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**Original Article**

# A Comparative Study of Facial Ratio, Facial Masculinity and Digit Ratio of Ex-convicts and Non-Convicts Males in Kano State, Nigeria

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## Abstract

The basic principle of biological theories holds that crime is caused by a genetic or physical defect. Indeed, biological theories assume that people who commit crimes are 'born criminals' and their biological features may differ from non-criminals. The aim of the present study was to compare the Facial Ratios, Facial Masculinity, and Digit Ratio between ex-convicts and non-convicts in Kano state and to generate equations for criminal discrimination using linear measurements, ratios, and indices of the face. Five hundred and seventy-one (571) subjects were selected comprising of 252 ex-convicts and 319 non-convicts, using random sampling methods with age range of the participants between 18-50 years. Digital Vernier and spreading callipers were used to measure the facial linear dimensions of face directly. Facial ratios and indices were derived from facial distances. The lengths of the 2nd and 4th digits were determined using a direct method of measurement. The independent-samples t-test was used to determine the mean differences in facial ratio, facial masculinity, and 2D:4D between ex-convicts and non-convict participants. Binary logistic regression analyses were used to discriminate the face. It was observed that there were significant (P<0.001) differences between ex-convicts and non-convicts in the following facial ratios and indices, upper facial width upper face height, face height, nose width with, and nasal index (P<0.005). The upper facial width index shows higher significant difference among the facial parameters. The present study found that 4D both right and left sides show significant differences only between the study populations, none of the digit ratios show significant differences between ex-convicts and non-convicts. The best predictor that discriminates between criminals and non-criminals was facial width followed by eye length with explained variance of 2.8 and 4.4% in the 1st and 2nd steps in the models respectively. The overall accuracy of prediction of the best predictor was 78.1%. The prediction accuracy was in favour of criminal group compared to their non-criminal counterparts. The models are significantly fit for the discrimination of criminals from non-criminals using facial dimensions.

Keywords: ***Digit ratio, Facial Masculinity, Facial Ratios, ex-convicts and non-convicts.***

## Introduction

Human faces contain a number of cues, e.g., identity, emotional expression, age, gender, ethnicity, attractiveness, personality traits, and so on. Decoding facial cues has been the subject of speculation for centuries [1]. Facial analysis using facial index is essential in the study, classification, and reconstruction of the human face; and it is therefore useful to anatomists, anthropologists, and plastic and maxillofacial surgeons [2,3]. Facial anthropometry is essential in establishing the identity and in the estimation of age of victims in forensic studies [4].

The most easily recognizable way to identify someone is from their face and therefore the methods of identification that cater to the face are all very important to forensic application [5]. Each method of identification has its purpose depending on which type of evidence is available. Whether the evidence available is from a video recording or eye witness, the application of facial identification techniques is vital to the investigation of crime and crucial to the well-being of family, friends, and the victims themselves. Facial analytics is the most important research topic nowadays. It is used to extract useful information about pose, key points, gender, expression, age, identity, etc. It is adopted in many application areas such as law enforcement, face biometrics for payments, self-driving vehicles, active authentication on devices, etc. Classification techniques are embracery used over large data sets of human faces to learn rich and compact representations of faces and train the model accordingly to perform face recognition of human beings [6]. With knowledge on standard facial traits, an individualized norm can be established to optimize facial attractiveness [7]. Facial morphology serves as a prominent identification tool at the points of entry into most developed countries [7]. Apart from DNA profiling, various morphological features and biometric parameters are usually employed in forensic investigation to distinguish one person from another. Some of the morphological features used for this purpose include fingerprints, facial traits, footprints, and gait patterns [8].

The basic principle of biological theories holds that crime is caused by a genetic or physical defect, and treatment is only effective in the reduction of aggression [9]. Indeed, biological theories assume that people who commit crimes are 'born criminals' and their biological features differ from non-criminals. Studies suggested that characteristics of the face may also provide cues as to the behavioural tendencies of the target. For example, women's judgements of the extent to which a man was interested in infants based on facial expression can predict his actual interest in infants [10]. Ratters' judgements of facial masculinity [11] and dominance [12] predicted sexual behaviour of men. People also show some accuracy at identifying 'cheaters' in a Prisoner's Dilemma game based on facial photographs [13]. Collectively, these findings suggest that people can make accurate inferences about others' personality traits and behavioural dispositions based on certain signals conveyed by the face. Individual differences in the facial width-to-height ratio were positively related to aggressive behaviour as measured by the number of penalty minutes per game obtained over a season. In conclusion, these findings suggest that the sexually dimorphic facial width-to-height ratio may be an 'honest signal' of propensity for aggressive behaviour [14].

One feature that may signal formidability and aggressive potential is the facial width-to-height ratio (face ratio), first described by [15] violent men had wider faces than those who were nonviolent [16], and professional mixed martial art fighters with a higher proportion of fight victories had wider faces than those with a lower proportion of fight victories [17]. Amygdala reactivity to threat, which is associated with aggression in clinical populations [18], shared a stronger link with self-reported aggression in men with larger rather than smaller face ratios [19] Several studies have found that the face ratio may be used for appraisals of trustworthiness [20,21].

Researches had established an association between 2D: 4D ratios and testosterone-dependent traits. A study indicated the indirect signal that E (estrogen) motivates the growth of the second finger whereas T (testosterone) excites prenatal growth of the fourth finger. A low 2D: 4D ratio might act as a marker for a uterine environment low in E and high in T, and such a ratio is more commonly seen in males. Equally, a high 2D: 4D ratio may aid as a marker for a uterine environment low in T and high in E, more commonly found in females [22]. Previous studies of facial masculinity and digit ratio between ex-convicts or convicts and non-convicts in northern Nigeria are limited. The human tendency to form impression on others based on physiognomy such as facial appearances is well documented [23]. Studies on facial ratios, facial masculinity, and digit ratio between ex-convicts and non-convicts that provide data used for human identification in Nigeria are scanty and are given less attention. The present study tends to provide reference data on the facial ratio, facial masculinity, and 2D: 4D ratio in relation to crime and criminal behaviour among northern Nigerian population, which may serve as a useful reference across the globe. In these parts of the world where terroristic tendencies are on the rise, the ability to detect such behaviours as crime and criminal behaviour by security personnel has remain invaluable for providing safety for citizens The aim of the present study was to compare facial ratios, facial masculinity, and digit ratios between ex-convicts and non- ex-convicts in Kano state Nigeria.

## Materials and Methods

### Study area

The study was conducted among Hausa ethnic group (one of the largest ethnic groups in Nigeria) of Kano State, Nigeria. The state has a population of 9,383,682 million people as at the 2006 Nigerian census. The principal inhabitants of the state are Hausa people [24].

### Study design

The study adopted a cross-sectional prospective approach

### Study subjects

The population is made up of male ex-convicts and non-convicts in Kano State, Nigeria. Five hundred and seventy-one (571) subjects were selected using random sampling methods with 252 and 319 from ex-convicts and non-convicts. The age range of the participants was between 18-50 years. Those participants who reported injuries on the face and second or fourth digits (including injuries to the carpus and disruption of tendons finger anomalies, deformities, scars, or inflammation), subjects who were not indigenes of Kano State and non-Hausa ethnic groups were excluded from the study.

### Ethical consideration

Before the commencement of the research, ethical approval was sought from the Ethical Committee of the Ministry of Health, Kano State, Nigeria. Informed consents were sought from the participants before enrolment in the study.

### Methodology

### Methods

A questionnaire was printed for the participants. The questionnaire includes age, tribe, identification number, birth order, how many times being to prison, and the reasons for being to prison, Facial masculinity and 2D: 4D measurements were also included in the questionnaire.

### Bio-data

**Measurement of the digit's length and determination of 2D: 4D**

The lengths of the 2$^{nd}$ and 4$^{th}$ digits were determined using a direct method of measurement. Following Manning and Tailor [25-27], the participants were asked to remove rings, and the lengths of the 2$^{nd}$ and 4$^{th}$ digits were measured directly (using digital Vernier callipers to the nearest 0.01 mm) on the ventral surfaces of both right and left hands from the basal crease of the digit to its tip. Every digit was measured twice, and the average was taken. When there was a band of creases at the base of the digit, the most proximal crease was considered. Digits length measured (in mm) were computed for determination of the 2D: 4D by dividing the 2$^{nd}$ digit length by the 4$^{th}$ digit length (**Plates 1**).

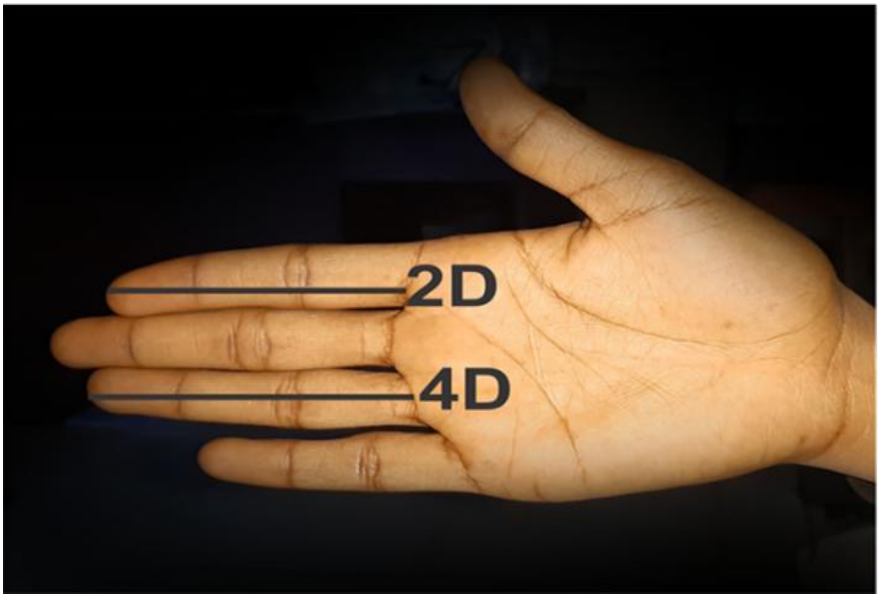


**Plate 1: The landmarks for measurements of the length of 2D and 4D Digits**

**Direct Measurements of Facial Features**

A direct facial anthropometry was adopted [3,28,29,30]. This involved asking a participant to sit with his head in Frankfurt position. A digital vernier and spreading calipers were used to measure the facial linear dimensions of face directly (**Plate: II**).

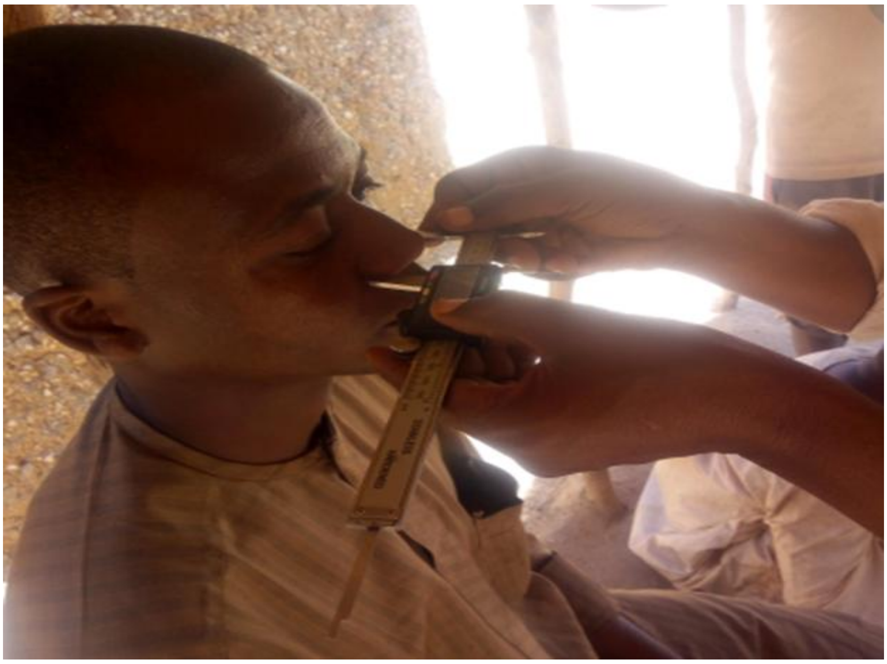

**Plate II: Direct Measurements of Facial Distances**

**Table 1: Anatomical Landmarks Used in the Measurement of Facial Dimensions [31-34].**

| S/N | Land marks | Abbr. | Anatomical description |
|---|---|---|---|
| 1. | Alar | al | This is the most lateral point of the nasal wings |
| 2. | Endocanthion | en | This is the inner corner of the eye fissure at the meeting points of eyelids. |
| 3. | Exocanthion | ex | It is the outer corner of the eye fissure where the eyelids meet |
| 4. | Gnathion | gn | It is the lowest point on the lower border of the chin, in the midline |
| 5 | Labiale inferious | li | This is the mid-point of the lower vermilion line |
| 6. | Labiale Superious | ls | This is the mid-point of the upper vermilion line |
| 7. | Nasion | n | This is the midpoint of the nasofrontal suture. |
| 8. | Palpebrale Inferious | pi | This is the lower eyelid center |
| 9. | Palpebrale Superious | ps | It is the upper eyelid center |
| 10. | Stomium | st | This is the mid-point of the mouth orifices |
| 11. | Trichion | tr | This is the mid-point of the hair line at the top of forehead |

| S/N | Land marks | Abbr. | Anatomical description |
|---|---|---|---|
| 12. | Zygoma/zygion | zy | This is the most lateral point on the zygomatic arch |
| 13. | Prosthion | pr | It is a point on the alveolar arch mid-point between the median upper incisor teeth. |
| 14 | Gnathion | gn | It is the midpoint of the lower border of human mandible |
| 15 | Gonion | go | The point or apex of the angle of the lower jaw |
| 16 | Glabella | g | This is the most prominent point in the median sagittal plane between the supraorbital ridges. |
| 17 | Subnasale | sn | It is the junction between the lower border of the nasal septum and the cutaneous portion of the upper lip, in the midline. |
| 18 | Vertex | v | This is the highest point on the head with the head in the Frankfort horizontal plane. |
| 19 | Pupil | p | This is a hole located in the centre of the iris of the eye |

**Facial Linear Dimensions**

The facial linear distances were obtained from the distance between one anatomical landmark to another (**Table 2**), 9 horizontal and 5 vertical direct measurements. The face parameters were measured using direct method. Fourteen standard anthropometric measurements were obtained (**Table 2**). Standard anthropometric methods were used for all measurements. Linear measurements were reported in millimeters.

**Table 2: Linear Facial Dimensions with their Corresponding Landmarks**

| SN | Facial Dimensions | Landmarks |
|---|---|---|
| 1 | Facial width | zy-zy |
| 2 | Upper face height | n-pr |
| 3 | Face height | tr-gn |
| 4 | Nose wide | al-al |
| 5 | Special face height | n-gn |
| 6 | Lower face width | go-go |
| 7 | Eye length right | ex-en |
| 8 | Eye length left | ex-en |
| 9 | Intercanthal distance | en-en |
| 10 | Mouth width | ch-ch |
| 11 | Forehead width | ft-ft |
| 12 | Biocular width | ex-ex |
| 13 | Special face height | en-g |
| 14 | Lower face height | sn-gn |
| 15 | Nose length | n-sn |
| 16 | Height of lower third of the face | st-gn |

**Facial Measures of Masculinity**

The facial measures of masculinity used in the present study include the following:

**1. Facial width to upper face height ratio (fWHR):** This was measured as a ratio of the distance between left and right zygions (bizygomatic width) and upper facial height (a distance between nasion and prosthion) (Plate X) [14,26].

**2. Nasal index:** This was measured as a ratio of the distance from nasion (outer point of intersection between the nasion-sella line and the soft tissue profile) to the subnasale as height of the nose (NH) over the nasal width which measured from one ala to another.

Nasal index was calculated using the formula:

Nasal index = (Nasal width/ Nasal height x 100) [29].

**3. Prosopic(facial) index:** This was measured as a ratio of the distance from nasion to menton as a face length over distance between zygomatic arches as a face width. Thereafter, facial (prosopic) indices were calculated using the formula below [32].

Prosopic index (PI) = Facial length/ Facial width x 100

**Statistical analyses**

The data were expressed as mean ± SD, frequency, and percentages. The independent-samples t-test was used to determine the mean differences in facial ratio, facial masculinity, and 2D:4D, between convicts and non-convict participants. Binary logistic regression analyses were used to discriminate the face of ex- prisoners from non-convict participants. The analyses were carried out using SPSS version 20. $P < 0.05$ was considered as level significance.

## Results

**1: Descriptive Statistics of the Age, Facial Parameters, and Digit ratio of the Study Population**

Table 3: Shows descriptive statistics of the age, facial parameters, and digit ratio of the study population. It was observed that the mean age of the study population was 38.20±8.19 years. The average FWHR was 1.72±0.19mm and facial index was found to be 100.94±7.50mm, nasal index and nasal ratio mean value were found to be 1.06±0.12mm and 105.55±12.47mm respectively. For the digit ratio, the average value of right and left 2D:4D were 0.98±0.05 and 0.96±0.05 respectively, higher on the right side than the left.

**2: Comparison of facial ratios, and facial indices between ex-convicts and non-convicts of the study population**

Table 4: Shows comparison of facial ratios, and facial indices between ex-convicts and non-convicts of the study population. It was observed that there was significance ($P<0.001$) differences between ex-convicts and non-convicts in the following facial rations and indices, upper facial width (zy1_zy2), upper face height (n_pr), face height (tr_gn), nose width (al1_al2), and nasal index ($P<0.005$). The upper facial width (zy1_zy2) index shows higher significant difference among the facial parameters.

**Table 3: Descriptive Statistics of the Age, Facial Parameters, and Digits ratio of the Study Population**

| | N | Minimum | Maximum | Mean± std. |
|---|---|---|---|---|
| AGE | 574 | 18.00 | 50.00 | 38.20±8.19 |
| zy1_zy2 | 574 | 82.96 | 145.24 | 112.19±10.14 |
| n_pr | 574 | 40.88 | 96.80 | 65.78±8.16 |
| fWHR. | 574 | 1.29 | 2.74 | 1.72±0.19 |
| tr_gn | 574 | 146.06 | 234.65 | 190.69±16.98 |
| al1_al2 | 574 | 35.66 | 61.88 | 47.52±4.89 |
| n_gn | 574 | 79.40 | 154.12 | 111.59±11.60 |
| zy1_zy2 /n_gn | 574 | 0.70 | 1.30 | 1.01±0.07 |
| facial index | 574 | 70.37 | 130.24 | 100.94±7.50 |
| n_gn/tr_gn | 574 | 0.50 | 0.78 | 0.59±0.03 |
| go1_go2 | 574 | 87.46 | 154.62 | 116.45±11.38 |
| zy1_zy2:go1_go | 574 | 0.75 | 1.24 | 0.97±0.07 |
| ex1_en1 | 574 | 20.20 | 43.24 | 30.25±3.73 |
| ex2_en2 | 574 | 21.16 | 45.60 | 30.38±3.75 |
| en1_en2 | 574 | 25.76 | 54.91 | 39.30±4.50 |
| ch1_ch2 | 574 | 40.03 | 72.30 | 56.42±6.01 |
| ft1_ft2 | 574 | 80.72 | 130.34 | 104.18±10.31 |
| ex1_ex2 | 574 | 78.71 | 125.67 | 100.01±9.17 |
| sn_gn | 574 | 44.93 | 91.23 | 66.22±7.90 |
| n_sn | 574 | 30.58 | 65.66 | 45.49±6.01 |
| nasal ratio | 574 | 0.67 | 1.46 | 1.06±0.12 |
| nasal index | 574 | 66.65 | 146.28 | 105.55±12.47 |
| 2DR | 574 | 55.65 | 87.21 | 72.29±4.77 |
| 4DR | 574 | 54.47 | 88.00 | 74.19±5.04 |
| R2D4DR | 574 | 0.83 | 1.13 | 0.98±0.05 |
| 2DL | 574 | 52.86 | 87.45 | 72.25±4.86 |
| 4DL | 574 | 57.14 | 90.42 | 75.21±5.30 |
| L2D4DR | 574 | 0.84 | 1.11 | 0.96±0.05 |

**Table 4: Comparison of facial ratios, and facial indices between ex-convicts and non-convicts of the study population**

| | **non -prisoners=319** | **ex-prisoners=255** | | |
|---|---|---|---|---|
| **Variables** | **Mean±std** | **Mean±std** | **t-value** | **p-value** |
| zy1_zy2 | 110.67±10.58 | 114.10±9.23 | -4.070 | 0.000 |
| n_pr | 64.79±8.26 | 67.01±7.88 | -3.280 | 0.000 |
| fWHR. | 1.72±0.20 | 1.72±0.17 | 0.310 | 0.760 |
| tr_gn | 189.12±17.10 | 192.66±16.65 | -2.490 | 0.010 |
| al1_al2 | 47.03±4.90 | 48.13±4.89 | -2.700 | 0.010 |
| n_gn | 110.65±11.77 | 112.77±11.29 | -2.180 | 0.030 |
| zy1_zy2 /n_gn | 1.00±0.07 | 1.02±0.07 | -1.960 | 0.050 |
| facial index | 100.39±7.47 | 101.63±7.49 | -1.960 | 0.050 |
| n_gn/tr_gn | 0.59±0.03 | 0.59±0.03 | -0.140 | 0.890 |
| go1_go2 | 114.92±11.44 | 118.37±11.03 | -3.640 | 0.000 |
| zy1_zy2:go1_go | 0.97±0.07 | 0.97±0.06 | -0.250 | 0.800 |
| ex1_en1 | 30.23±3.80 | 30.26±3.65 | -0.090 | 0.930 |
| ex2_en2 | 30.32±3.92 | 30.45±3.52 | -0.410 | 0.680 |
| en1_en2 | 38.73±4.34 | 40.02±4.61 | -3.450 | 0.000 |
| ch1_ch2 | 55.87±6.07 | 57.10±5.88 | -2.450 | 0.020 |
| ft1_ft2 | 103.14±10.54 | 105.47±9.88 | -2.760 | 0.010 |
| ex1_ex2 | 99.38±9.37 | 100.79±8.87 | -1.830 | 0.070 |
| sn_gn | 65.85±8.02 | 66.69±7.74 | -1.270 | 0.200 |
| n_sn | 44.89±6.01 | 46.22±5.95 | -2.630 | 0.010 |
| nasal ratio | 1.06±0.13 | 1.05±0.12 | 0.640 | 0.520 |
| nasal index | 105.85±12.60 | 105.18±12.32 | 0.640 | 0.520 |

**3: Comparison of digit length and digit ratios between ex-convicts and non-convicts of the study population** Table 5: Shows comparison of digit length and digit ratios between ex-convicts and non-convicts of the study population. It was observed that right and left hands 4D showed significant differences only between the study populations, none of the digits ratio showed significant difference between ex-convicts and non-convicts.

**Table 5: Comparison of digit length and digit ratios between ex-convicts and non-convicts of the study population**

| | Criminal/Non-Criminal | N | Mean±std | t-value | p-value |
|---|---|---|---|---|---|
| 2DR | non-prisoners | 319 | 71.97±4.74 | -1.80 | 0.07 |
| | ex-prisoners | 255 | 72.69±4.79 | | |
| 4DR | non-prisoners | 319 | 73.77±5.04 | -2.23 | 0.03 |
| | ex-prisoners | 255 | 74.71±5.00 | | |
| R2D4DR | non-prisoners | 319 | 0.98±0.04 | 0.66 | 0.51 |
| | ex-prisoners | 255 | 0.97±0.05 | | |
| 2DL | non-prisoners | 319 | 72.04±4.89 | -1.17 | 0.24 |
| | ex-prisoners | 255 | 72.51±4.82 | | |
| 4DL | non-prisoners | 319 | 74.79±5.26 | -2.10 | 0.04 |
| | ex-prisoners | 255 | 75.73±5.32 | | |
| L2D4DR | non-prisoners | 319 | 0.96±0.05 | 1.31 | 0.19 |
| | ex-prisoners | 255 | 0.96±0.05 | | |

**4. Generated equations for criminals' discrimination using linear, ratio, and index of the face.**

Table 6 shows generated equations for criminals' discrimination using linear, ratio, and index of the face. The best predictor that discriminates between criminal and non-criminal was facial width followed by eye length with explained variance of 2.8 and 4.4% in the 1st and 2nd steps in the models respectively. The overall accuracy of prediction of the best predictor is 78.1%. The prediction accuracy was in favour of criminal group compared to their non-criminal counterpart. The models are significantly fit for the discrimination of the criminals from non-criminals using facial dimensions.

**Table 6: Generated equations for criminal discrimination using linear, ratio, and index of the face.**

| Step | equations (y=mx+c) | Accuracy (%)1 | Accuracy (%)2 | Accuracy (%)3 | 2 Log likelihood | Cox & Snell $R^2$ | Nagelkerke $R^2$ | $X^2$ |
|---|---|---|---|---|---|---|---|---|
| 1 | Criminal = 0.034(zy1_zy2) - 4.077 | 78.1 | 28.6 | 56.1 | 772.123 | 0.028 | 0.038 | 16.46 |
| 2 | Criminal= 0.055(zy1_zy2) + (-0.089(ex1_ex2)-3.699 | 78.7 | 34.5 | 59.1 | 762.805 | 0.044 | 0.059 | 25.78 |

*The cut value is 0.5 (Negative value indicate criminal), *p<0.05.*

## Discussion

The basic principle of biological theories holds that crime is caused by a genetic or physical defect [9]. Indeed, biological theories assume that people who commit crimes are 'born criminals' and their biological features may differ from non-criminals. Hence, the present study hypothesizes the existence of such biological features manifested in facial morphology between ex-convicts and non-convicts in Kano state Nigeria.

The observed significantly higher facial dimensions, ratios, and indices among the ex-convicts is supported by the fact that in pubertal males, a high testosterone-to-oestrogen (T/E) ratio is thought to facilitate the lateral growth of the cheekbones, mandibles, and chin, the forward growth of the bones of the eyebrow ridges and the lengthening of the lower face leading to a more robust face shape, while the influence of oestrogen leads to a more gracile facial shape with high eyebrows, less robust jaws and fuller lips [35]. This indicates the higher level of testosterone among ex-convicts which was reflected in their facial morphology. This also project the higher level of aggression observed in the ex-convicts which can be linked to their testosterone level in addition to environmental factors.

To explain further the role of testosterone as a connector of facial masculinity with behavioural traits including crime, it was documented that exposure to testosterone during development produces several changes in the male body, such as greater musculoskeletal development and the rise of secondary sexual characteristics. It also affects males' nervous system [36]. Thus, exposure to T influences both human male behaviour [37] and their physical appearance [38]. Therefore, one should expect a correlation between the level of physical masculinization and the degree of "behavioural masculinity" as both are affected by exposure to T during development. Masculinity, and facial masculinity in particular, is also related to other features and behaviours such as perceived trustworthiness [23], aggressiveness and dominance [14], and risk-taking [39]. The face plays an important role in the identity of an individual, the gender, tribe, or race of the person; and one of the unique facial features utilized in this regard is the facial index [4].

The 2D:4D ratio has been documented to be a proxy marker of T and T/E and also the sexual dimorphs in the ratio is well-documented phenomenon [40]. In the present study, none of the digit ratios shows significant difference between ex-convicts and non-convicts. This may support intra sexual stability of the digit ratio. However, the observed higher value of the right and left 4D length among the ex-convicts may indicate the tendency of criminals to higher exposure to high T level which manifest in the digit lengths. This showed that 2D:4D is substitute marker of prenatal testosterone [40]. Individual 2D:4D values remain comparatively stable across development [41]. A study indicated the indirect signal that E (estrogen) motivates the growth of the second finger whereas T (testosterone) excites prenatal growth of the fourth finger. A low 2D: 4D ratio might act as a marker for a uterine environment low in E and high in T, and such a ratio is more commonly seen in males. Equally, a high 2D: 4D ratio may serve as a marker for a uterine environment low in T and high in E, more commonly found in females [22]. The study conducted on relationship between the digit ratios in two-year-old children and the levels of prenatal testosterone and estradiol in the amniotic fluid for the period of their prenatal development revealed that low 2D:4D correlates with high concentrations of prenatal testosterone in comparative to estrogen [42]. Early exposure to higher levels of T is expected to produce more male-like characteristics (masculinization) and less female characteristics (defeminization) [12], whereas less exposure to T is expected to produce more female characteristics (defeminization) and fewer male-like characteristics (masculinization). Ökten et al., confirmed that sex differences in 2D: 4D are as a result of differences in prenatal androgen levels, with those exposed to high levels developing low 2D: 4D ratios [43]. Individuals with congenital adrenal hyperplasia (a trait associated with high prenatal androgen) have a tendency to have low “masculinized” 2D:4D [44].

It was reported that the relationship between 2D:4D and sexually dimorphic personality traits i.e aggressiveness and competitiveness [45]. Significant negative correlations were established between right 2D:4D and indicators of physical aggression in Russian Boys samples of children and adolescents [46]. Aggression in humans is strongly sex-dependent, such that men tend to show more same-sex physical aggression compared to women. Digit ratio (2D:4D) a putative marker of prenatal androgen activity has been shown to correlate with self-reported physical aggression and dominance behaviour, especially in male children and adolescents [46].

Previous studies on facial masculinity and digit ratio between ex-convicts and non-convicts in northern Nigeria are limited. The human tendency to form impression on others based on physiognomy such as facial appearances is well documented [23]. The potential of facial width and eye width in prediction of criminal status may explain the variation in the contribution of vertical and horizontal distances in discriminating the criminal face. This may be supported by the hormonal variation in the facial architecture between the E and T. It was reported that a high testosterone-to-oestrogen ratio is thought to facilitate the lateral growth of the cheekbones, mandibles, and chin, the forward growth of the bones of the eyebrow ridges and the lengthening of the lower face leading to a more robust face shape, while the influence of oestrogen leads to a more gracile facial shape with high eyebrows, less robust jaws and fuller lips [35]. This indicates the higher level of testosterone among expressions which was reflected in their facial morphology. It can be suggested that the finding will help the security personnel in detecting such behaviours as crime and criminal behaviour, it will be very helpful in human mate choice, recruitments, admissions, migrations, psychiatric diagnosis, plastic surgery, and forensic science.

## Conclusion

The present study observed significance differences between ex-convicts and non-convicts in the upper facial width, upper face height, face height, nose width, and nasal index. It was observed that 4D right and left shows significant differences only between the study populations, none of the digit ratios showed significant differences between ex-convicts and non-convicts. The best predictor that discriminates between ex-convicts and non-convicts was facial width then followed by eye length, the overall accuracy of prediction of the best predictor is 78.1%. The prediction accuracy was in favour of criminal group compared to their non-criminal counterparts. The models are significantly fit for the discrimination of the criminals from non-criminals using facial dimensions. This suggested that not all the facial characteristics that are discriminative of the criminal from non-criminal significantly more than by chance.

## List of Abbreviations

2D: Second digit length
2D:4D: Second digit to Fourth digit ratio
4D: Fourth digit length
al: Alar
al-al: Nose wide
ch-ch: Mouth width
E: Oestrogen
ebo-ebi: Eyebrow length
en: Endocanthion
en1-en2: Intercanthal distance
ex1-en1: Eye length right
ex1-ex2: Biocular width
ex2-en2: Eye length left
FH: Total face length
ft: Fronto-temporale.
ft-ft: Forehead width
fWHR: Facial width to upper face height ratio
g: Glabella
gn: Gnathion
gn: Gnathion
go: Goniom
go-go: Lower face width
g-sn: Special upper face height
LFW: Lower facial width
li: Labial Inferious
ls: Labial Superious
ls-st: Upper lip height
n: Nasion
n-gn: Special face height
n-gn: Special face height
NH: Nasal height
n-pr: Upper face height
n-sn: Nose length
NW: Nose width
p: Pupil
pi: Palpebrale Inferious
pr: Prosthion
SD: Standard deviation
SFH: Special face length
sn: Subnasale
sn: Subnasale
sn-gn: Lower face height
st: Stomium
st-li: Lower lip height
T: Testosterone
tr: Trichium
UFW: Upper facial width
v: Vertex
zy: Zygion
zy-zy: Facial width

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## Conflict of Interest

No conflict of interest was declared.

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## Data Availability

The data of this study will be available upon request at Department of Human Anatomy, Yusuf Maitama Sule University, Kano Nigeria.

## Authors' contributions

II designed the work and wrote the initial draft manuscript, II and LHA; statistical analyses and contributed to discussion part; HA; contributed in the data collection, II, SN, MAB, YA; LHA, MGT; modified the concept and/or critically proofread the manuscript. All authors approve the final version of the manuscript.

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