurrent therapy for or possessed skin disorders on face and other body regions such as eczema, psoriasis, vitiligo, and skin cancer were excluded. All the subjects were required washed face and acclimated for 15 minutes before testing.

2.4 | Statistical analysis

The data were analyzed statistically using IBM SPSS Statistics for Windows, version 22.0 (Armonk, NY: IBM Corp. Released 2013) and R (3.6.0). To establish the age prediction model, critical parameters were selected after correlation analysis. Subjects over 50 years old were excluded due to insufficient data points in these ages. A stepwise optimized lineal regression algorithm was built for chronological age prediction by the selected parameters. Evaluation of exposome was conducted by one-way ANOVA, with predicted age

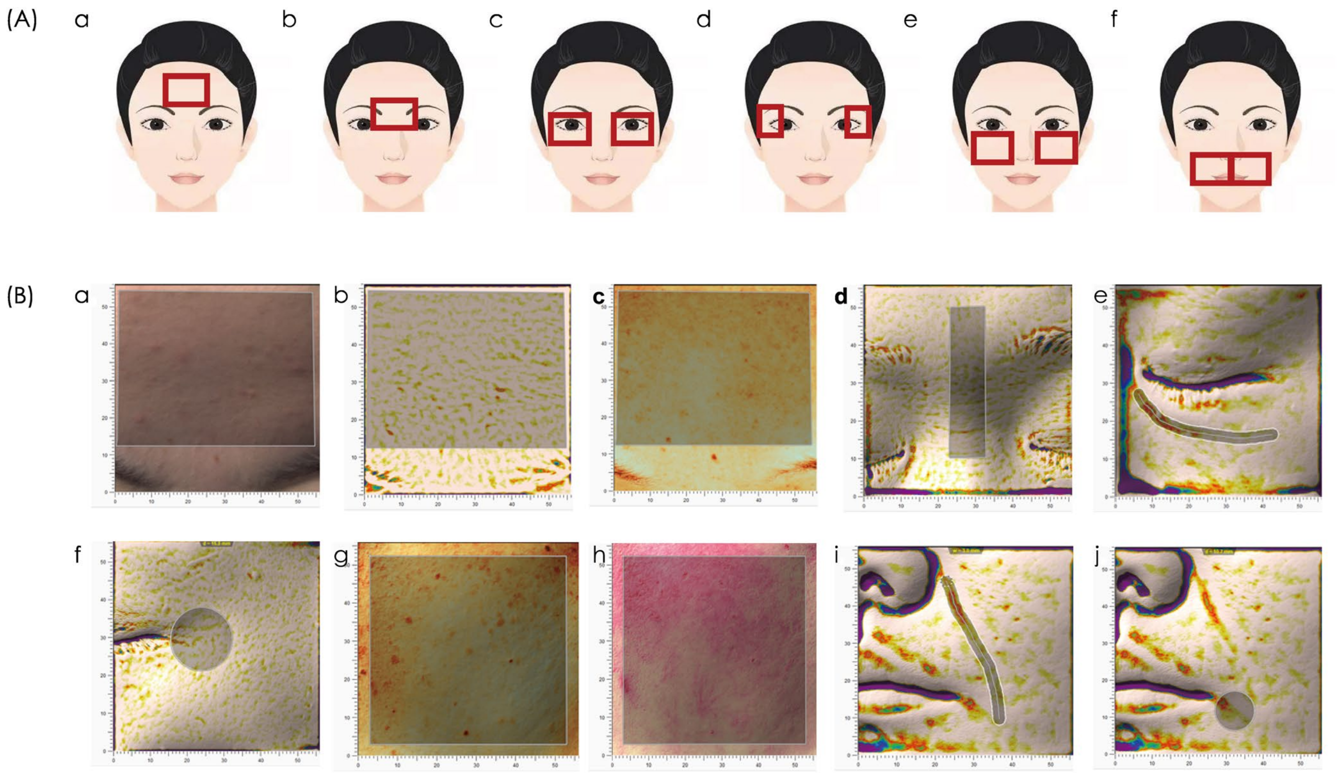

FIGURE 2 Facial aging analysis by Antera 3D. A, Represents the facial area of analysis, (a-f) represent for forehead, glabellum, periorbital, eye corner (both side), face, and mouth, respectively. B, Represents detailed approach which including region of interest (ROI) and analysis parameter for facial aging evaluation. (a-c) represent forehead area analysis, (a-c) represent L*a*b*, melanin, and hemoglobin, respectively; (d) evaluated the small wrinkle hallow and maximum depth of ROI, ROI of glabellum area is a 10 × 40 mm vertical rectangle; (e) evaluated medium wrinkle hallow and maximum depth of ROI, ROI of periorbital area is a rod with diameter equal to 3 mm, begin with inner corner of the eye lasing to the outer corner of the eye; (f) evaluated the small wrinkle hallow and maximum depth of ROI, ROI of eye corner area is a circle with d = 10.7 mm; (g-h) represent face area, ROI for face is all area captured by Antera 3D camera, and we evaluated the relative disparity of melanin and hemoglobin (g and h, respectively); (j) represents medium wrinkle analysis for mouth area, ROI is a rod with d = 10.7 mm, starting from nose wing to fiews line

as dependent variable and actual age as well as other life styles as independent variables.

3 | RESULTS

3.1 | Aging quantitative approach development

Quantification of selected facial aging traits was done by using the installed tool of software. In total, quantification method of 48 parameters was developed, which covered most aging traits.

Three testers were trained to use the machine and evaluate same subjects for reliable test. On average, Cronbach's alpha in eighteen representative parameters is 0.892 (Table 1), and the data indicate high reliability of different testers.

3.2 | Subjects

Photographs were taken from 297 subjects. Demographic characteristics of the study subjects are showed in Table 2. Most of the subjects are aged from 30 to 39 (35%), following by the group of 20-29 (29.3%). In terms of BMI, only 11.78% subjects are considered overweight and none is obese. A total of 38 subjects were menopausal, composing 12.79% of the whole cohort. In nonmenopausal group, 75 reported have irregular period and 10 reported have irregular phase.

3.3 | Age prediction model

Average value of left and right faces was calculated before correlation study. Pair-wise correlation has shown that (Figure S1) most parameters have high positive correlation with each other.

In linear model, after stepwise procedure, all predictors were reduced 9 for optimal prediction model (Table 3). In all the predictors, wrinkle of month (m_De, m_id), crow's feet (et_id, e_Os), face tone/melanin (f_b, f_dL), and forehead skin tone (fh_dafh_dL) are critical factors, suggesting these characteristics are important in skin aging of Chinese women. The R^2 of the model is .6, suggesting high prediction power (Figure 3).

TABLE 1 Reproducibility of the testing result in 3 testers

Parameter	Cronbach's alpha
eb_id	0.97
fh_a	0.95
fh_dE	0.88
fh_HRv	0.79
fh_MRv	0.92
fh_MV	0.92
le_de	0.85
le_os	0.95
re_os	0.93
let_id	0.93
ret_id	0.95
lf_a	0.95
lf_b	0.97
lf_HAI	0.95
lm_De	0.94
ret_md	0.59
rf_dL	0.67
rm_id	0.95

3.4 | Effect of exposome

Life styles factors such as time of sun exposure, diet, and smoking are categorized as "exposome." In variance analysis, the predicted age can be most explained by the chronological age, but only very partially explained by captured exposome (Figure S2). An important factor in exposome is time to go to sleep. Individual start sleeping late at night is more likely to shown aged skin traits (Table 4).

TABLE 2 Description of the population

Description	Sample size	%
Total sample	297	
Vitiligo	1	0.34%
Pregnancy	2	0.67%
Age (years)		
10-19	5	1.7%
20-29	87	29.3%
30-39	104	35.0%
40-49	58	19.5%
50-59	27	9.1%
60-69	12	4.0%
n/a	4	0.7%
BMI classification		
Underweight < 18.5	38	12.79%
Normal 18.5-23.9	215	72.39%
Overweight 24-27	35	11.78%
Obese > 32	0	0.00%
n/a	9	0.67%
Hormonal status		
Nonmenopausal (normal)	167	56.23%
Nonmenopausal (irregular period)	75	25.25%
Nonmenopausal (irregular phase)	10	3.37%
Menopausal	38	12.79%
Others	7	2.36%
Plastic surgery history		
Yes	64	21.55%
No	233	78.45%

Abbreviation: BMI, body mass index.

4 | DISCUSSION

The machine Antera 3D chosen in this study is portable and relatively low price compared to machine such as VISIA, making it a good alternative option. The machine has been applied in other studies including wrinkle and roughness measurement,[21] pore measurement,[22] skin color, redness, and melanin content.[23] The aging evaluation method here making use of this advanced tool could provide

TABLE 3 Summary of prediction model

Step	Variable	Added/ Removed	R^2	AIC	RMSE	t	P value
1	m_De	addition	.294	1357.75	7.02	3.338	.001
2	et_id	addition	.386	1331.54	6.56	5.135	0
3	f_b	addition	.461	1307.34	6.16	6.538	0
4	f_dL	addition	.512	1289.65	5.88	−3.443	.001
5	e_Os	addition	.539	1280.21	5.73	3.709	0
6	fh_dL	addition	.558	1273.34	5.62	−3.68	0
7	m_id	addition	.573	1268.84	5.55	2.454	.015
8	fh_da	addition	.587	1264.12	5.47	2.545	.012
9	f_MRv	addition	.597	1260.94	5.41	2.232	.027

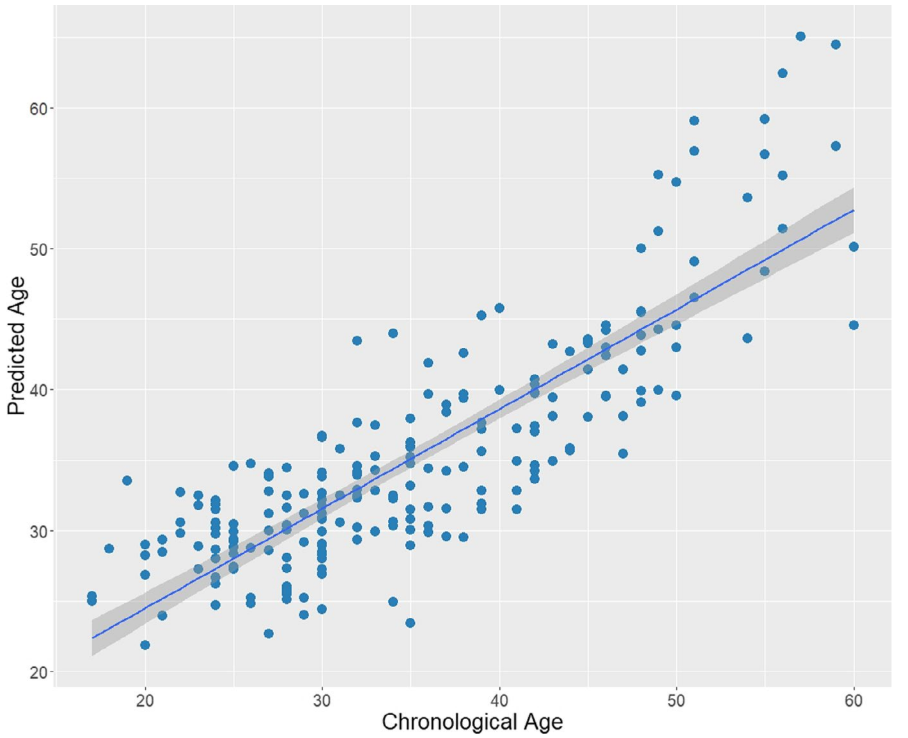

FIGURE 3 Correlation between the predicted and chronological age. Each dot indicates the actual/chronological and predicted age of one subject. The linear line is plotted by constructed model

TABLE 4 The model variance analysis

	Df	Sum Sq	Mean Sq	*F* value	Pr(>F)	Significant
Actual_age	1	4667	4667	322.448	<2e-16	***
Daily sun exposure	2	25	13	0.872	0.4198	
Sleeping condition	2	57	28	1.952	0.1451	
Time start sleep	4	142	36	2.456	0.0476	*
Exercise frequency	3	102	34	2.341	0.0751	
Laugh	1	14	14	0.969	0.3263	
Fruits	3	4	1	0.092	0.9641	
Smoking frequency	2	6	3	0.217	0.8055	
Smoking history	3	53	18	1.228	0.301	
period	1	4	4	0.297	0.5862	
Food—spicy	1	4	4	0.303	0.583	
Food—sweet	1	35	35	2.388	0.1242	
Food—fried	1	11	11	0.735	0.3925	
Food—alcohol	1	10	10	0.717	0.3983	
Food—vegetable	1	0	0	0.001	0.9722	
Residuals	169	2446	14			

Abbreviations: Df, degree of freedom; Mean Sq, mean of square; Sum Sq, sum of square.

***Significant at the <0.001 level.

**Significant at the <0.01 level.

*Significant at the <0.05 level.

convenient while accurate solution for dermatologist and researcher in skin aging study.

Chinese skin aging scales were also explored in previous studies. For instance, facial wrinkle grading scale for Chinese women was established by using 242 Chinese women, including crow's feet, forehead lines, glabellar frown lines, and nasolabial folds.[24] In addition, clinical trial by using the scales also suggests the method is applicable in skin study. However, other study about Chinese women aging applied non-Chinese standard. A study investigating skin aging related gene used [25] SCINEXA^{TM} standard, which was originally developed by Germen women.[2] In multi-ethnicity research, graphical scales were mostly used.[15,20] Our method serves as alternative in future Chinese women aging study.

A universal skin aging score or age prediction is useful in skin aging detection result. It can generalize different characteristics of skin aging and provide a score for direct comparison. According to dermatologist survey, signs of atrophy (wrinkles, eye bags, etc), discoloration (melasma, etc), and malignant skin lesions are important in general aging assessment score.[26] Nonetheless, no statistical/mathematical model was given. One study showed a skin age score, a linear model with 2 plateaus, has strong correlation with chronological age.[27] To generate a general index, we developed the predicted age, which has high correlation to the actual chronological age. In this model, crow's feet, skin tone, and wrinkle around mouth are critical predictors.

In our study, pigmentation is critical factor in the model. Previous research showed grades of pigment spots are critical signs of Asian aging, and appearance of wrinkle is later than the Caucasian counterpart.[17] Also, Asian skin tends to have higher melanin level with smaller, more clustered melanosome in comparison with Caucasian for UV protection.[28] In addition, dark spots are also critical in perceived age of Chinese women.[29] Our result shows pigmentation on the cheek, and skin tone on the forehead is important aging factor, which agrees with previous study.

Exposome describes the totality of exposures to which an individual is subjected, including both external and internal factors as well as the human body's response to these factors.[30] Our study showed that exposome information collected from questionnaire only cover approximately 6% of variation in skin aging traits. In addition, 32.27% variance left unexplained in the model, indicating missing information. Genetic factor could be one of the most important aspects. Previous studies showed up to 60% of the skin aging variation between individuals can be attributed to genetic factors.[31] For instance, people with specific genotype have more severe crow's feet in Chinese population.[25] Other factors, such as psychological stress[32] and air pollution,[33] which proved to be critical in skin aging, were not in this study. Further study should also consider these factors.

In conclusion, our study established a new skin aging evaluation method for Chinese women. We built a prediction model and explore the factors associated with aging traits. This method could be used in research such as effect of cosmetic for further application.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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