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Facial Anthropometry Measurements Using 3D Stereophotogrammetry Analysis Among Nigerians.

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ABSTRACT

This study aimed to determine the normative facial anthropometry measurement among Nigerians using 3D Stereophotogrammetry analysis.

This study was carried out in Lagos, Nigeria over a period of three years. The sample population was Nigerians of diverse ethnic groups, age 16 and above with no history of congenital or acquired craniofacial deformities.

A total of 452 subjects participated in the study with 56.2% males and 43.8% females. Most of the participants were between the ages of 25-49 (54.4%), 40.7% were less than 25 years of age and only 4.4% were more than 50 years old. The mean Body Mass Index (BMI) for males was 22.7 and 23.4 for females. Mean values of upper facial height, midfacial height, lower facial height, intercanthal distance, interpupillary distance, upper facial width, and lower facial width are 69.13±5.91mm, 49.89±3.56mm, 67.85±6.12mm, 35.19±3.20mm, 67.04±3.67mm, 139.43±7.11mm, and 124.29±9.72mm; respectively. The upper facial height, commissure width, upper lip length, and lower jaw width were significantly affected by age, while the BMI of an individual was a determinant of the inter-pupillary distance, facial width, and lower jaw width.

This study demonstrated that there was a statistically significant difference in the facial dimensions of males when compared to females across all ages among the study population. We also observed that age and BMI are significant predictors of variations in some of the measurements.

Keywords; 3D Stereophotogrammetry; Facial Anthropometry; BMI

INTRODUCTION

Face and the fingerprint are among the biological features that determine the uniqueness of an individual.[1] Although beauty is subjective, the neo-classical canons have been used as a basis for defining a beautiful face from antiquity to modern days.[2] This has been useful to clinicians in the description, diagnosis, and surgical treatment of abnormal skeletal and facial patterns.[3] Normal values of head circumference, inner canthal, and outer canthal distances can be used by clinicians in the evaluation and treatment of congenital or post-traumatic deformities of the facial region. The results of such data could also be used for anthropometric and forensic purposes.[3]

Fronto-occipital circumference, inner canthal distance, outer canthal distance, and inter-pupillary distance are important measurements in the evaluation of several systemic syndromes, craniofacial abnormalities, and the surgical treatment of post-traumatic telecanthus.[4,5,6] They provide reproducible landmarks that serve as a guide to facial dimension and thus, guide reconstruction and assess treatment outcomes.

Previous studies using cohorts in Nigeria have been published. [3,5] However, they are either in study populations of less than 18years in age[3,7] or focused on specific ethnic groups.[3,5] Furthermore, most are based on direct anthropometric measurements. The major disadvantage of direct anthropometry is its inability to provide a digital coordinate record of the participants for later use to extract new facial measurements.[8] Also, the use of metallic instruments (e.g., Vernier, Sliding, or Spreading Calipers) may occasionally cause indentation on the measured soft tissues. The accuracy and reliability of this technique are therefore skeptical. The 3D surface imaging technology can serve as a powerful tool to capture and quantify craniofacial morphology accurately.[9] It is better than direct anthropometric measurements, especially in terms of accuracy and additional depth the image taken provides.[8]

Due to the lack of comprehensive data of facial measurements among the West African population, it is therefore pertinent to develop a databank of nomograms with accurate quantitative facial measurements among this population group. This study will serve as a guidepost for surgeons in the detection of anomalies, trauma-induced craniofacial changes, and surgical management of dentofacial deformities that correspond to normal facial dimensions amongst Nigerians and by extension, individuals of West African origin.

MATERIALS AND METHODS

This study was conducted at the Craniofacial Research Laboratory, Lagos University Teaching Hospital, Lagos, Nigeria. Nigeria is the most populous African nation and Lagos is a metropolitan city, with the largest population in Nigeria. Subject recruitment was between February 2016 and May 2019. Subjects recruited were at least 16 years of age. Eligible subjects did not have a history of congenital or acquired craniofacial deformity, history of facial trauma, or surgical interventions involving the face. Written Informed consent was obtained from the subjects before recruitment into the study.

Acquisition of 3D facial photographs was done using a Vectra H1 portable 3D photogrammetry imaging system (Canfield Imaging, Parsippany, NJ, USA). Before 3D image capture, each participant was asked to remove any jewelry and pull back any hair that was obstructing the forehead and ears to expose the full facial surface. Image acquisition was done with subjects standing, and directed to keep a neutral facial expression, and gaze fixed at a colored landmark placed permanently on a fixed wall in front of the subject. All images were acquired in the same environment under the same conditions by two members of the research team (AA and OA). The members of the team were trained and calibrated to ensure accuracy and consistency of results. The process of image acquisition using the Vectra H1 SLR camera is well described by Camison et al.[10]. Three images were acquired for each participant following the manufacturer’s guidelines for image acquisition; a right-lateral, frontal, and left lateral image. The images were recorded directly on a PC with the installed Vectra 3D image acquisition software. The images were then stitched automatically by the imaging software to produce a single 3D image. In cases where automatic stitch failed, landmarks were placed by the researcher following the software prompt, and automatic image stitch attempted again. Images were recaptured if this failed. Unstitched and stitched images were stored in individual subject folders labeled with subject recruitment numbers for confidentiality.

Facial image surface analysis and measurements commenced after the termination of subject recruitment. For analyses, the stitched image was imported into the surface analysis tool of the imaging software. Facial evaluation mode was selected, and landmarks were placed (Figure 1 and Figure 2). A total of 19 landmarks were placed (Supplemental Table 1). Ocular, horizontal, and vertical facial measurements were done using these landmarks.

Vertical facial measurements done were upper facial height (tr – n), middle facial height (n-sn), and lower facial height (sn – gn), also percentages of these facial heights to total facial height (tr – gn) were also measured. Also, upper lip height (sn – ls), lower lip height (li - gn) were also measured. Ocular measurements included interpupillary distance (P_r - P_l), palpebral fissure width (ex – en), and intercanthal distance (en – en). Horizontal facial measurements were upper facial width (zy – zy), and the mandibular width/lower facial width (go-go).

Additional data collected included age, gender, height, and weight. Data collected were entered into Microsoft Excel® sheet 2016 (Microsoft, Raymond, WA) for sorting and subsequently transferred to Statistical Package for Social Sciences Software for Windows (IBM SPSS® Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp) for analysis. Descriptive analyses of collected data were done to derive means, median, and percentages, and a test of associations performed using an independent samples t-test. Regression analysis was further performed to predict the effect of variables such as age and BMI on measurements. The level of significance was set at $\alpha<0.05$.

RESULTS

A total of 452 participants were recruited during the 3 years study period. Participants were drawn from the three major ethnic groups in Nigeria, including other minor ethnic groups. Fifty-six percent of the study participants were males (n= 254), and the age of participants ranged from 16.6 to 63.8 years (mean 29.6±10.1 years). The mean age of males and females was 29.8±9.7 years and 29.4±10.5 years; respectively. The difference in age between both genders was not statistically significant (*p* = .705, 95% CI -1.520 – 2.245). Majority of the participants were between the ages of 25 and 49.9 years (n = 246, 54.4%), 40.7% (n = 184) were less than 25 years old, and only 4.4% (n = 20) were older than 50 years. Overall Mean Body Mass Index (BMI) of participants was 23.0±4.5 (range 14.9 – 45.5). The mean BMI for males was 22.7±4.1 Kg/m^2, and females 23.4±4.9 Kg/m^2. The difference in mean BMI between both genders was not statistically significant (*p* = .097, 95% CI -1.591 - .133).

Mean values of upper facial height, midfacial height, lower facial height, intercanthal distance, interpupillary distance, upper facial width, and lower facial width are 69.13±5.91 mm, 49.89±3.56 mm, 67.85±6.12 mm, 35.19±3.20 mm, 67.04±3.67 mm, 139.43±7.11 mm, and 124.29±9.72 mm (Supplemental Table 2). There were statistically significant gender differences (predicted probability is for female gender) in the measurements of upper facial height (*p* <0.001, OR 0.907, 95% CI 0.875 -0.939), midfacial height (*p* = 0.002, OR 0.917 95% CI 0.869 – 0.969), lower facial height (*p* <0.001, OR 0.879, 95% CI 0.847 – 0.913), intercanthal distance (*p* = <0.001, OR 0.894, 95% CI 0.841 – 0.950), interpupillary distance (*p* <0.001, OR 0.798, 95% CI 0.750 – 0.849), nasal lobule width (*p* <0.001, OR 0.769, 95% CI 0.719 – 0.821), inter-commissural width (*p* <0.001, OR 0.903, 95% CI 0.863 – 0.945), upper lip height (*p* <0.001, OR 0.825, 95% CI 0.766 – 0.877), lower lip height (*p* <0.001, OR 0.874, 95% CI 0.836 – 0.914), upper facial width (*p* <0.001, OR 0.890, 95% CI 0.861 – 0.919), and lower facial width (*p* <0.001, OR 0.888, 95% CI 0.862 – 0.916). The regression analysis results showed age and BMI, in addition to gender, are significant predictors of lower facial width measurement only (Adjusted R squared 0.175). In contrast, BMI in addition to gender, are significant predictors of upper facial width measurement (Adjusted R squared .193, p <0.001) and interpupillary distance (Adjusted R squared 0.145, p = .020) while age is a significant predictor of upper facial height (Adjusted R squared 0.084, p =0.028), upper lip height (Adjusted R squared 0.269, p <0.001) and inter-commissural distance (Adjusted R squared .072, p =0.005) Supplemental Table 3a-b.

DISCUSSION

The purpose of this study was to provide normative data on the facial anthropometric values of Nigerians, and by extension individuals of West African origin, using 3D photogrammetry. Also, this study aimed to identify gender differences in facial anthropometric measurements and predict the effects of age and body mass index (BMI) on these values. The measurements selected for the study were intended to develop a satisfactory image of the morphological structure of the craniofacial complex on the African population which can be utilized during craniofacial reconstruction. Results of this study confirm that there are significant differences in facial measurements between males and females and that age and Body Mass Index, a measure of body fat in relation to height and weight, are significant predictors of facial anthropometric measurements.

Measurements of facial heights derived from this study are similar to values previously published.[2,11–13] Particularly, The mid-face length in this study was similar to reported measurements in other Africans and African-Americans (AA) but shorter than measurements in Caucasians.[14] This supports the finding that most Caucasian's vertical facial measurements conform more to the Neo-classical canon where the upper facial, mid-facial, and lower facial heights are of equal proportion. Africans tend to have a longer upper face and lower face with a relatively short mid-face and nose. These findings support the conclusions of the study by Olusanya et al[13] that anthropometric measurements of the Nigerian face do not conform to the neoclassical canons.

The recorded mean inter-canthal distance (en-en) was in a similar range to those reported in other Africans though smaller than measurements in Chinese.[13] However it is relatively larger than measurements in Caucasians,[14,15] Persians[11], and South Americans.[16] The mean palpebral fissure width (ex-en) and face width (zy-zy) were also larger than measurements in

Caucasians[14] and Chinese[13,17] but smaller than those in Indians.[18] This indicates that Nigerians have wider orbital dimensions than Caucasians, but the Chinese tend to have a wider face width with wider intercanthal distance but smaller palpebral fissure width. Other facial width measurements like nose width (al-al), mouth width (ch-ch), and mandibular angle width (go-go) are larger in our study, similar to previous studies in Nigerians and those of AA (when compared to measurements in Caucasians and Asians).[13,14] The observation in AA is not surprising since most of them are from regions around modern-day Nigeria and thus provides further evidence of the genetic and anthropometric similarities between both populations.[19] This must be taken into consideration in classical facial proportion measurements in surgical reconstruction as Africans have a nose with a wider base and mouth which tends to be wider with fuller lip structure.

When comparing gender differences, all measurements were significantly higher in males when compared to females in the vertical dimension. In the mean facial width measurements, males have larger face width except for the palpebral fissure width (ex-en) while females have a slightly larger width though this difference is not statistically significant ($p=0.60$). These imply that African men tend to have longer and wider faces when compared with African women. The women tend to have shorter and more rounded facial structures.

Various factors have been reported to affect anthropometric measurements of the face such as age, gender, genetics, ethnicity, nutritional status, and BMI.[20–22] Gender and race tend to be a major determinant of facial dimensions as differences in individuals of the same race is minimal, which is noted with the results of this study when compared with that of African-Americans in other studies. Generally, most studies report that males have greater facial dimensions than females.[2,17] Though this study considers only subjects who are adults, it shows that age and BMI influence facial dimensions. The upper facial height, commissure width, upper lip length, and lower jaw width are significantly affected by age. The BMI of an individual is a determinant of the individual's inter-pupillary distance, facial width, and lower jaw width. This is probably because the measurements in this study utilize soft tissue landmarks and soft tissue dimension will change with increased accumulation of body fat.[23]

The strength of the present study is that it considered people of different ethnic groups who live in Lagos, a cosmopolitan city; therefore, giving a better representation of West African facial dimensions. The use of 3D imaging that provides for precise locations of points, the stability of an image that avoids subjects moving during measurements, and precise measurements of points by the computer application are also added advantages compared to previous studies in the same population that utilized direct anthropometric measurements using verniers.

This study has reported normative data on 3D photogrammetry derived facial anthropologic measurements among individuals of a West African population with categorization by age and gender. This study also shows that a statistically significant difference was noted in facial dimensions of males when compared to females, and age and BMI are important predictors of facial dimension. Surgeons need to note the differences in racial and gender dimensions during the reconstruction of the craniofacial region. Studies of normative facial variations are also essential prerequisites for studies into the genetics of facial variation as a proxy for understanding congenital facial malformations like orofacial clefts.

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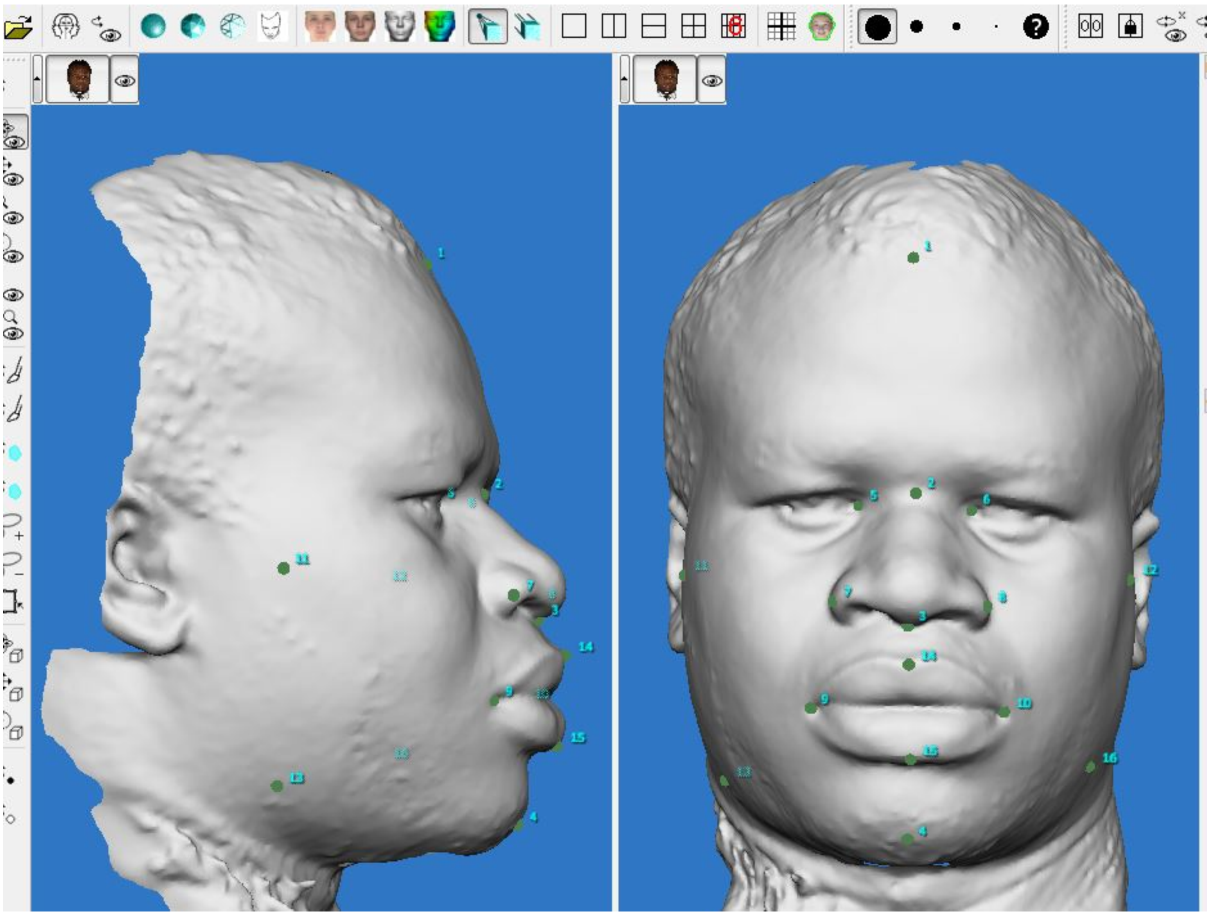
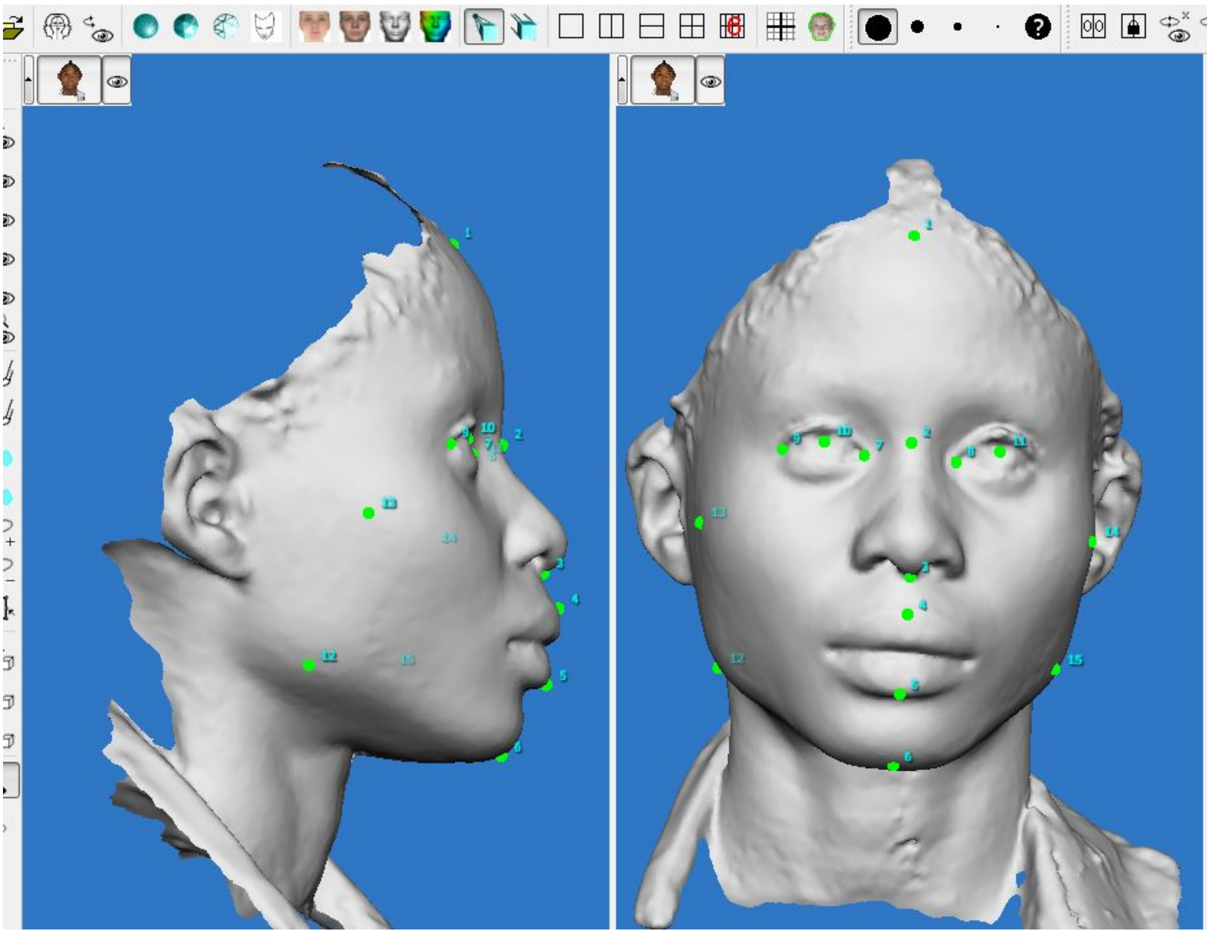
Figure 1. frontal and profile views of 3D facial photograph and landmarks identified for measurements in a male participant.

Figure 2. frontal and profile views of 3D facial photograph and landmarks identified for measurements in a female participant.





Supplemental Table 1. Anthropometric landmarks used in the analysis (adapted from Zacharopoulos et al.[15])

Landmark	Definition
Trichion(tr)	The point on the hairline in the midline of the forehead
Nasion (n)	The point in the midline of both the nasal root and the nasofrontal suture
Subnasale (sn)	The midpoint of the columella base at the apex of the angle where the lower border of the nasal septum and the surface of the upper lip meet
Gnathion (Gn)	The lowest median landmark on the lower border of the mandible
Labiale superius (ls)	The midpoint of the upper vermilion line
Labiale inferius (li)	The midpoint of the lower vermilion line
Alare (al)	The most lateral point on each alar contour
Chelion (ch)	The point located at each labial commissure
Zygion (zy)	The most lateral point of each zygomatic arch
Gonion (go)	The most lateral point on the mandibular angle close to the bony gonion

Exocanthion (ex)	The point at the outer commissure of the eye fissure
Endocanthion (en)	The point at the inner commissure of the eye fissure
Pupil (p)	Center of the pupil

Supplemental Table 2. Mean values of anthropometric facial measurements.

age category	Gender		tr – n	n-sn	sn-gn	TFH	en-en	ex-en	p-p	al-al	ch-ch	sn-ls	li-gn	zy-zy	go-go
<25yrs	Female	Mean	66.81	49.27	65.25	180.59	34.19	28.64	65.18	39.56	50.88	12.95	32.01	136.46	119.27
		SD	5.34	3.01	5.14	11.72	3.01	2.26	3.04	2.92	3.70	2.33	4.78	6.98	6.66
	Male	mean	69.46	50.43	69.25	189.15	35.83	28.56	68.17	42.23	52.04	14.56	35.09	139.50	124.32
		SD	5.95	3.41	6.20	9.35	3.02	2.37	3.63	2.83	4.12	2.56	4.16	6.28	7.68
	Total	Mean	68.16	49.86	67.27	184.92	35.02	28.60	66.70	40.91	51.47	13.76	33.57	137.99	121.82
		SD	5.80	3.26	6.03	11.40	3.12	2.31	3.66	3.16	3.95	2.57	4.73	6.79	7.61
25-49.9yrs	Female	Mean	68.01	49.23	65.98	183.22	34.95	28.27	66.02	40.42	51.48	14.70	31.94	137.00	121.44
		SD	5.62	3.64	4.89	9.93	3.27	2.60	3.46	4.32	4.90	2.53	3.66	6.71	13.45
	Male	Mean	71.05	50.14	69.63	190.82	35.58	28.69	68.26	43.83	54.37	15.66	34.48	142.99	128.93
		SD	5.77	3.61	6.29	10.77	3.23	6.56	3.49	3.19	3.70	2.70	6.19	6.38	7.33

	Total	Mean	69.88	49.79	68.22	187.88	35.33	28.53	67.40	42.52	53.25	15.29	33.49	140.67	126.03
		SD	5.89	3.64	6.05	11.07	3.25	5.38	3.64	4.02	4.42	2.67	5.49	7.12	10.76
>50yrs	Female	Mean	65.82	50.29	64.11	180.22	34.13	28.23	64.35	41.78	52.68	16.90	29.34	134.33	121.08
		SD	4.17	5.25	7.43	13.67	3.20	3.71	3.59	3.85	4.32	2.13	5.86	7.22	8.53
	Male	Mean	71.59	52.62	73.03	197.25	35.71	27.90	67.39	41.06	50.58	20.04	39.78	140.91	130.14
		SD	6.97	4.19	4.67	10.70	3.25	3.28	3.67	9.26	14.96	2.46	2.99	6.08	7.51
	Total	Mean	68.71	51.46	68.57	188.73	35.67	28.07	65.87	41.42	51.63	18.47	34.56	137.62	125.61
		SD	6.33	4.77	7.58	14.80	3.24	3.41	3.86	6.91	10.77	2.76	7.01	7.32	9.10
Total	Female	Mean	67.35	49.30	65.54	181.85	35.55	28.44	65.55	40.09	51.26	14.00	31.84	136.61	120.42
		SD	5.45	3.45	5.15	11.02	3.15	2.51	3.30	3.74	4.35	2.65	4.35	6.85	10.59
	Male	Mean	70.49	50.34	69.63	190.46	35.68	28.61	68.19	43.14	53.37	15.43	34.91	141.62	127.28
		SD	5.91	3.58	6.22	10.35	3.15	5.29	3.54	3.57	4.88	2.84	5.51	6.52	7.78

Total	Mean	69.13	49.89	67.85	186.71	35.19	28.54	67.04	41.81	52.45	14.81	33.57	139.43	124.29
	SD	5.92	3.56	6.12	11.46	3.20	4.30	3.67	3.94	4.77	2.84	5.26	7.11	9.72

Supplemental Table 3a. Result of regression analysis with age as the covariate.

	Age			
Dependent variables	Adjusted Mean (SD)	Co-efficient	95% confidence interval	*p* value
tr - n	69.06 (5.95)	.104	.006 - .115	.028*
n- sn	49.92 (3.58)	.067	-.010 - .057	.170
sn -gn	67.81 (6.09)	.050	-.024 - .085	.277
en - en	35.14 (3.19)	-.001	-.031 - .030	.862
ex – en	28.51 (4.42)	-.009	-.046 - .038	.857
p-p	67.04 (3.68)	-.025	-.042 - .024	.588
al – al	41.81 (4.01)	.085	-.002 - .069	.062
ch – ch	52.51 (4.76)	.137	.020 - .109	.005*
zy – zy	139.58 (7.13)	.003	-.060 .064	.951
sn – ls	14.81 (2.87)	.449	.103 - .151	<.001*
li – gn	33.54 (5.27)	.019	-.039 - .059	.698
go – go	124.30 (9.93)	.147	.056 - .231	.001*

**p* is Significant at < 0.05.

Supplemental Table 3b. Results of regression analysis with BMI as the covariate.

	BMI		
Dependent variables	Co-efficient	95% confidence interval	*p* value
tr - n	.038	.425 - -.075	.425
n- sn	-.032	-.105 - .053	.515
sn -gn	.033	-.082 - .173	.484
en - en	.051	-.033 - .107	.302
ex – en	.072	-.026 - .170	.151
Interpupil	.108	.014 - .165	.020*
al – al	.098	.003 - .165	.043
ch – ch	.071	-.026 - .178	.145
zy – zy	.257	.270 - .555	<.001*
sn – ls	-.012	-.063 - .047	.775
li – gn	-.004	-.117 - .107	.928
go – go	.142	.117 - .519	.002*

**p* is Significant at < 0.05.