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A comparative study of 40 facial phenotypic measurements in Naga population of India

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Abstract

This study analysed 40 different anthropometric landmark measurements of various facial phenotypes in the Naga population of India. The Nagas, a tribal population belonging to the North-East region of India, have lacked anthropometric data records pertaining to the facial features necessitating this study. Using digital sliding caliper and spreading calipers, 300 subjects (200 Naga: 123 male, 77 female; 100 North Indian population: 60 male, 40 female) aged between 18-30 years were measured, excluding those with any craniofacial deformities or surgeries. Statistical differences were found in facial measurements between Naga and Northern Indian populations, with sexual dimorphism observed in both. The male facial measurements tended to be higher, except for the ear lobes. Naga facial measurements differed from other published populations due to ethnic and environmental factors, yet few similarities were noted with the Japanese population. This study provided insights into the intricate morphological features of the face encompassing the ear, nose, eyes and mouth, in the Naga and Northern population of India. The findings of this research can contribute to establishing a reliable reference dataset for comprehensive facial traits in the realms of forensic anthropometry, forensic DNA phenotyping, facial reconstruction and aid in medical surgical procedures and craniofacial disorders.

Keywords: Naga, Nagaland, North-India, Forensic Anthropology, Anthropometry, Forensic Science.

Introduction

The human facial morphology, one of the most easily observable features of an individual is determined by the underlying skeletal framework, the tissues, and the cartilage which helps manifest the morphology of the face. It is the synergism of these spatial arrangements that gives each individual human face its unique morphology. [1, 2]. This is primarily due to the facial phenotypic consistency and variability traits which can be seen both within and between individuals of different races and ethnic groups respectively [3]. A person's phenotypic traits such as eye and skin color, and other distinctive facial features (i.e., face morphology, eyes, forehead, lips, nose, etc) are all inheritable complex traits affected by both environmental as well as genetic factors [4]. However, the proportion of genetic and environmental factors varies greatly as these facial phenotypic characters are polygenic in nature i.e. controlled by a number of genes, these phenotypes are considered a product of the quantitative or combinatorial effects of all the polymorphisms in the genes involved and the environmental factors [5]. Several factors such as the environment, geographical and ecological location, race, gender, and age, etc are also known to affect the dimensions of the human face [6]. Genomic variation inherited from parents to offspring plays a significant role in facial traits, making facial dimensions valuable for identifying characteristics such as race, age and sex [7]. The science of facial morphology spans disciplines dealing with identification in forensics, facial recognition through the use of computer software, predictions of facial aging, anthropology and craniofacial developmental studies and in facial reconstructions [8].

India’s distinctive geographic location in the northern and eastern hemispheres of Asia has made it a hotbed of complex migration and admixture events throughout history and as a result has accommodated populations from a myriad of diversified ancestries over time which originated from Eurasia and South-East Asian descent [9, 10]. The population hailing from the state of Nagaland, India called as the “Nagas” are a race of Mongolian origin belonging to the Tibeto-Burman ethnolinguistic group. The exact origin and migration history of the Naga population in India remains shrouded in mystery due to a lack of studies available. Mongoloid populations, including the Naga ethnic groups, are commonly described as having relatively fair skin tone, obliquely set eyes, prominent cheekbones, sparse body hair and an average medium stature. The most peculiar facial features are broad-head, fair or light complexion and scanty facial and body hair, with nose types varying from fine to broad. Their facial structure tends to be flat, with oblique eyes featuring epicanthic folds. The majority of population from Northern region of India belongs to the Indo-Aryan ethnolinguistic group, closely resembling traditional Aryans who colonized India. They

generally have a tall build, medium to light skin, dark eyes, and abundant facial and body hair often characterised by long noses and head shapes [11].

Several anthropometric studies on facial phenotypic characteristics have been carried out in different populations of the world however, facial anthropometric information on the Indian population particularly the Naga population is least explored. Considering these factors, this study was chosen to be undertaken to study and evaluate the complete facial phenotypes/features using anthropometric measurements of the Naga and Northern population of India. As far as currently available literature indicates, this is the first study conducted to assess 40 facial phenotypic parameters in the Naga population (belonging to Tibeto-Burman ethnolinguistic group) of India and to compare the findings with preciously reported data from Indian and global populations.

Materials and methods

A structured questionnaire with details of demographic profile and other necessary information was used to access and determine the inclusion of the subjects according to the prerequisites of the current study. The study objectives and their significance were clearly communicated to all volunteers and written informed consent was obtained before the anthropometric measurements were carried out. The present study included 300 subjects; 200 from Naga Population (male= 123, female=77) and 100 from North Indian population (male=60, female=40) aged between 18-30 years. The inclusion criteria included the volunteers who had no craniofacial deformities or history of craniofacial surgeries or orthodontic surgeries.

Anthropometric measurements

All anthropometric readings were obtained using digital sliding and spreading calipers, with subjects seated comfortably in an upright posture with their head aligned along the Frankfurt horizontal plane. Each parameter was taken three times to obtain optimal results and avoid any errors. The final value used was the average mean of the three readings. This study evaluated 40 anthropometric parameters across multiple facial regions, including the head, face, eyes, nose, ears and mouth, by measuring a range of defined anatomical landmarks (Figure 1A-F). The anatomical reference points employed in the present study are listed below:

- al- Alae
- ch- Cheilion
- cph- Crista philtre
- en- Endocanthion
- ex- Exocanthion

- g- Glabella
- gn- Gnathion
- go- Gonion
- li- Labiale inferius
- ls- Labiale superius
- n- Nasion
- pa- Postaurale
- pra- Preaurale
- prn- Pronasale
- sa- Superaurale
- sba- Subaurale
- sl- Sublabiale
- sn- Subnasale
- sto- Stomion
- tr- Trichion
- zy- Zygomatic

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics Version 29.0.1.0(171). Mean and standard deviation were calculated for all variables. Group comparisons were performed using unpaired Student's t-tests with significance assessed at a 95% confidence interval. A p-value <0.01 was regarded as extremely statistically significant, p-values between 0.01-0.05 was considered statistically significant, while >0.05 were considered not statistically significant, indicating differences too small to be visually distinguishable.

Comparison with global population published dataset

The collected complete facial parameter data of the Naga and Northern Indian populations were compared with the published data of 6 populations which included Japan, India, Singapore, Thailand, Vietnam and North America as reported by [12]. The study assessed multiple craniofacial parameters related to the face, mouth, nose, ears and eyes, including face, mandible and mouth width (zy-zy; go-go; ch-ch), facial length dimensions (n-gn; tr-gn; sn-gn), left ear length (sa-sba), nasal dimensions (al-al; n-sn), eye dimensions (ex-ex; en-en; ex-en) taken from 60 individuals from each population.

Results

Interpopulation comparison

Facial phenotype measurements

Out of the 11 facial measurements, 8 measurements (zy-zy, n-gn, tr-gn, go-go, g-gn, inter tragi distance, g-sn and sn-gn) had high statistical interpopulation variation ($p<0.01$) between the Naga and Northern population of India, except the upper face height (tr-g) which was found to be comparable between the two populations ($p>0.05$). The distances between the right and left tragus to nasion of both ears of Nagas displayed significant differences ($p=0.01$-0.05) as compared to Northern population of India. The Nagas had greater values in all the measurements compared to Northern population of India, the greatest variation was observed in the face height (tr-gn), in which the Naga (mean=186mm ±11.26) and North Indian (mean=170.72mm ±14.62) had a difference of 15.89mm (Table 1).

Nasal phenotype measurements

Out of the 8 nasal measurements, 4 measurements (al-al, prn-sn, n-prn, n-sn) showed extremely significant variation ($p<0.01$) while the remaining measurements were not statistically different ($p>0.05$) between the Naga and Northern population of India. The distance of the nose depth (prn-sn) was higher in North Indians while the nasal width, height and length (al-al; n-sn; n-prn) were more in Naga population (Table 1).

Mouth phenotype measurements

Only upper lip height (sn-sto) and philtrum length (sn-ls) showed highly significant differences ($p<0.01$) between the Naga and the Northern population of India. Mouth width (ch-ch) also showed a significant interpopulation variation ($p= 0.01$-0.05), while the remaining parameterts did not exhibit statistically meaningful differences ($p>0.05$). The Northern Indian population displayed comparatively greater mouth width (ch-ch) values, while the Naga population showed larger upper lip height (sn-sto) and philtrum length (sn-ls) measurements (Table 1).

Ear phenotype measurements

From the total 10 ear measurements, except for the ear lengths of both ears (sa-sba) ($p>0.05$), the remaining 8 measurements (left pra-pa, right pra-pa, right auricle base length, left auricle base length, left a-sba, right a-sba, left b-c, right b-c) showed extremely statistical variation ($p<0.01$) between the Naga and Northern population of India. Only right and left auricle base length were observed to be higher in the Naga population, while other measurements i.e. ear widths (pra-pa), lobular height (a-sba) and lobular width (b-c) of both ears were observed to be higher in the Northern population of India (Table 1).

Eye phenotype measurements

Except for the biocular width (ex-ex) ($p>0.05$), the remaining 3 measurements (en-en, left ex-en, right ex-en) were extremely statistically different ($p<0.01$) among Naga and the Northern population of India. The Naga population had higher biocular and intercanthal widths (ex-ex; en-en) than Northern population of India while higher fissure lengths (ex-en) of both eyes were observed in Northern population of India (Table 1).

Sexual dimorphism: Intra population comparison

Facial phenotype measurements

In comparison of the males (n=123) and females (n=77) of the Naga population, 10 facial phenotypic measurements (zy-zy, n-gn, tr-gn, go-go, g-gn, inter tragi distance, left tragus to nasion, right tragus to nasion, g-sn, sn-gn) showed statistical variation ($p<0.01$) except for the upper face height (tr-gn) ($p>0.05$). Similarly among the males (n= 60) and females (n=40) of the Northern population of India, 9 of the measurements (zy-zy, n-gn, tr-gn, go-go, g-gn, inter tragi distance, left tragus to nasion, right tragus to nasion, sn-gn) were observed to be extremely statistically different ($p<0.01$) except the mid and upper face height (g-sn; tr-gn) ($p>0.05$) (Table 2). Therefore, it can be stated that both the population of Naga and Northern India showed sexual dimorphism on the basis of facial measurement. In both the Naga and Northern population of India, generally males were found to have greater values of facial measurements than the females.

Nasal phenotype measurements

Of the 8 nasal measurements, 6 measurement (al-al, n-sn, n-prn, inter alae width, right alae to pronasale, left alae to pronasale) showed extremely significant sex-based differences ($p<0.01$) in the Naga population while the nose depth (prn-sn) was statistically different ($p=0.01$-0.05). Only the width of columnella ($p>0.05$) was not statistically different. The Northern population of India showed no statistical difference in many of nasal dimensions (n-sn; n-prn; prn-sn), width of columnella and inter alae width ($p>0.05$), while the rest of the measurements (al-al, right alae to pronasale, left alae to pronasale) was found to be extremely statistically different ($p<0.01$) (Table 2). In both the Naga and Northern population of India, the males were generally observed to have greater nasal measurements than the females.

Mouth phenotype measurements

Out of the 7 measurements, 4 measurements (sn-sto, sn-ls, ch-ch, cph-cph) had extremely significant difference ($p<0.01$) between both genders of the Naga population. While the remaining 3 measurements (ls-sto, sto-sl, sto-li) showed no statistical difference ($p>0.05$). Similarly, in the Northern population of India, there was no statistical difference observed in height of vermillion of the upper and lower lips (ls-sto; sto-li) along with the philtrum length (sn-ls) ($p>0.05$). While the rest of the measurements (sn-sto, sto-sl, ch-ch) were extremely statistically different ($p<0.01$). The philtrum width was also found to be statistically different ($p=0.01-0.05$) (Table 2). In both populations, the males generally had greater values than the females.

Ear phenotype measurements

In the Naga population, out of the 10 measurements, 6 measurements (left pra-pa, right pra-pa, left sa-sba, right sa-sba, right auricale base length, left auricle base length) were observed to be extremely statistically different in male and female ($p<0.01$), while the right lobular height was found to be statistically different ($p=0.01-0.05$) whereas in the Northern population of India, only three measurements viz; the right ear width (pra-pa) ($p=0.01-0.05$) , the right and left ear length (sa-sba) ($p<0.01$) were significantly different between the two genders, while the remaining 7 measurements had p values >0.05 and thus were not statistically different (Table 2).Therefore, on the basis of ear measurements, Naga showed more sexual dimorphism than Northern population of India. Only the right and left lobular height were observed to be higher in females compared to male in the both populations, whereas, similar to other facial phenotypic measurements, the remaining ear measurements generally showed greater values in male than the females in both the populations.

Eye phenotype measurements

In the Naga population, all the 4 eye measurements showed sexual dimorphism. The eye width (en-en) was only statistically different ($p=0.01-0.05$) while the remaining measurements (ex-ex, right and left ex-en) showed extremely statistical differences between both genders ($p<0.01$). On the other hand, the Northern population of India showed extremely statistical difference in the measurement of both the eye and biocular width (en-en; ex-ex) ($p<0.01$), while the right and left eye fissure length (ex-en) were not statistically different ($p>0.05$) between both genders and hence showed no sexual dimorphism (Table 2). In both populations, the males generally had greater values than the females.

Comparison with other published population data

Facial phenotypic measurements of the Naga and Northern population of India were compared with the published dataset of six populations (Japan, India, Singapore, Thailand, Vietnam and North America) reported by [12].

Facial phenotype measurements

The face height measurements (tr-gn) showed statistical differences ($p<0.01$) in Naga and Northern population of India when compared with all published populations of Farkas et al., 2005 (6 out of 6) (Table 3A-3F). The face width (zy-zy) of Naga population was also found to be extremely statistically different when compared with all the six published population whereas face width (zy-zy) of Northern population of India was not observed to be significant with the Japanese, Thai and Singaporean populations ($p>0.05$) (Table 3B,3C and 3E). The mandible widths (go-go) of Naga population were found to be extremely statistically different in comparison with the North American Whites and the Japanese ($p<0.01$) (Table 3B and 3F). However, there was no significant difference between the mandible width of Nagas and the Thai and Vietnamese populations ($p>0.05$) (Table 3C and 3D). Significant difference was observed in facial phenotypes of North Indians when compared with all the East Asian populations (Japanese, Thai and Vietnamese), except with the Singaporean population ($p>0.05$) (Table 3B-3E). The facial length and lower face height (sn-gn; n-gn) were statistically different ($p<0.01$) between the Nagas and published East Asian populations (Japanese, Thai, Vietnamese and Singaporean) (Table 3B-3E). Furthermore, all of the 5 facial measurements (zy-zy, tr-gn, go-go, n-gn, sn-gn) considered were extremely statistically different ($p<0.01$) when compared with the northern Indian and Pan Indian population (published population datasets).

Nasal phenotype measurements

The measurement of the nose width (al-al) of the Naga population was extremely statistically different ($p<0.01$) with the Indian, Thai, Vietnamese and North American Whites and was not significant ($p>0.05$) with the Japanese and Singaporean population. Similarly, the nose height (n-sn) was also found to be extremely statistically different in 5 populations (Indian, Thai, Vietnamese, Singaporean and North American Whites) except with the Japanese ($p>0.05$) when compared with Naga population (Table 3A-3F). Furthermore, the nose width (al-al) in northern Indian populations and East Asian populations (Japanese, Thai, Vietnamese and Singaporean) were found to be extremely statistically different ($p<0.05$). No pronounced significant difference ($p>0.05$) was seen in the nose width measurement between the Northern Indian population and the pan Indian published dataset (Table 3A). Similarly, the nose height (n-sn) measurements were also extremely statistically

different ($p<0.05$) between the northern Indian and the other populations (Japanese, Singaporean, Indian and North American Whites) except with the Thai and the Vietnamese population ($p>0.05$).

Ear and Mouth phenotype measurements

The mouth width (ch-ch) measurement among all the published population datasets (6 out of 6) did not show significant difference ($p>0.05$) when compared with both the Naga and the Northern population of India. Similarly, the ear length measurement (sa-sba) of both the studied populations were also similar to the Vietnamese, Thai and North American white population ($p>0.05$). Ear lengths showed significant difference ($p<0.01$), with Indian, Japanese and Singaporean populations ($p<0.01$), when compared with the Naga population (Table 3A-3F).

Eye phenotype measurements

Comparing the eye measurements of Naga population with the 6 published population dataset, only the biocular width (ex-ex) in the pan Indian (published population dataset) and Japanese population showed no statistical significance ($p>0.05$). While, eye width (en-en) was found to be similar between the Naga and Japanese populations ($p>0.05$). Moreover, Northern population of India was observed to have similar eye width with North American Whites ($p>0.05$), while the biocular width was similar with the Thai populations. Furthermore, the fissure length of the left eye (ex-en) was statistically different among all (6 out of 6) populations when compared with both the Naga and Northern Indian population ($p>0.05$) (Table 3A-3F).

Discussion

This is the first study that analysed a total of 40 different facial anthropometric measurements in Nagaland population which is a rarely explored North-Eastern population of India. Comparison of the two study populations of the Naga and Northern Indian populations showed numerous differences in various facial anthropometric measurements. The overall facial measurements showed the most variation which was reflected in 10 of the 11 facial measurements being statistically different ($p<0.05$) except in upper facial height (tr-g). The ear measurements also showed variation in 8 of the 10 measurements except in lengths of both ears (sa-sba). Eye measurements were also distinct and different in 3 of the 4 measurements except biocular width (ex-ex). In contrast, the nose and mouth measurements reflected less variation in many of the measurements. The nasal measurements showed variations in 4 out of 8 measurements which included the nose width, height, length and depth (al-al; n-sn; n-prn; prn-sn) expect width of columnella, inter alae width and right and left alae to pronasale measurements. The mouth had comparatively less variations, showing

differences in only 3 out of 7 measurements (sn-sto; ch-ch; sn-ls). The remaining 4 measurements (ls-sto; sto-sl; sto-li; cph-cph) were found to be statistically insignificant. In total, 28 of the 40 total measurements were distinct and different between the two study populations while 12 measurements showed less variation and hence were not statistically different (Table 1).

Comparative analysis of studied 40 facial phenotypes of Naga population with different published worldwide populations showed both stark contrasts and similarities. According to the facial measurement findings of this study, the Nagas were found to have larger bizygomatic width distance (zy-zy) (149.68±6.90mm) as compared to the other East Asian populations (Japan=144.20±6.46mm; Thailand=142.70±7.30mm; Vietnam=139.15±6.13mm and Singapore=140.40±6.42mm). Similarly, the facial length and lower face height (n-gn; sn-gn), left eye fissure length (ex-en) and nose height (n-sn) were greater in the Nagas as compared to the other East Asian populations (Table 3A-3F). The Naga population was also found to share more similarities with the Japanese population. These two populations shared similar measurements of the face height (tr-gn), nose height and width (n-sn; al-al), biocular and eye width (ex-ex; en-en) and mouth width (ch-ch) ($p>0.05$). While, with the rest of the East Asian populations, the Nagas shared similarities in only 2 to 3 of their facial features which by itself weren't distinct enough to be considered as an important feature to distinguish between the races. The anthropometric data seems to suggest that despite having Mongoloid origin, the facial measurements are somewhat distinct and unique even among different East Asian populations. The comparison of facial measurements among the different populations in this study highlights the extent of variation that may occur within populations belonging to the same racial group. The findings of this study are valuable as it contributes to the scope of differentiating and possibly characterizing these individuals even within a particular ethnic group using their facial features.

The facial morphologies although genetically inherited, have been shown to be largely influenced by various other factors such as the environmental conditions, latitude, nutrition and food habits, lifestyle etc which may have influenced the morphologies to conform with conditions over time throughout generations [4]. Owing to their different ethnicities, the facial measurement data were distinctly different between the Nagas, and the Indian and North American Whites published data. These groups belong to different races and ethnolinguistic groups which are reflected in their varied and diverse facial phenotypic measurements (Table 3A and 3F).

In sexual dimorphism analysis, out of 40 facial measurements, 38 were considerably higher ($p<0.05$) in males compared to females in both the Naga and North Indian populations (Table 2). Only the ear lobe heights (a-sba) of both the left and right ears were found to be higher in the females than the

males. The longer length of the ear lobes could be explained by the regular use of earrings by the females, which has been shown to increase the length of the ear lobes over time due to the weight of the earrings [13]**.** Therefore, sexual dimorphism was observed in Naga and Northern population of India based on facial anthropometric measurements. The present study observation is corroborating with previous studies that have shown that males have generally broader and longer face facial features [14], for which most reasonable explanation is the influence of the sex hormones in the two genders. Sexual dimorphism is a biologically driven characteristic influenced during adolescence by the balance between testosterone and estrogen levels [15]**.** Testerone, together with other growth hormones, promotes the growth of facial bones, while the estrogen limits the growth of facial bones by early twenties [16]**.** This elevated levels of testosterone are primarily responsible and contribute significantly to the formation of typical masculine facial characteristics and morphologies in males. The data obtained in this study shows consistency with previous reports demonstrating that males generally possess larger facial dimensions compared to females [17-19]. Therefore, the data from this study may serve as a useful reference dataset for gender characterisation and differentiation.

Future implications

This facial anthropometric measurement data of Naga and Northern population of India can be used as reference dataset which can find numerous applications in the fields of forensics for identification of unidentified bodies and remains, facial reconstruction, anthropology, medical cosmetic and surgery establishments and various other fields. It can contribute to the database for digital biometric systems and could have valuable applications in the automated investigation and analysis of standardized image datasets. Such information is particularly important in forensic investigations, where population specific reference database for different ethnic groups is required for criminal identification. In forensic genetics, such information may also support genotype-phenotype genome wide association studies in relation to facial trait prediction analysis which have potential applications in creating database of Indian population to find genetic signals useful in Forensic DNA Phenotyping (FDP) for identification of criminals. Further studies taking genetic factors into consideration are encouraged to study these features more extensively and associate it with genes to decode and understand their polymorphic nature.

Conclusion

This study provides a complete insight into the anthropometric measurement of the complex morphological variations of multiple facial components (including ear, nose, eyes and lips) in the Naga and Northern population of India. Inter population comparison showed the statistical difference

in facial measurements of different phenotypes in Naga and Northern population of India. The present study showed sexual dimorphism in both the Naga and Northern population of India. With exception of the ear lobe measurement, males generally demonstrated greater dimensions across the evaluated facial traits when compared with females. The findings also reported some distinction as well as similarities in facial measurement of Naga population when compared with other published East Asian and other populations which may have resulted due to their vastly different ethnicities and environmental influences. This study would provide credible reference datasets of complete facial traits in the field of forensic anthropometry, facial reconstruction as well as in medical field for surgeries and craniofacial disorder prediction. However, further studies involving larger and more diverse populations are required to validate and strengthen the findings of the present investigation.

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Table 1: Mean and p-values of facial phenotypic measurements of Naga and Northern population of India

		Naga n=200		North Indian n=100		P value
	Parameters	Mean	SD	Mean	SD	Naga vs North India
Facial measurements	Face Width (zy-zy)	149.68	6.90	142.05	9.47	**<0.0001
	Face Length (n-gn)	131.03	8.92	119.60	9.68	**<0.0001
	Face Height (tr-gn)	186.61	11.26	170.72	14.62	**<0.0001
	Mandible Width (go-go)	107.48	9.35	103.82	10.21	**0.0021
	Total Facial Height (g-gn)	132.82	8.10	124.56	9.52	**<0.0001
	Inter tragi distance	146.84	8.32	136.62	8.89	**<0.0001
	Left tragus to nasion	121.79	6.02	119.83	8.46	*0.0215
	Right tragus to nasion	121.24	5.76	119.34	6.51	*0.0104
	Upper face height (tr-g)	53.89	6.80	53.23	9.03	NS
	Mid face height (g-sn)	67.24	5.62	64.51	5.28	**<0.0001
	Lower face height (sn-gn)	70.14	4.93	63.52	7.16	**<0.0001
Nasal Measurements	Nose Width (al-al)	37.34	3.68	35.82	5.30	**0.0041
	Nose height (n-sn)	55.12	5.70	50.21	5.10	**<0.0001
	Nose length (n-prn)	53.61	5.18	50.38	5.27	**<0.0001
	Nose depth (prn-sn)	17.17	4.92	18.98	3.36	**0.001
	Width of columnella	7.45	3.96	7.12	2.43	NS
	Inter alae width	25.18	3.17	25.95	6.55	NS
	Right alae to pronasale	31.41	2.66	30.74	4.56	NS
	Left alae to pronasale	30.75	3.32	30.54	4.89	NS
Mouth Measurements	Upper lip height (sn-sto)	21.17	2.66	19.05	2.93	**<0.0001
	Vermillion height of upper lip (ls-sto)	7.94	1.42	7.73	3.02	NS
	Lower lip height (sto-sl)	15.98	1.75	15.82	3.53	NS
	Vermillion height of lower lip (sto-li)	10.18	1.58	10.66	3.04	NS
	Width of mouth (ch-ch)	47.61	4.45	48.74	4.41	*0.0384
	Philtrum length (sn-ls)	15.49	4.46	13.60	2.75	**0.0001
	Philtrum width (cph-cph)	12.83	1.79	12.67	2.62	NS
Ear Measurements	Left ear width (pra-pa)	30.27	3.37	32.10	3.61	**<0.0001
	Right Ear Width (pra-pa)	29.24	3.23	32.30	3.52	**<0.0001
	Left ear length (sa-sba)	60.93	4.83	61.07	5.90	NS
	Right ear length (sa-sba)	59.80	5.40	60.54	6.71	NS
	Right auricle base length	49.10	5.41	42.75	7.05	**<0.0001
	Left auricle base length	49.88	4.74	42.28	7.42	**<0.0001
	Right lobular height (a-sba)	18.25	2.38	19.25	3.62	**0.0045
	Left lobular height (a-sba)	17.65	2.58	19.18	4.10	**<0.0001
	Right lobular width (b-c)	13.72	2.92	20.14	2.91	**<0.0001
	Left lobular width (b-c)	13.19	3.01	19.58	2.89	**<0.0001
Eye measurements	Biocular Width(ex-ex)	97.25	5.16	96.30	5.39	NS
	Intercanthal/ Eye Width(en-en)	35.23	5.38	31.66	3.55	**<0.0001
	Right eye fissure length (ex-en)	32.70	2.59	34.63	4.24	**<0.0001
	Left eye fissure length (ex-en)	32.70	2.30	33.88	3.35	**0.0004

*= statistically significant (p=0.01-0.05); **= extremely statistically significant (p<0.01); NS= Not significant (p>0.05)

Table 2: Gender wise mean and p-values of facial phenotypic measurements of Naga and Northern Indian population.

		Naga		North Indian		p-value	
		Male (n=123)	Female (n=77)	Male (n=60)	Female (n=40)	Naga (Male VS Female)	North India (Male vs Female)
Facial measurements	Face width (zy-zy)	151.84±6.66	146.25±5.83	144.31±9.86	138.66±7.79	**<0.0001	**0.003
	Face length (n-gn)	133.54±8.15	127.03±8.67	122.39±9.52	115.41±8.27	**<0.0001	**0.0003
	Face height (tr-gn)	190.02±9.40	181.17±11.89	173.88±15.46	165.98±11.93	**<0.0001	**0.0074
	Mandible width (go-go)	109.94±9.67	103.56±7.30	106.13±10.77	100.34±8.29	**<0.0001	**0.0049
	Total facial height(g-gn)	134.56±7.61	129.53±6.19	127.53±10.55	120.12±5.30	**<0.0001	**<0.0001
	Inter tragic distance	149.64±8.58	142.36±5.48	139.72±9.24	131.98±5.88	**<0.0001	**<0.0001
	Left tragus to nasion	124.40±5.10	117.62±4.96	122.40±6.77	115.99±9.32	**<0.0001	**<0.0001
	Right tragus to nasion	123.90±4.78	116.99±4.50	122.03±5.93	115.31±5.16	**<0.0001	**<0.0001
	Upper face height(tr-g)	54.02±7.62	53.68±5.29	54.62±8.27	51.15±9.80	NS	NS
	Mid face height (g-sn)	68.59±5.66	65.08±4.85	65.21±5.56	63.45±4.71	**<0.0001	NS
	Lower face height(sn-gn)	71.50±4.64	67.98±4.62	65.44±7.25	60.63±6.03	**<0.0001	**0.0008
Nasal Measurements	Nose width (al-al)	38.50±3.87	35.50±2.40	36.91±5.54	34.18±4.51	**<0.0001	*0.0109
	Nose height (n-sn)	56.04±6.23	53.63±4.39	50.95±5.38	49.11±4.48	**0.0034	NS
	Nose length (n-prn)	54.83±5.02	51.67±4.86	50.34±5.65	50.44±4.71	**<0.0001	NS
	Nose depth (prn-sn)	17.80±5.52	16.15±3.56	19.20±3.08	18.64±3.76	*0.0205	NS
	Width of columnella	7.70±4.87	7.04±1.65	7.05±2.23	7.23±2.73	NS	NS
	Inter alae width	26.23±2.82	23.50±3.00	26.55±6.55	25.04±6.53	**<0.0001	NS
	Right alae to pronasale	32.68±2.14	29.39±2.12	32.16±4.35	28.60±4.04	**<0.0001	**<0.0001
	Left alae to pronasale	32.11±3.04	28.59±2.51	31.99±4.70	28.36±4.39	**<0.0001	**<0.0001
Mouth Measurements	Upper lip height (sn-sto)	21.95±2.28	19.91±2.75	19.77±2.99	17.97±2.49	**<0.0001	**0.0022
	Vermillion height of upper lip (ls-sto)	7.96±1.42	7.90±1.41	7.72±2.86	7.73±3.27	NS	NS
	Lower lip height (sto-sl)	16.16±1.83	15.70±1.59	16.62±3.50	14.60±3.25	NS	**0.0045
	Vermillion height of lower lip (sto-li)	10.22±1.63	10.13±1.49	10.81±3.17	10.44±2.84	NS	NS
	Width of mouth (ch-ch)	48.28±5.04	46.55±3.04	49.66±4.70	47.36±3.57	**0.0072	**0.0099
	Philtrum length (sn-ls)	16.15±5.19	14.42±2.65	13.99±2.80	13.01±2.59	**0.0073	NS
	Philtrum width (cph-cph)	13.30±1.90	12.08±1.31	13.15±2.81	11.96±2.12	**<0.0001	*0.0248
Ear Measurements	Left ear width (pra-pa)	31.12±3.36	28.91±2.92	32.64±3.77	31.28±3.25	**<0.0001	NS
	Right ear width (pra-pa)	30.19±3.23	27.72±2.61	32.96±3.76	31.31±2.90	**<0.0001	*0.0209
	Left ear length (sa-sba)	62.01±5.03	59.22±3.95	62.58±5.17	58.80±6.27	**<0.0001	**0.0014
	Right ear length (sa-sba)	61.49±4.35	57.11±5.84	62.41±5.63	57.72±7.26	**<0.0001	**0.0005
	Right auricle base length	50.40±5.36	47.03±4.85	43.74±7.31	41.25±6.43	**<0.0001	NS
	Left auricle base length	51.14±5.02	47.86±3.42	43.19±7.73	40.90±6.81	**<0.0001	NS
	Right lobular height (a-sba)	17.96±2.45	18.70±2.21	19.19±3.59	19.35±3.69	*0.0322	NS
	Left lobular height (a-sba)	17.50±2.88	17.90±2.01	19.06±3.67	19.36±4.71	NS	NS
	Right lobular width (b-c)	13.81±3.06	13.59±2.68	20.39±2.78	19.78±3.09	NS	NS
	Left lobular width (b-c)	13.44±3.21	12.78±2.62	19.83±2.77	19.21±3.07	NS	NS
Eye measurements	Biocular width(ex-ex)	98.86±4.98	94.67±4.34	97.87±5.07	93.95±5.05	**<0.0001	**0.0003
	Intercanthal /Eye width (en-en)	35.83±6.16	34.28±3.65	32.55±2.95	30.32±3.97	*0.0471	**0.0017
	Right eye fissure length(ex-en)	33.47±2.44	31.46±2.36	35.07±4.28	33.97±4.13	**<0.0001	NS
	Left eye fissure length (ex-en)	33.26±2.16	31.80±2.25	34.14±3.35	33.50±3.34	**<0.0001	NS

*= statistically significant (p=0.01-0.05); **= extremely statistically significant (p<0.01); NS= Not significant (p>0.05)

Table 3A: Comparison of facial phenotypic measurements of study populations with published Indian population data.

Parameters	Naga n=200		North Indian n=100		Indian [12] n=60		p-value	
	Mean	SD	Mean	SD	Mean	SD	Naga vs Indian	North Indian vs Indian
Face Width (zy-zy)	149.68	6.90	142.05	9.47	130.35	8.63	**<0.0001	**<0.0001
Face Height (tr-gn)	186.61	11.26	170.72	14.62	162.15	6.10	**<0.0001	**<0.0001
Mandible Width (go-go)	107.48	9.35	103.82	10.21	100.10	5.21	**<0.0001	**0.0096
Facial length (n-gn)	131.03	8.92	119.60	9.68	107.00	7.85	**<0.0001	**<0.0001
Lower face height (sn-gn)	70.14	4.93	63.52	7.16	59.95	5.47	**<0.0001	**0.0011
Nose Width (al-al)	37.34	3.68	35.82	5.30	35.85	3.62	**0.0062	NS
Nose height (n-sn)	55.12	5.70	50.21	5.10	45.45	4.03	**<0.0001	**<0.0001
Width of mouth (ch-ch)	47.61	4.45	48.74	4.41	48.75	4.47	NS	NS
Left ear length (sa-sba)	60.93	4.83	61.07	5.90	59.10	4.84	*0.0106	*0.0306
Biocular Width(ex-ex)	97.25	5.16	96.30	5.39	98.15	4.33	NS	*0.0254
Eye Width (en-en)	35.23	5.38	31.66	3.55	32.50	3.02	**0.0002	NS
Left eye fissure length (ex-en)	32.70	2.30	33.88	3.35	30.75	2.16	**<0.0001	**<0.0001

*= statistically significant (p=0.01-0.05); **= extremely statistically significant (p<0.01); NS= Not significant (p>0.05)

Table 3B: Comparison of facial phenotypic measurements of study populations with published Japanese population data.

Parameters	Naga n=200		North Indian n=100		Japanese [12] n=60		p-value	
	Mean	SD	Mean	SD	Mean	SD	Naga vs Japanese	North Indian vs Japanese
Face Width (zy-zy)	149.68	6.90	142.05	9.47	144.20	6.46	**<0.0001	NS
Face Height (tr-gn)	186.61	11.26	170.72	14.62	187.10	8.84	NS	**<0.0001
Mandible Width (go-go)	107.48	9.35	103.82	10.21	116.45	6.84	**<0.0001	**<0.0001
Facial length (n-gn)	131.03	8.92	119.60	9.68	118.30	7.74	**<0.0001	NS
Lower face height (sn-gn)	70.14	4.93	63.52	7.16	66.10	6.82	**<0.0001	*0.0261
Nose Width (al-al)	37.34	3.68	35.82	5.30	37.65	2.49	NS	*0.013
Nose height (n-sn)	55.12	5.70	50.21	5.10	55.10	5.19	NS	**<0.0001
Width of mouth (ch-ch)	47.61	4.45	48.74	4.41	47.45	6.71	NS	NS
Left ear length (sa-sba)	60.93	4.83	61.07	5.90	63.75	4.20	**<0.0001	**0.0024
Biocular Width(ex-ex)	97.25	5.16	96.30	5.39	98.60	6.14	NS	**0.0142
Eye Width (en-en)	35.23	5.38	31.66	3.55	36.25	3.19	NS	**<0.0001
Left eye fissure length (ex-en)	32.70	2.30	33.88	3.35	29.95	2.27	**<0.0001	**<0.0001

*= statistically significant (p=0.01-0.05); **= extremely statistically significant (p<0.01); NS= Not significant (p>0.05)

Table 3C: Comparison of facial phenotypic measurements of study populations with published Thai population data.

Parameters	Naga n=200		North Indian n=100		Thai [12] n=60		p-value	
	Mean	SD	Mean	SD	Mean	SD	Naga vs Thai	North Indian vs Thai
Face Width (zy-zy)	149.68	6.90	142.05	9.47	142.70	7.30	**<0.0001	NS
Face Height (tr-gn)	186.61	11.26	170.72	14.62	178.95	10.24	**<0.0001	**0.0002
Mandible Width (go-go)	107.48	9.35	103.82	10.21	107.75	5.10	NS	**0.0061
Facial length (n-gn)	131.03	8.92	119.60	9.68	118.15	7.75	**<0.0001	NS
Lower face height (sn-gn)	70.14	4.93	63.52	7.16	67.50	6.87	**0.0011	**0.0007
Nose Width (al-al)	37.34	3.68	35.82	5.30	40.50	2.63	**<0.0001	**<0.0001
Nose height (n-sn)	55.12	5.70	50.21	5.10	50.50	2.90	**<0.0001	NS
Width of mouth (ch-ch)	47.61	4.45	48.74	4.41	47.85	3.78	NS	NS
Left ear length (sa-sba)	60.93	4.83	61.07	5.90	61.35	4.71	NS	NS
Biocular Width(ex-ex)	97.25	5.16	96.30	5.39	95.25	6.05	*0.0121	NS
Eye Width (en-en)	35.23	5.38	31.66	3.55	36.60	2.80	*0.052	<0.0001
Left eye fissure length (ex-en)	32.70	2.30	33.88	3.35	29.35	1.93	<0.0001	<0.0001

*= statistically significant (p=0.01-0.05); **= extremely statistically significant (p<0.01); NS= Not significant (p>0.05)

Table 3D: Comparison of facial phenotypic measurements of study populations with published Vietnamese population data.

Parameters	Naga n=200		North Indian n=100		Vietnamese [12] n=60		p-value	
	Mean	SD	Mean	SD	Mean	SD	Naga vs Vietnamese	North Indian vs Vietnamese
Face Width (zy-zy)	149.68	6.90	142.05	9.47	139.15	6.13	**<0.0001	*0.04
Face Height (tr-gn)	186.61	11.26	170.72	14.62	176.00	9.11	**<0.0001	*0.0128
Mandible Width (go-go)	107.48	9.35	103.82	10.21	107.60	5.12	NS	**0.0084
Facial length (n-gn)	131.03	8.92	119.60	9.68	117.15	6.16	**<0.0001	*0.03
Lower face height (sn-gn)	70.14	4.93	63.52	7.16	67.55	6.02	**0.0008	**0.0004
Nose Width (al-al)	37.34	3.68	35.82	5.30	40.00	2.09	**<0.0001	**<0.0001
Nose height (n-sn)	55.12	5.70	50.21	5.10	51.25	3.61	**<0.0001	NS
Width of mouth (ch-ch)	47.61	4.45	48.74	4.41	48.00	4.79	NS	NS
Left ear length (sa-sba)	60.93	4.83	61.07	5.90	59.85	2.53	NS	NS
Biocular Width(ex-ex)	97.25	5.16	96.30	5.39	90.70	3.12	**<0.0001	**<0.0001
Eye Width (en-en)	35.23	5.38	31.66	3.55	36.65	2.49	*0.0488	**<0.0001
Left eye fissure length (ex-en)	32.70	2.30	33.88	3.35	29.15	2.19	**<0.0001	**<0.0001

*= statistically significant (p=0.01-0.05); **= extremely statistically significant (p<0.01); NS= Not significant (p>0.05)

Table 3E: Comparison of facial phenotypic measurements of study populations with published Singaporean population data.

Parameters	Naga n=200		North Indian n=100		Singaporean [12] n=60		p-value	
	Mean	SD	Mean	SD	Mean	SD	Naga VS Singaporean	North Indian VS Singaporean
Face Width (zy-zy)	149.68	6.90	142.05	9.47	140.40	6.42	**<0.0001	NS
Face Height (tr-gn)	186.61	11.26	170.72	14.62	181.75	9.52	**0.0027	**<0.0001
Mandible Width (go-go)	107.48	9.35	103.82	10.21	104.80	5.24	*0.0349	NS
Facial length (n-gn)	131.03	8.92	119.60	9.68	119.25	6.70	**<0.0001	NS
Lower face height (sn-gn)	70.14	4.93	63.52	7.16	64.30	5.81	**<0.0001	NS
Nose Width (al-al)	37.34	3.68	35.82	5.30	38.20	2.71	NS	**0.0015
Nose height (n-sn)	55.12	5.70	50.21	5.10	52.75	3.30	**0.0024	**0.0007
Width of mouth (ch-ch)	47.61	4.45	48.74	4.41	48.45	3.25	NS	NS
Left ear length (sa-sba)	60.93	4.83	61.07	5.90	59.15	4.13	*0.0103	*0.0282
Biocular Width(ex-ex)	97.25	5.16	96.30	5.39	89.50	5.11	**<0.0001	**<0.0001
Eye Width (en-en)	35.23	5.38	31.66	3.55	36.85	3.31	*0.0281	**<0.0001
Left eye fissure length (ex-en)	32.70	2.30	33.88	3.35	28.90	1.54	**<0.0001	**<0.0001

*= statistically significant (p=0.01-0.05); **= extremely statistically significant (p<0.01); NS= Not significant (p>0.05)

Table 3F: Comparison of facial phenotypic measurements of study populations with published North American Whites population data.

Parameters	Naga n=200		North Indian n=100		North American Whites [12] n=60		p-value	
	Mean	SD	Mean	SD	Mean	SD	Naga VS North American	North Indian vs North American
Face Width (zy-zy)	149.68	6.90	142.05	9.47	133.50	6.01	**<0.0001	**<0.0001
Face Height (tr-gn)	186.61	11.26	170.72	14.62	180.00	10.82	**<0.0001	**<0.0001
Mandible Width (go-go)	107.48	9.35	103.82	10.21	94.10	6.54	**<0.0001	**<0.0001
Facial length (n-gn)	131.03	8.92	119.60	9.68	116.55	7.68	**<0.0001	*0.0393
Lower face height (sn-gn)	70.14	4.93	63.52	7.16	68.70	6.17	NS	**<0.0001
Nose Width (al-al)	37.34	3.68	35.82	5.30	33.05	2.80	**<0.0001	**0.0003
Nose height (n-sn)	55.12	5.70	50.21	5.10	50.95	3.69	**<0.0001	**0.0007
Width of mouth (ch-ch)	47.61	4.45	48.74	4.41	51.55	3.67	**<0.0001	**<0.0001
Left ear length (sa-sba)	60.93	4.83	61.07	5.90	60.45	4.03	NS	NS
Biocular Width(ex-ex)	97.25	5.16	96.30	5.39	88.10	3.99	**<0.0001	**<0.0001
Eye Width (en-en)	35.23	5.38	31.66	3.55	32.25	2.62	**<0.0001	NS
Left eye fissure length (ex-en)	32.70	2.30	33.88	3.35	30.95	1.58	**<0.0001	**<0.0001

*= statistically significant (p=0.01-0.05); **= extremely statistically significant (p<0.01); NS= Not significant (p>0.05)

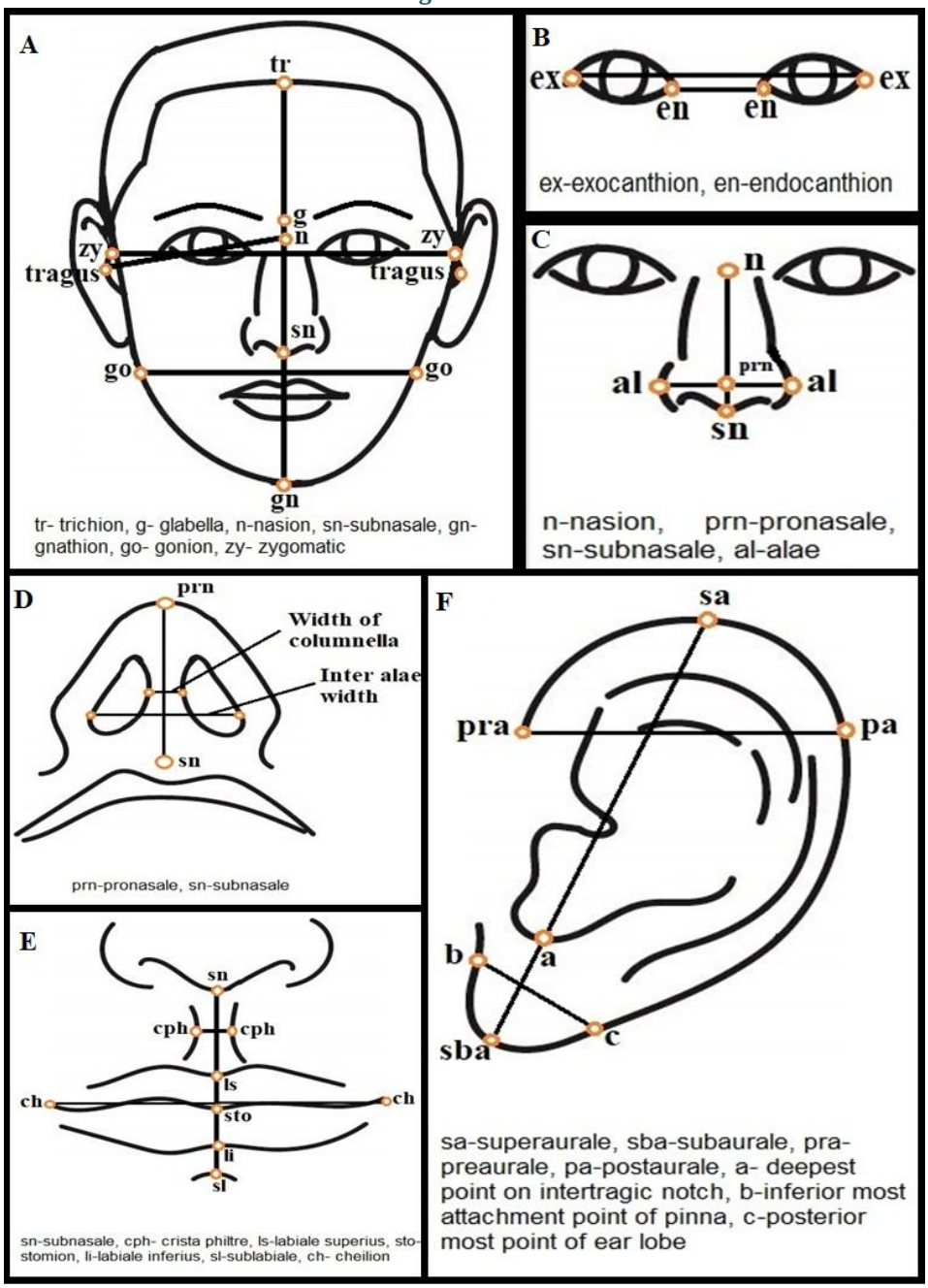

FIGURE 1: Various anthropometric measurements taken for the study**. A: Face:** Face width (zy-zy), face length (n-gn), face height (tr-gn), mandible width (go- go), total facial height (g-gn), inter tragi distance, left tragus to nasion, right tragus to nasion, upper face height (tr-g), mid-face height (g-sn) and lower face height (sn-gn); **B: Eye:** Biocular width (ex-ex), intercanthal width (en-en), left eye and right eye fissure length (ex-en); **C & D: Nose:** Nose width (al-al), nose height (n-sn), nose length (n-prn), nose depth (prn-sn), width of columnella, inter alae width, right alae to pronasale and left alae to pronasale; **E: Mouth:** Upper lip height (sn-sto), height of vermillion of upper lip (ls-sto), lower lip height (sto-sl), height of vermillion of lower lip (sto-li), width of mouth (ch-ch), philtrum length (sn-ls) and philtrum width (cph-cph); **F: Ear:** Left ear and right ear width (pra-pa), left ear and right ear length (sa-sba), left ear and right ear auricle base length, left ear and right ear lobular height (a-sba), left ear and right ear lobular width (b-c).