Skin color diversity and skin quality of Chinese women

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Abstract

Skin color is a key aspect (even tone, without pigmented spots, and transparent skin) in the concept of Chinese beautiful skin. Even if skin color overlaps between ethnic groups, Asian skin color has its specificities and diversity [1], [2]. The aim of this study was to measure and identify skin color and skin quality typologies among the diversity of Asian skin color as identify in the literature.
A 2-phases study was set up. First, we conducted a literature review of skin color, focused on Asian skin color. Secondly, a pre-inclusion study was run with 176 Chinese women with the objective to select about 100 women to represent the full range of Asian skin color as identified in the literature. Skin color and skin quality items were quantified on 102 women among them.
10 publications corresponding to more than 8000 subjects were gathered to obtain a map of the Asian skin color, showing that Asian skin color tends to be lighter and a little bit quite yellower, with important differences between countries, cities and between women.
Skin color characterization on 102 women highlighted that Chinese skin has a great variety of colors and qualities, with modulation of skin items from skin color, skin color homogeneity to translucency, hydration, elasticity and firmness but also pores, allowing to identify several typologies of skin.
The skin color with its skin quality items is a key tool for understanding the diversity of concerns and needs of Chinese women.

Key words: Asian skin color; translucency; elasticity; hydration; skin typologies

Introduction

Chinese conception of beautiful skin is multidimensional. Skin color seems to be a major criteria. According to consumers definition of ideal skin color, their tone has to be even, without pigmented spots, and transparent. Worldwide skin color diversity covers a large continuous space color, with overlaps between ethnic groups and even if Asian skin color seems to have its own characteristics, its diversity remains [1], [2]. For example, in 2016, from an international study with 3721 subjects, 6 ethnic groups, in 9 countries (US, China, Japan, Korea, Thailand, France, Russia, Brazil and India), including 1993 Asian women, Baras et Caisey showed the ethnic differences and similarities [2]. The authors highlighted that Asian and Indian skins are the most yellow (even if some Caucasian and Hispanic skins can also be yellow). Meanwhile, some Asian women have pink tones. The clarity for Asian, Caucasian and Hispanic women was similar and Thai skins are darker than Asian skins.
Beyond the major concern of skin color, Chinese consumers take also a great care about their “skin quality”, which is a large concept that includes not only items of color and its repartition but also radiance, skin relief (texture and wrinkles), hydration or ptosis and associated mechanical properties. These concerns are well known to evolve with age with differences and specificities between ethnic

groups. For example, Asian skins are less concern by wrinkles compared to Caucasian skins, but they are concerned in earlier live stages by brown spots [3], [4], [5] and more generally by skin color changes (darkens, becomes yellower) and skin color heterogeneity [6], [7], [8].
Nowadays, a lot of instrumentation tools or scoring techniques can provide information about the different aspects of skin color and skin quality. Skin color can be measure with noninvasive instrumental tools such as colorimeters and spectrophotometers. The colorimeters are objective color quantification tools that represent human color vision whereas spectrophotometers analyze the entire spectral characteristics of a color [9]. Measurement techniques for quantification of skin texture, wrinkles, pores, hydration or mechanical properties variation with age are well documented with the development of non-invasive tools or image analysis but a few data remain unpublished, especially on translucency. For example, Kim et al. in 2017 [10] showed with an experimental design of sleep privation that translucency could be linked to hydration whereas Kim et al. in 2015 [11] and Cho et al. in 2019 [12] highlighted the decreased of translucency with advancing age.
The specificities of skin color and/or skin quality of several ethnic groups, countries or cities have been investigated but these publications lack of investigation about two topics: what about the differences within each ethnic groups to explore woman's uniqueness skin and what about cross analysis of skin color / skin quality on a large number of Asian subjects in order to identify different skin typologies? And these two topics could be of a great interest especially for makeup industry knowledge since, beyond ethnic groups, diversity of skin tones, perceptions, expectations, and makeup strategies, taking into account bare skin color, allow to explain why and how women enhance, correct or transform their skin [2]. Since nowadays makeup products are more and more hybrid products, with skincare characteristics and benefits, these typologies work about skin major concerns for Asian beautiful skin could help to better fulfill needs of Asian women for skin ideal product enhancer.
Thus, the aims of this study were therefore: i) by a scientific review, to map Asian skin color, ii) to measure and identify skin color and skin quality typologies among the diversity of Asian skin color as identify in the literature within a Chinese women population.

Methods

Phase 1: scientific literature review

A scientific literature review of skin color with a focus on Asian skin color allowed a meta-analysis of the skin color ranges. Studies, either from academic or cosmetic field research, were included if they had a research designed that measures Asian skin color through spectral measurement, provide descriptive statistics (raw data or at least the minimum, maximum and/or mean), and must have been written in English. For each study, year of publication, country where the study was set up, number of Asian subjects among the total number of subjects, country of origin of Asian subjects, gender, measurement tool, measuring area and L*, a*, b*, C*, h data (minimum, maximum and/or mean) were recorded.
After applying these inclusion criteria, publications were gathered to obtain a h, L* map of the Asian skin color among the worldwide skin color. The data are expressed in the CIE 1976 standard colorimetric space L*C*h which allows to describe each color through three coordinates that reflect perception by human eye: h for hue angle (from red to yellow for skin color, $h^* = \arctan(b^*/a^*)$), C* for chroma (from muted, even close to gray color to vivid and intense color, $C^* = (a^{*2} + b^{*2})^{1/2}$), and L* for lightness (from dark to white, using a gray scale).

Phase 2: skin color pre-inclusion and study on skin color and quality of Chinese women

Subjects
For the pre-inclusion phase, we were looking for a large number of women who were users of cosmetics from the selective market, within an age range from 18 to 68 y.o. Successfully recruiting 176 Chinese women, we measured their facial skin color with the objective to select about 100 women to

represent the full range of Asian skin color as identified in the literature. The 176 volunteers were from 19 to 59 years old (mean = 34; standard deviation = 7.4). Measurements were made in a room where temperature was standardized (21°C +/- 3°C).
For the study on skin color and quality, 102 Chinese women among the 176 women of the pre-inclusion phase, selected because their skin color homogeneously covers the full range of Asian skin color diversity identified in the literature, were recruited. Women were selected because they were users of selective foundation at least twice a week. The volunteers were from 20 to 68 years old (mean = 42.2; standard deviation = 13.5).
All participants were informed about the objective of the study, signed an informed consent form including image rights on their arrival and received a gift for their participation at the end of the test.
Measurements were made in a room where temperature was standardized (21°C +/- 3°C). At the beginning of the appointment, each woman cleansed her face with makeup removal, lotion and thermal water to remove any trace of care or make-up product.

Experimental acquisition devices
For a quite complete skin color and skin quality study, we used non-invasive devices to measure facial skin color in different areas, translucency, pores, hydration and elasticity.
For both skin color pre-inclusion and study on skin color and quality of Chinese women, to take into account skin color and skin color heterogeneity, bare skin color was measured using a spectrophotometer (Spectrophotometer RM200QC, X-Rite Inc, Michigan, USA) on the forehead and on the cheek. This spectrophotometer belongs to the category of non-invasive tools that are able to analyze the spectral characteristics of a color. It is easy to use for screening or knowledge studies on large cohorts of subjects, with an easy and rapid access to L*, a*, b*, C*, h data. Nevertheless, it is a measuring device in contact with the skin with the drawback that the skin will turn a little bit redder than with a non-contact device. Even if the skin color was already measured in the pre-inclusion phase, it was remeasured on the same subjects for the study phase. Indeed, since the fieldwork dates of the two phases differed a little and that the color of the skin can vary according to the season [7], it was more relevant to remeasure the skin color for the 2 phases.
For the study on skin color and quality of Chinese women, on the cheek, hydration, meaning the capacitance of the skin, which represents the hydration level of the stratum corneum (SC) in the epidermis was measured 5 times and the mean was considered (Corneometer® CM825, Courage + Khazaka Electronic GmbH, Cologne, Germany). Elasticity measurements were made 3 times on the cheek (Cutometer® MPA580, Courage + Khazaka Electronic GmbH, Cologne, Germany) and the mean was considered. Also on the cheek, translucency (Translucencymeter® TLS850, Dia Stron Limited, Hampshire, United Kingdom) was measured and pores, through image analysis, (VISIA-CR®, Canfield Scientific Inc., Fairfield, NJ, USA) were quantified. Skin translucency (or transparency) represents characteristics relating to the lower epidermal layers with parameters reflecting internally scattered light.

Statistics
Data analysis were performed using JMP (JMP®, Version 13.2.1. SAS Institute Inc., Cary, NC, 1989-2016) and R statistical environment (v.3.5.1). Clusters of women were made separately for skin color, considering the color of the bare skin on the cheek and the gap between the bare skin color on the cheek and the bare skin color on the forehead (L*, a*, b*, C* and h data), and skin quality according to CAH « two-step clustering » method, in order to identify skin typologies.
For elasticity, we included 6 variables to our clustering: final deformation meaning extensibility or distensibility (R0 = Uf), gross elasticity including viscous deformation (R2 = Ua/Uf), residual deformation meaning the last minimum amplitude (R4), viscous deformation on elastic deformation meaning the visco-elastic portion (R6 = Uv/Ue), net elasticity without viscous deformation (R5 = Ur/Ue) and recovery after deformation or biological elasticity (R7 = Ur/Uf).
For transparency we considered the K (amount of light detected by the probe as close to the light source as possible), area (total amount of light scattered into the material) and alpha parameters (rate

of attenuation of the light level moving away from the source, a high alpha representing a rapid attenuation of light intensity) [11].
For pores, we considered their occupation rate, their number and some shape factors (round or elongated pore).

Results

Phase 1: scientific literature review

In total, 10 reviewed publications, ranging from 2006 to 2020, allowed to gather skin color data measurement corresponding to more than 8000 Asian subjects [1], [2], [6], [7], [13], [14], [15], [16], [17], [18]. Scientific literature review revealed that it is quite difficult to build a map of Asian skin color due to the low availability of raw data but also to the diversity of skin color measurement tools that have a great impact when computing colorimetric data.
Compared to worldwide skin color (i.e [19], [20], [2], [13], [15]), our scientific literature review showed that Asian skin color tends to be lighter (min L* = 44.3; max L* = 80.5; mean L* = 62.9) and a little bit quite yellower (min h = 37.7; max h = 80.4; mean h = 52.2) even if some Asian women have a rather red skin.
Nevertheless, important differences remain between countries, cities (i.e in China [21]) and between women, even within a country (i.e in Japan [1]). For example, the consolidated data from our literature review showed that Chinese skin seems to be less yellow but more red and darker than Japanese skin.

Phase 2: skin color pre-inclusion and study on skin color and quality of Chinese women

The pre-inclusion phase with 176 Chinese women showed the good skin color diversity for lightness (min L* = 52.2, max L* = 71.4, mean L* = 63.6, delta L* = 19.2, standard deviation = 3.1) and hue (min h = 41.5, max h = 82.9, mean h = 63.3, delta h = 41.4, standard deviation = 6.5), quite equivalent to the one identified in the literature, especially for hue, but in a lesser extent for lightness.
The skin color measurement of the 102 Chinese women, selected because their skin color covers the full range of Asian skin color diversity identified with the first phase, showed good skin color diversity, almost equivalent to the one identified in the literature and pre-inclusion. Indeed, the lightness maximum gap was of 19.3 (min L* = 52.9, max L* = 72.2, mean L* = 62.5, standard deviation L = 3.54) and the hue maximum gap (from red to yellow) was of 50.1 (min h = 37.6, max h = 87.7, mean h = 63.1, standard deviation h = 6.88).
The selected women also showed a great variety of skin quality. Hydration ranged from 27.2 to 103.1 (mean = 65.7, standard deviation = 15.2). Elasticity on cheek (R5) was extended from 0.29 to 0.89 (mean = 0.47, standard deviation = 0.10). There was also a wide variety of translucency (min K = 1308, max K = 2115, mean K = 1764, standard deviation K = 155) and pores number on cheek from 4 to 297 (mean = 96, standard deviation = 49).
As shown in table 1 a and b, skin color characterization highlighted 3 groups of women of rather equivalent numbers, based on their skin color on the cheek and the skin color difference between the forehead and the cheek:

- The first group was composed of 24 women with the yellowest skin and homogeneous skin color. They were the oldest women (Mean age = 52.5 y.o).
- The second group was composed of 37 women with lighter and desaturated skin. Their skin color was heterogeneous for the C* (saturation). They were the youngest women (Mean age = 34.0 y.o).
- The third group was composed of 41 women with darker and redder skin. Their skin color was homogeneous for the L* (light component) but heterogenous for the h* (hue component). The mean age of this group was 43.6 years old.

The groups are illustrated with standard I VISIA-CR images in Figure 1.

a.	L*		a*		b*		C*		h	
	Mean	*Standard deviation*	Mean	*Standard deviation*	Mean	*Standard deviation*	Mean	*Standard deviation*	Mean	*Standard deviation*
Group 1 (24 women)	63.75 b	*0.56*	7.26 a	*0.34*	17.84 b	*0.41*	19.28 b	*0.34*	67.94 c	*1.38*
Group 2 (37 women)	66.66 c	*0.45*	6.99 a	*0.27*	13.98 a	*0.33*	15.76 a	*0.28*	62.24 b	*1.11*
Group 3 (41 women)	60.88 a	*0.43*	10.95 b	*0.26*	14.89 a	*0.31*	18.64 b	*0.26*	53.05 a	*1.05*
F	42.77		66.93		27.86		41.08		40.42	
Pr > F	< 0.0001		< 0.0001		< 0.0001		< 0.0001		< 0.0001	

b.	dL*		da*		db*		dC*		dh		dE	
	Mean	*Standard deviation*	Mean	*Standard deviation*	Mean	*Standard deviation*	Mean	*Standard deviation*	Mean	*Standard deviation*	Mean	*Standard deviation*
Group 1 (24 women)	-3.00 a	*0.49*	1.14 b	*0.35*	1.23 a	*0.38*	1.60 a	*0.35*	-1.47 a	*1.21*	4.41 a	*0.43*
Group 2 (37 women)	-3.84 a	*0.40*	1.08 b	*0.29*	3.91 b	*0.31*	3.90 b	*0.28*	3.57 b	*0.98*	6.40 b	*0.34*
Group 3 (41 women)	-0.02 b	*0.38*	-1.82 a	*0.27*	3.74 b	*0.29*	2.19 a	*0.27*	10.92 c	*0.93*	4.85 b	*0.33*
F	26.30		34.54		17.39		15.49		36.64		8.27	
Pr > F	< 0.0001		< 0.0001		< 0.0001		< 0.0001		< 0.0001		0.0004	

Table 1 a and b: Summary of colorimetric means and standard deviation by group of women from 1-factor Anova (Group) and Tuckey post hoc tests (a. LabCh on cheek; b. color heterogeneity between forehead and cheek areas). Two different letters indicate a significant difference for the same variable at the 5% level.

Group 1: Yellow and homogeneous

Group 2: Light and desaturated; heterogeneous for saturation

Group 3: Dark and red; homogeneous for lightness and heterogeneous for hue

Figure 1: Representation of the 3 groups of skin color (cheek area from standard I VISIA-CR images)

Skin quality characterization (hydration, elasticity, pores and translucency) highlighted 3 groups of women (table 2):

- The first group was composed of 27 women with transparent and poreless skin, but lacking hydration (Mean age = 42.6 y.o).
- The second group was composed of 25 women with hydrated and elastic skin. They were the youngest (Mean age = 34.2 y.o).
- The third group was composed of 50 women with a less transparent skin and more pores. They were the oldest (Mean age = 45.9 y.o).

Figure 2 illustrates with standard I VISIA-CR images the different groups of skin quality.

	Hydration		R5		Pores number		K	
	Mean	*Standard deviation*	Mean	*Standard deviation*	Mean	*Standard deviation*	Mean	*Standard deviation*
Group 1 (27 women)	52.66 a	*2.52*	0.44 a	*0.02*	46.84 a	*4.12*	1808 b	*28.60*
Group 2 (25 women)	70.47 b	*2.62*	0.56 b	*0.02*	75.96 b	*4.28*	1817 b	*29.72*
Group 3 (50 women)	70.35 b	*1.85*	0.44 a	*0.01*	132.82 c	*3.03*	1714 a	*21.02*
F	18.14		19.75		42.89		5.67	
Pr > F	< 0.0001		< 0.0001		< 0.0001		0.004	

Table 2: Summary of means and standard deviation for skin quality variables by group of women from 1-factor Anova (Group) and Tuckey post hoc tests. Two different letters indicate a significant difference for the same variable at the 5% level.

Group 1: Poreless and transparent skin, lack of hydration

Group 2: Elastic and hydrated skin

Group 3: Less transparent skin with pores

Figure 2: Representation of the 3 groups of skin quality (nasal ala area from standard I VISIA-CR images)

To investigate the relationship between skin color and skin quality of Chinese women, the counts of the 3 skin color typologies and the 3 skin quality typologies were crossed. The result of this analysis allowed us to define 9 typologies of skin colors and skin qualities (Table 3). The typology crossings revealed that a skin color was not associated with a particular skin quality typology. Nevertheless, some trends were observed, especially on color groups 1 (yellow and homogeneous) and 3 (dark and red, homogeneous for lightness and heterogeneous for hue). Indeed, most women with these skin colors represented the skin quality identified by the least transparent skin with pores.

	Group 1 (N=24): Yellow and homogeneous	Group 2 (N=37): Light and desaturated, heterogeneous for saturation	Group 3 (N=41): Dark and red, homogeneous for lightness and heterogeneous for hue
Group 1 (N=27): Poreless and transparent skin, lack of hydration	7	12	8
Group 2 (N=25): Elastic and hydrated skin	3	15	7
Groupe 3 (N=50): Less transparent skin with pores	14	10	26

Table 3: Number of women in the 9 typologies of skin colors and skin qualities (3 color typologies in columns and 3 quality typologies in lines)

Discussion

Our 3 phases study allows us to set up a knowledge study about Asian skin color and quality with the possible widest range of skin colors.
First, the scientific review had brought to light that it is quite difficult to build a consolidated data base from literature because of the lack of raw data and to the different measurement tools. If worldwide data are quite easily available, Asian data (or at least raw data) seem to be less numerous. Go deeper with a meta-analysis specifically on differences between Asian countries seems to be even more complicated but key because of the great diversity of Asian skin color, especially in India [2], Korea [22], [18] or in China with Mongolian skins [20].
Our pre-inclusion phase on 176 women allows to select 102 Chinese women to represent Asian skin color diversity as identified by our scientific literature review. Skin color can depend on the season (i.e [7]), so we thought important to remeasure the skin color of the 102 selected women since the pre-inclusion took place from December to February and the study from March to April. These timing, possibly coupled with measurement error could explain why the skin color measurement are not strictly the same between the two phases, with wider range of skin color for the study vs the pre-inclusion. Nevertheless, the range of skin color with these 102 women is good, almost equivalent to the literature on Asian skin color, especially concerning the hue (h). The difference concerning the lightness (L*) between our data and the range of colors of Asian skin identified in the literature could be explained by the fact that we won't reach the darkest Asian tones represented by Indian skins and lightest Asian tones, represented by Korean skins.
With 102 Chinese women, we could then identify 3 groups of women among the variety of skin colors: the yellowest skin and homogeneous skin color, the lighter and desaturated skin and the darker and redder skin, in rather equivalent numbers. We observe a slightly effect of age within these groups since the lightest skin corresponds to the youngest women and the yellowest to the oldest women. These results are partly in line with the literature. Indeed, Qiu et al. in 2011, in a study on 354 Chinese subjects, reported that aging leads to progressively darker skin tones (L* and C) and more hyperpigmented spots [7] meanwhile de Rigal et al. in 2010 showed that Chinese skin becomes yellower with age [6]. Mayes et al. in 2010 have reported chronological age-related darkening of the skin surface in Chinese populations, thereby explaining the darker skin color of elderly Chinese women (lower L*and ITA) [23]. Nevertheless, our results didn't confirm that the skin becomes darker with age probably because of the weak mean age difference between our three groups, even if significant (Group 1 = 52.5 y.o; Group 2 = 34.0 y.o; Group 3 = 43.6 y.o). As a comparison, Qiu et al. in 2011 worked with women age from 18 to 80 y.o to reach that conclusion [7].
About skin qualities, we observed modulation of skin items to identify 3 groups of women: the transparent and poreless skin but lacking hydration, the hydrated and elastic skin and the less transparent skin with more pores. We observe a slightly effect of age within these groups since hydrated and elastic skin corresponds to the youngest women and the less transparent skins and with more pores corresponds to the oldest. These observations are in line with the literature. For example, in a study with 100 healthy Korean women aged from 20 to 60 y.o, Cho et al. in 2019 demonstrated that aging significantly affects human skin in terms of parameters such as wrinkles, skin color, elasticity, and epidermal hydration [12]. The authors highlighted that skin elasticity and wrinkles were observed to show and inversely proportional relationship in the early 40s and that skin transparency and brown spots change rapidly in the early 30s and the late 50s, transparency changes probably induced by higher heterogeneity of structural component of the epidermis. As transparency is important for radiance perception of a face for consumers and could be modulate by cosmetic products [24], this item is of a great interest when examining skin quality.
Finally, cross-analysis of skin colors and skin qualities revealed 9 typologies of skin colors and skin qualities with no strong link between these two aspects. Nevertheless, we observed some trends showing that women with less transparent skin with pores are the ones with probably a more yellow or dark and red skin and rather homogeneous. Women with light and desaturated probably have either a poreless and transparent skin but with a lack of hydration or an elastic and hydrated skin. These

results mean that for a given skin color, there is not one given skin quality and conversely. Lifestyle habits like solar exposition, tobacco consumption, or hormonal status or cosmetic usage can be some of the numerous factors that could explain and modulated the differences between women. In addition, it would have been also interesting to quantify skin thickness because it could have an impact on these age-related items (ie. [25] for an example).

Conclusions

Our work of cross-analysis definition of typologies on skin colors and skin qualities allowed to highlight woman's uniqueness with regard to the diversity of skin tones and qualities among Chinese women. The skin color with its skin quality items is a key tool for understanding the diversity of concerns and needs of Chinese women, both for skin care and makeup usage. It should be considered by cosmetic industry for diagnosis or future product developments to better fit the multiple needs of consumers through high personalization. This work was of a great importance for the formulation and development of a new makeup foundation range, especially developed for Asian skin in all their color and quality diversity.

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Conflict of Interest Statement

None

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