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Effect of aging in periocular appearances by comparison of anthropometry between early and middle adulthoods in Chinese Han population

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Summary *Purpose:* Age-related change in ocular appearance occurs throughout adulthood, and involutional alterations in periocular tissues are common in middle-aged or older adults. This study sought to investigate significant differences in periocular anthropometry between young and middle-aged adults of Chinese Han ethnic group.
Methods: A total of 589 Chinese Han adults were recruited for cross-sectional investigation: 309 young adults (20 to 30 years), and 280 middle adulthood (50 to 70 years). Standardized, frontal view photographs were taken from each subject for measurements of 17 ocular anthropometric parameters (11 linear, three angular and three indicial parameters) detailing dimensions of palpebral fissures, and eyebrows. Eyelid crease morphologies were also evaluated.
Findings: Distribution of eyelid crease subtypes were different between the two age-groups, and an eyelid subtype (Type VI Closed Crescent) was uniquely found in middle-aged adults. Significant differences were found in majority of the ocular parameters. For most of the fissure-related measurements, values were greater in young adults. For some distance-dimensions between eyes and eyebrows, values were greater in the middle-aged adults. Detailed evaluation of periocular parameters of different age was individually performed for two subjects, which embodied findings from the cross-sectional analysis.

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Conclusions: By comparison of anthropometries between age-groups, we found alterations in periocular and eyelid morphologies under effect of aging, with association of laxity and loss of elasticity in periocular tissues. This study was the first to provide normative periocular dimensions of early and middle adulthoods in Chinese Han, which is useful for considerations in esthetic surgical decision-making for this population.

Introduction

The facial appearance is the most variable part of the human body and carries information that allows one being identified from others. Details of the ocular region such as the eye fissure, eyelids, and eyebrows are important landmarks that play crucial roles in facial attractiveness, emotional expression, and identification of ethnicity, gender, and age. In cosmetic, anatomical relationships of these landmarks should be carefully referenced in surgical procedures for correction, restoration, or aesthetics, to ensure a normal postoperative appearance.[1]

Among gender[2,3] and ethnicity,[4,5] aging is one important factor that cause changes in ocular appearances. First signs of aging could occur in the late 20s and early 30s,[6] and changes begin with periocular skin, with possible involvements of laxity of the periocular tissues.[7,8] Information regarding normal ocular features at different age categories might be useful in understanding age-related morphological alterations.

Han ethnicity, being by far the largest ethnic group in the world[9] that accounts for over 92% of the total population in China, is the representative appearance of Chinese in general understanding. To date, numerous anthropometric studies on ocular appearances of Caucasians have been reported,[2,10] yet information on Chinese, in particular the Han ethnicity is merely available.

We have previously reported anthropometric values of periocular landmarks in a group of Chinese Han young adults of 20 to 30 years of age,[11] and conducted an age-related, comparative investigation with the children aged between 7 and 10 years.[12] To further our understandings on anthropometric information from previous studies, the present study sought to extend investigations on age-influenced morphological changes in adults of Chinese Han population from young adults of 20 to 30 years, to mid-adulthood of 50 to 70 years.

Methods

Patients

This study was a cross-sectional, observational and analytical investigation carried out in Zhongshan Ophthalmic Center (ZOC), Guangzhou, China. Subjects were recruited between November 2015 and September 2016. A total of 589 volunteers of the Chinese Han ethnic group were recruited, including 264 males and 325 females. They were of two age groups: 309 young adults of 20 to 30 years of age (149 males and 160 females) with a mean age of 25 years; and 280 of middle adulthood group at 50 to 70 years of age (115 males and 165 females) with a mean age of 60 years. Subjects were excluded for having conditions that could affect measurement of periocular features, such as congenital craniofacial anomalies, diseases or tumors occurred at the orbit, and surgical history or trauma at the periocular regions. The Chinese Han ethnicity was determined by his/her ethnic background stated in registry record.

Acquisition of photographs

Two colored, frontal view photographs of each subject were acquired by a digital camera (NIKON D7100, Japan), with his/her head held in a natural, upright posture: the first photograph was taken from the subject with his/her brows relaxed and eyes open in a primary gaze; the second photograph was taken with the subject's eyes gently closed (Supplementary Figure 1). A scale bar of 20 mm was included in each photograph or calibration to avoid measurement bias due to focal distance. Standardization of photograph was achieved by aligning the camera with the axial plane of the eyes. The standardized photographs were analyzed with an image processing software (IMAGE J, 1.4.3.67).

Well-preserved, frontal view photographs were generously provided by one male and one female volunteers: photographs were taken throughout the time span of their adulthood, from their 20s, for approximately every decade till the current age of 60 to 70 years.

Collection of anthropometric landmarks at ocular region

Ocular anthropometric landmarks were identified on each photograph. With fiduciary of anthropometric landmarks, a total of 17 parameters were studied in this investigation: including 11 linear, three angular measurements, and three further derived analytical indices (Figure 1). The eyelid creases were classified into six subtypes according to their unique features, and they have been defined with specific terms in our previous publication (Supplementary Table 1).[12]

For the two individual subjects who provided photographs at different ages, it would be difficult to standardize the photographs due to lack of scale bar; therefore, anthropometrical evaluation was only made for angle of

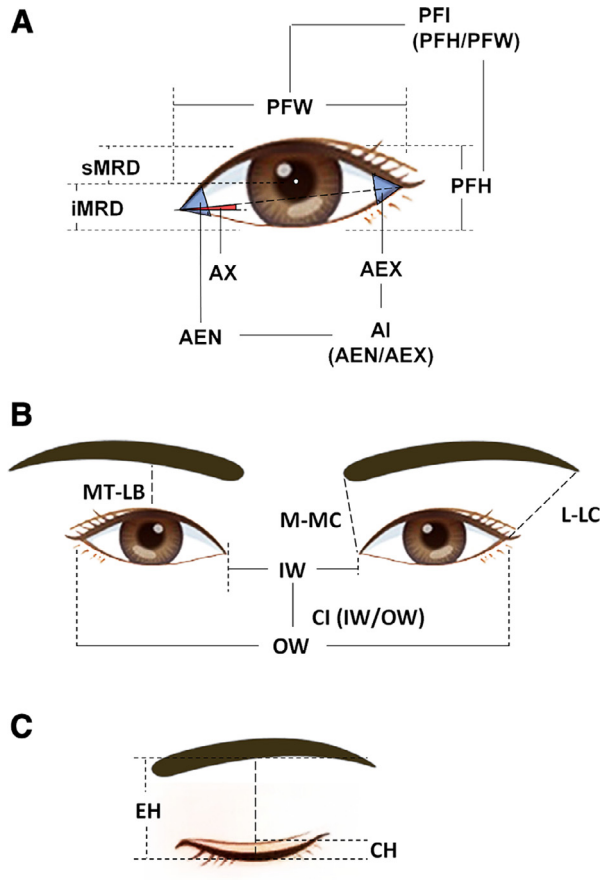

Figure 1 Anthropometric parameters at the ocular region. (A) Dimensions of an eye fissure. (B) Distance-related dimensions between eyes and eyebrows. (C) Measurements of eyebrow height and crease height while the eye is gently closed. En, endocanthion; Ex, exocanthion; Lb, lateral end of the eyebrow; Mb, medial end of the eyebrow; MTb, midtarsal related lower end of the eyebrow; Pc, pupil center; Ps, palpebrae superius; Pi, palpebrae inferius; Us, upper eyelid crease; PFH, palpebral fissure height; PFW, palpebral fissure width; sMRD, margin reflex distance of the palpebrae superius; iMRD, margin reflex distance of the palpebrae inferius; IW, intercanthal width; OW, outercanthal width; M-MC, distance from the medial end of the eyebrow to the medial canthus; MT-LB, distance from the midtarsal to the lower end of the eyebrow; L-LC, distance from the lateral end of the brow to the lateral canthus; EH, eyebrow height; CH, crease height; AEN, angle of endocanthion; AEX, angle of exocanthion; AX, acclivity of palpebral fissure; PFI, palpebrae fissure index; AI, angular index; CI, canthal index.

acclivity (AX), indicial parameters, and eyelid morphologies. Other periocular conditions such as development of lower-lid sacs, ectropion or entropion were evaluated.

Statistical analysis

Statistical analysis was performed with SPSS (version 22.0; SPSS, Chicago, USA). For continuous parametric data, statistics were analyzed as mean with standard deviation (SD),

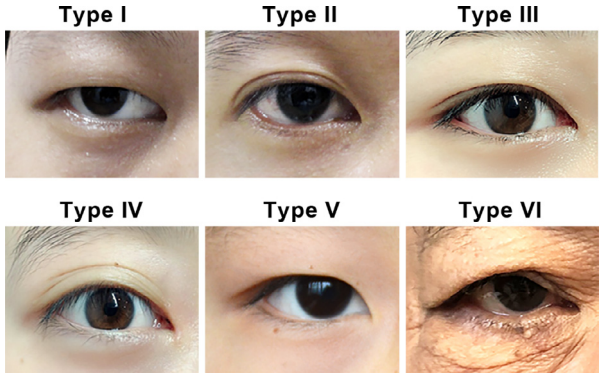

Figure 2 Subtypes of upper eyelid creases. Representative images of eyelid crease subtypes in Chinese Han adults.

and the statistical significances between the age groups were analyzed with *t*-test. The Chi-square test was performed to examine the distribution differences of eyelid profiles between age groups. Statistical significances were considered at $p < 0.05$.

Results

Different eyelid morphologies in different age groups

For the Chinese Han young adult age group (20 to 30 years), 5 subtypes of eyelid creases were identified; in contrast, 6 subtypes were identified for the middle adulthood group of Chinese Han (50 to 70 years). Representative images of eyelid crease subtypes were demonstrated in Figure 2. The distribution of eyelid creases was statistically significant between the two age groups (Table 1, $p < 0.0001$, Chi-square test). Type I (Single-fold) was the most common subtype found in both age groups. Type VI (Closed-end Crescent) was a unique eyelid subtype identified in the middle adulthood age group, which accounted for 26.07%. The crease height was not much different between the young adult and middle adulthood age groups ($p = 0.147$, *t*-test).

Epicanthal folds are another feature of eyelid-related morphologies in Asian. In this study on Chinese Han ethnic group, the difference in prevalence of epicanthal folds in young and middle-age adult groups was statistically significant ($p < 0.0001$, Chi-square test).

Comparison of ocular anthropometry between age groups

Comparison of anthropometric data between young adults (20 to 30 years) and middle-aged adults (50 to 70 years) is detailed in Table 2.

Eye fissure measurements

In this study, there were 9 parameter measures of the palpebral fissure, illustrating the details in the shape of the eye. The palpebral fissure width (PFW) and height (PFH), the superior marginal reflex distance (sMRD) and interior MRD (iMRD), angles of endocanthion (AEN) and exocanthion

Table 1 Comparison of prevalence of different features of eyelid morphologies in Chinese Han adults.

Age groups (*n*)	20-30 years (309)		50-70 years (280)		*p*-value*
	Presence (*n*)	%	Presence (*n*)	%	
Type I (Single-fold)	122	39.48	110	39.29	<0.0001
Type II (Parallel-fold)	82	26.54	50	17.86	
Type III (Open-ended Crescent)	25	8.09	20	7.14	
Type IV (Classic Crescent)	68	22.01	9	3.21	
Type V (Hidden-fold)	12	3.88	18	6.43	
Type VI (Closed crescent)	0	-	73	26.07	
Epicanthus	129	41.75	89	31.79	<0.0001

* Chi-square test for comparison of categorical data. Statistically significant at $p < 0.05$.

Table 2 Comparison of ocular anthropometry between young and middle-age adult groups.

Age groups	20-30 years ($n = 309$)			50-70 years ($n = 280$)			Change (%)	*p*-value*
	Mean	SD	Range	Mean	SD	Range		
Fissure-related measurements								
PFW (mm)	28.24	2.56	21.32-34.57	25.10	3.82	12.97-34.63	−11.1	<0.0001
PFH (mm)	9.97	1.50	5.77-14.12	8.19	1.26	4.28-11.95	−17.9	<0.0001
sMRD (mm)	3.31	0.49	2.08-4.72	2.43	0.65	0.61-4.40	−26.6	<0.0001
iMRD (mm)	5.45	1.00	2.82-8.60	5.00	0.54	3.62-6.77	−8.3	<0.0001
CH (mm)	1.80	1.60	0.0-7.17	1.62	1.49	0.0-5.00	−10	0.147
AEN (deg)	58.41	10.61	33.10-96.30	42.89	14.74	17.42-69.16	−26.6	<0.0001
AEX (deg)	81.57	15.39	37.50-121.50	65.42	8.64	52.92-83.00	−19.8	<0.0001
AX (deg)	9.71	2.74	2.70-17.40	9.54	3.69	4.19-16.55	−1.8	0.532
PFI (%)	35.46	5.78	19.82-50.89	32.56	4.12	21.28-43.16	−8.2	<0.0001
AI (%)	73.28	15.50	42.38-123.47	65.40	21.80	32.91-111.04	−10.8	<0.0001
Distance-dimensions between eyes and eyebrows								
IW (mm)	33.28	2.63	26.32-39.75	33.55	2.63	29.41-37.86	+ 0.8	0.221
OW (mm)	86.72	6.31	68.10-110.20	83.61	2.94	75.27-88.46	−3.6	<0.0001
M-MC (mm)	17.58	2.25	10.14-23.92	18.34	3.26	9.95-27.43	+ 4.3	0.0035
MT-LB (mm)	10.25	1.34	5.43-13.59	10.65	2.46	3.50-17.57	+ 3.9	0.0227
L-LC (mm)	16.84	1.53	12.85-21.97	15.49	2.07	10.08-21.07	−8.0	<0.0001
EH (mm)	18.98	2.12	12.49-25.44	19.67	2.19	11.83-24.95	+ 3.6	<0.0001
CI (%)	38.41	3.09	28.69-47.98	40.08	2.62	31.91-47.33	+ 4.3	<0.0001

Fissure-related measurements: PFH, palpebral fissure height; PFW, palpebral fissure width; sMRD, margin reflex distance of the palpebrae superius; iMRD, margin reflex distance of the palpebrae inferius; CH, crease height; AEN, angle of endocanthion; AEX, angle of exocanthion; AX, acclivity of palpebral fissure; PFI, palpebrae fissure index; AI, angular index. **Distance-dimensions between eyes and eyebrows:** IW, intercanthal width; OW, outercanthal width; M-MC, distance from the medial end of the eyebrow to the medial canthus; MT-LB, distance from the midtarsal to the lower end of the eyebrow; L-LC, distance from the lateral end of the brow to the lateral canthus; EH, eyebrow height; CI, canthal index.

* Student *t*-test, statistical significance at $p < 0.05$.

(AEX), palpebral index (PI) and angular index (AI) were significantly greater in the young adult group than the middle adulthood ($p < 0.0001$, *t*-test). It is worth to note that the PFH, sMRD, AEN and AEX had greater mean change percentages: all decreased by over 15% when age increased. Angle of acclivity (AX) was not much different between the two groups ($p < 0.532$).

Distance-related parameters

Seven parameters that were relevant to the positional relationship of the eye on the face, in relation to the other eye or to the eyebrow, providing a general impression of the periocular region. While intercanthal width (IW) was not statistically significant, the outer-canthal width (OW) was greater in the young adults, and the canthal index (CI) was therefore smaller ($p < 0.0001$, *t*-test). The distances between eyes and eyebrows at medial (M-MC) and midtarsal (MT-LB) points were greater in middle-aged adults ($p = 0.0035$ and 0.0227, respectively), while the eyebrow distance at the lateral end (L-LC) was greater in young adults ($p < 0.0001$). The eyebrow height (EH) was greater for middle adulthood ($p < 0.0001$).

Anthropometric changes in two individual subjects

Alterations in eyelid morphologies and anthropometric parameters were evaluated and summarized in Table 3.

The male subject had eyelid crease and periocular morphology change throughout his adulthood (Figure 3). The

Table 3 Evaluation of aging in periocular morphologies for two individual subjects throughout adulthood.

Age (years)	Male				Female			
	28	40	53	69	28	40	53	62
Eyelid morphologies								
Subtype	V	II	VI	VI	V	V	V	V
Epicanthus	Yes	No	No	No	Yes	Yes	No	No
Anthropometry								
Palpebral fissure index (%)	32.2	31.7	30.3	32.9	33.8	41.7	40.5	37.8
Canthal index (%)	39.2	38.9	38.5	41.6	43.7	41.6	41.3	45.1
Angle of endocanthion (deg)	61.9	51.9	37.0	45.0	68.5	77.5	64.3	50.7
Angle of exocanthion (deg)	55.0	61.8	67.9	67.8	54.3	68.3	97.8	97.0
Angle of acclivity (deg)	14.0	11.8	8.6	7.0	4.7	11.1	7.6	5.3
Angular index (%)	112.6	84.0	54.5	46.0	126.2	113.4	65.7	52.3
Periocular symptoms								
Lower-lid sacs	No	No	Mild	Advanced	No	No	Mild	Moderate
Ectropion	No	No	No	Mild	No	No	No	No

subject's eyelid crease subtype was of Type V (Hidden-fold) at his 20s and changed to Type II (Parallel-fold) at his early 40s, subsequent alteration to Type VI (Closed Crescent) occurred at his 50s and retained till current age of late 60s. Regression of epicanthi took place at his 40s. Changes in the subject's angular and indicial parameters were noted: both of the PFI and CI initially decreased very slightly till his mid-50s and increased at his late 60s; both of the AI and AX showed gradual declination with increase in age. The presence of lower-lid sacs was shown at the subject's middle-age and became advanced with aging.

The female subject also showed periocular morphology changes throughout her adulthood (Supplementary Figure 2). While she had a uniform eyelid crease subtype of Type V (Hidden-fold) throughout her adulthood, her epicanthi regressed since her 50s. Anthropometric change patterns in indicial and angular parameters were similar to that of the male subject. Lower-lid sacs appeared at her 50s and became advanced at her 60s.

Discussion

The ocular region is of immense importance in the evaluation of one's facial aesthetics and impressions to others. In the present investigation, measurements of the ocular landmarks have been found to change between young and middle-age adulthoods, indicating possible involvements of changes in periorbital tissues. The data in this study were cross-sectional, providing valid estimations of age-related trends in periocular morphological alterations.

Age-groups were determined by the distinctiveness of the ocular landmarks.[13] For instance, our previous report on comparison of young adults at 20 to 30 years of age and children of 7 to 10 years old demonstrated the significance in anthropometric values due to development of craniofacial complex and other ocular-related structures.[12] In this very study for aging effects, comparison was made between young adults and middle adulthood (50 to 70 years), and the time span between the age-groups could vary 30 to 50 years. Craniofacial structures have been well-developed by adulthood, yet soft tissue changes are many.

Aging of periorbital tissues is characterized by decrement of laxity and reduced collagen and elastic fibers, which are liable for tensile strength, flexibility and resiliency of tissues.[14,15] Loss of elasticity results from enzymatic elastolysis, which is associated with accumulative courses of various factors such as local ischemia, inflammation, and/or chronic, repeated mechanical stress.[16,17] Aging begins with skin, and the primary sign appears to be streaks of wrinkles, often seen at lateral periocular skin.[6] Dermatochalasis, an advanced skin aging, presented as an excessive skin being weighed down by the effect of gravity, is the most commonly seen symptom in middle-age and older.[7] Other anatomical structures being affected by laxity include tendons and ligaments,[2,7] as well as connective tissues such as orbital septum.[6] Displacement of facial and orbital adipose tissues is also a contributing factor to signs of aging.[6] Taken together, ocular anthropometric landmarks could be altered as a long-term result, and other adverse symptoms such as ectropion, entropion and lower-lid sacs are often associated.[8,18]

Unlike Caucasians who predominantly have wide double eyelid creases, profiling of eyelid creases in Asian ethnic groups, including those of Chinese, are more diverse, and could change at different stages in lifetime. According to data in our serial studies,[11,12] incidence rates of the Types II and IV eyelid creases increased with development after childhood, and decreased with aging at the middle-age. A previously-not-reported eyelid crease subtype, the Type VI - Closed Crescent, was uniquely found in approximately one-fourth of the middle-aged subjects, characterized by lapping of excessive upper-lid over the lateral tarsal. The individually examined male subject well demonstrated evolvement of eyelid crease physiognomy during his adulthood. With reference to data from our previous study,[12] we noted that crease height (CH) was similar in different age groups, regardless of childhood, youth, or middle-age adulthood.

Epicanthus is a distinctive feature in Asian eye morphologies,[19] and change of prevalence was observed in our serial studies, who demonstrated high incidence of epicanthus in childhood, and regression in early adulthood due to development.[12,20] In the present study, epicanthal regression was demonstrated in both of the two individually inspected

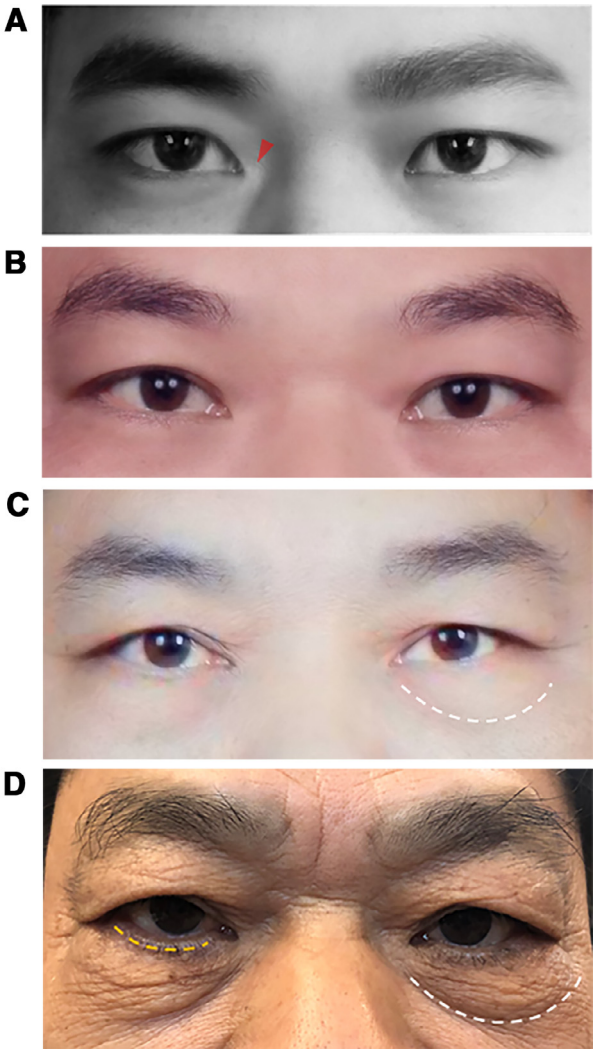

Figure 3 Ocular appearances of a male subject at different ages in adulthood. Front-view photographs at age of (A) 28 years; (B) 42 years; (C) 53 years and (D) 69 years. Periocular morphological features were highlighted: epicanthal folds were indicated by red arrowheads; lower-lid sacs were outlined by white dash-lines; a mild lower-lid ectropion of the OD was present in the male subject at 69 years, shown as yellow dash-line.

subjects, and as well as in the cross-sectional data, significant yet slight slower in incidence was observed during adulthood, indicating the regression of epicanthus in middle-adulthood may occur, yet this morphology tend to persist throughout adulthood in majority of the population.[20]

Anthropometric values are greatly affected by craniofacial development before adulthood, and aging of facial soft tissues during adulthood. Longitudinal anthropometric parameters such as palpebral fissure width (PFW), intercanthal width (IW) and outer canthal width (OW) are partially affected by the medial and lateral canthal tendons. Relaxation of tendinous support releases canthal tissue,[7] leading to shortening the PFW and OW, and widening of IW. Latitudinal parameters such as fissure height (PFH), marginal reflex distances (sMRD and iMRD), and relative distal relationship to the eyebrows (EH, M-MC, MT-LB and L-LC) may be affected by the weigh down of upper-lid tissues and possible loss of tensile stretch from lid retraction by the levator muscles.[6] Our data found that PFH, sMRD, and angular measures of endocanthus (AEN) and endocanthus (AEX) were parameters that had greatest mean change percentages, which leads to change of sizes and shapes of the eye fissures, and we anticipated these may be due to possible compounded effects of laxity of different types periorbital tissues that results in downward displacement of the upper eyelid. Rejuvenation of the periocular region often involve restoration or uplifting of the upper eyelids and the temporal tissues.[21] The two individuals were good examples that demonstrated physiognomic and quantitative changes in ocular parameters, such as palpebral fissure index (PFI), canthal width index (CI) and angular parameters.

Many facial-periocular disorders are associated with age-related morphological changes, for instance, ectropion and entropion are results of advanced dermatochalasis,[18] and development of sacs at the lower lid.[6] These phenomena were demonstrated in the two individuals at their middle-age stages.

Follow-up of morphological changes throughout lifetime is difficult, and cross-sectional study is by far the most appropriate approach in providing representing normative database on periocular anthropometrics. This cross-sectional study was conducted on a large pool of population with approximately 300 subjects per age-category, therefore, the obtained data was sufficient to be representative for the Chinese Han ethnic group. Moreover, we were fortunate to be permitted to inspect photographs of two individuals over the span of their adulthood, which made the study valuable. One of our previous studies demonstrated gender variance in ocular anthropometric measures in young adults,[11] however, because morphological alterations vary among individuals, the observed changes of the two subjects do not represent gender-specific significance in age-related evolvements.

Based on our acquaintance, the male subject is socially active, and works approximately 50 h per week with frequent travelling and outdoor activities, and he presented with advanced skin looseness. Whilst the female subject is a rather socially inert, self-hired individual who spends most time indoor, and we have noticed the skin condition was well maintained for her age. Socio-economic may contribute greatly in the process of aging, in the context of one's lifestyle and quality of living, occupational attribution, as well as the exposure to environmental stress. Cross-sectional data analysis in this study was acquired from the average laymen population of Han ethnicity, without further sorting according to socio-economic categories. It is hence worth to confine the categories for subject selection, and extend the study on extrinsic effects on development and aging.

Conclusion

The present investigation provided a normative anthropometric database for Chinese Han ethnic group of two age-categories in adulthood. Statistical analysis provided a

quantitative comparison of ocular landmarks with explanatory descriptions on periorbital structures caused by aging. We believe these norms are helpful in diagnosis and prognosis of age-related periocular disorders, and indicative in procedures and managements for correction, restoration or aesthetics.

Declaration of Competing Interest

None declared.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2019.07.030.

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