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# There is No Sex-, Handedness-, and Hand Grip Strength-related Dimorphism in Digit Ratio in both Sedentary and Athletic African Young People

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## ABSTRACT

*Introduction: The ratio of second-to-fourth digit length (2D:4D) is sexually dimorphic and is generally higher in females compared to males. Digit ratio is believed to be a marker of prenatal testosterone exposure, and is related to physical strength. Lower 2D:4D is associated with greater physical strength, better sporting performance and a propensity towards jobs demanding greater physical ability. Very recently, emerging data have shown absence of digit ratio in some ethnicities and geographical regions of the world. However, there is lack of data about digit ratio in African population. To this end, we investigated the sex- and handedness differences in digit ratio in African people.*

*Methods: 233 healthy young participants volunteered for the study. Of them, 125 were males (average age-19.31 years) and 108 were females (average age-17.79 years) with all between ages 16 and 25 years. Handedness was determined using the Edinburgh Handedness Inventory. The lengths of the 2nd and 4th fingers were determined using electronic digital caliper. Hand grip muscle strength was recorded using electronic dynamometer of PowerLab 26T (AD Instruments, Bella Vista, Australia).*

*Results: There was no significant sex and handedness related difference in both right and left hand digit ratios. Athletes had no significantly lower digit ratio than sedentary subjects and there was no significant correlation between digit ratios.*

*Conclusion: Sexual dimorphism and handedness related differences in digit ratio are not universal in humans.*

**Key words:** 2D:4D, Digit ratio, Sexual dimorphism, Handedness

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## INTRODUCTION

The ratio of second-to-fourth digit length is known as the digit ratio (i.e. 2D:4D) [1-3]. Digit ratio is associated with sexually dimorphic abilities such as physical strength: males generally have lower 2D:4D than females [2,3]. Lower digit ratio is associated with greater strength, better sporting performance in sprinting, endurance, surfing, rugby, rowing, and hand-grip strength, and a propensity towards jobs demanding greater physical ability, and possibly, the financial standing [3,4] in both males [5] and females [6]. Indeed a study conducted in London, United Kingdom, revealed that 2D:4D can predict economical or financial success and long-term profitability in business [7].

Digit ratio is also associated with other sexually dimorphic features including behaviours (aggression and risk-taking) [8,9], neurodevelopmental disorders (attention deficit hyperactivity disorder, autism, and dyspraxia) [10], as well as diseases (heart diseases, cancers, osteoarthritis, depression, respiratory diseases, alcohol dependency etc.) [2,11]. Thus digit ratio can be used as a marker of many life experiences and outcomes [12].

Digit ratio is believed to be a marker of prenatal androgen exposure *in utero*. Precisely, it indicates an intricate equilibrium between testosterone and estrogen levels in the fetus around the end of the first trimester of pregnancy [3,11]. Digit ratio is smaller for males compared to females [11]. Research has shown that digit ratio may be inversely related to prenatal testosterone exposure, which in turn, is related to handedness [2,11,13,14]. Indeed correlation between writing hand preference and the difference between left and right 2D: 4D had been reported [15]. A new significant correlation between left 2D:4D and writing hand preference was also shown (high left 2D:4D associated with left hand preference). The left 2D:4D was significantly larger than the right 2D:4D in male and female left-handed writers and the right hand 2D:4D was significantly larger than the left hand 2D:4D in male and female right-handed writers [15].

Digit ratio, handedness and related disorders are believed to be related to genetic polymorphism of the androgen receptor [11]. A recent genetic investigation on 2D:4D ratio has identified 11 genetic loci responsible for 3.8% of the variance in 2D:4D ratio, though the association between 2D:4D ratio and sensitivity to testosterone was weak and found in females, but not in males [2]. This suggests the need to investigate other genetic molecules that may interfere with sensitivity to testosterone *in utero* and postnatal life, thereby reducing or weakening the association between prenatal testosterone exposure and digit ratio. Digit ratio of the right or left hand and right or left handedness could not predict circulating levels of testosterone in adults [16]. Contradictory findings about digit ratio have been reported by Kornhuber et al. [11], and also documented elsewhere [17-19]. Furthermore, ethnic differences in digit ratio may be responsible for the inconsistencies in data reported by different authors around the world [18-20]. Even though there is a strong association between digit ratio and prenatal testosterone exposure *in utero* [21], a couple of researchers have not identified any strong relationship [17,19]. Data on the digit ratio, hand preference, and their sex differences in males and females are lacking in the African population. Furthermore, it is not clear whether or not the differences, if any exist, may be different between sedentary and athletic persons. Therefore the aim of this study was to investigate the relationship among sex, handedness, and hand-grip strength and digit ratio in black African sedentary and athletic university students.

## MATERIALS AND METHODS

### Ethical statement

This study was performed in accordance with the Declaration of Helsinki and approved by the Local Committee for Medical Research Ethics. Informed consent was obtained verbally after the aims and objectives of the study had been explicitly explained to the subjects. Participation was voluntary and subjects retained the right to refuse participation at any phase of the experiment.

### Participants

A total of 233 healthy young subjects were included in the study: 125 men (mean age=19.31 years, SD=2.43) and 108 women (mean age=17.79 years, SD=1.54) who ranged in age from 16 to 25. Subjects were selected from Nile University of Nigeria (Abuja, Nigeria) and students from visiting schools for 7$^{th}$ NPUGA (Nigeria Private University Games Association) games, held at the Nile University of Nigeria, Abuja, Nigeria. Male and female athletes and non-athletes were chosen randomly.

### Determination of handedness

Handedness was determined by the Edinburgh Handedness Inventory [22]. The test yielded scores from -100 to 100. A subject could only have scores from -100 to 0 (zero) or from 0 (zero) to 100. Subjects who scored from -100 to zero were considered to be left-handed, while those with scores from zero to 100 were considered to be right-handed.

### Measurement of digit lengths

The lengths of the 2$^{nd}$ and 4$^{th}$ digits were determined using a direct method of measurement. Subjects were asked to remove rings and all objects that could possibly interfere with the measurement. The lengths of the 2$^{nd}$ and 4$^{th}$ digits were measured directly using electronic digital caliper with an accuracy of ± 0.1 mm/0.01. The caliper was placed on the ventral surface of both left and right hands from the basal crease to the tip of the finger. The most proximal crease was considered when a band of creases appeared at the base of the digit. The right hand was measured first and the then the left hand. Digit lengths were measured in centimetres (cm) and computed for determination of the 2D:4D by dividing the lengths of the 2$^{nd}$ digit by the 4$^{th}$ digit.

### Hand-grip strength

Hand grip muscle strength was recorded by using a dynamometer attached to PowerLab 26T (AD Instruments, Bella Vista, Australia). The subject firmly grasps the dynamometer in their hands. The subject squeezes the dynamometer with maximum pressure for about 2 seconds. This was repeated twice for both hands. The maximum hand grip force was recorded for each attempt, and the average was computed for the right and left hands respectively. To determine the relative muscle strength, the average force of any given hand of a subject was divided by weight of the subject.

### Measurement of body weight

The weight measurement was done by floor type electronic weighing machine (RGZ-120, size: 385 × 280 mm, dimensions: 900 × 350 × 305 mm, weight: 24 kgs). The subjects were requested to keep their bags, shoes and any load interfering objects before mounting on the machine. The measurement of the weight was conducted as outlined by the manufacturer.

### Statistical analysis

The SPSS statistical software package (SPSS, version 18.0 for windows) was used to perform all statistical calculations. Results are expressed as mean ± standard deviation. Distributions were evaluated using One Sample Kolmogorov Smirnov Test. A two-tailed unpaired Student t-test was used for comparisons. Cross-tabulation was performed using Pearson chi square test. The intra-class coefficient or repeatability of measurements was estimated. Differences were considered statistically significant at $p<0.05$.

## RESULTS

Digit ratios of right and left hands were not statistically significant for both sexes (Table 1). There was also no statistically significant handedness difference in both right and left hand digit ratios (Table 2). Besides these, digit ratio of athletes was not significantly lower compared to the digit ratio of sedentary subjects (non-athletes) (Table 3). No statistically significant association between digit ratios of both the right and left hands and hand grip strength of both the right and left hands was identified. The intra-class coefficient or repeatability for right and left 2D:4D measurement was 0.53 (p=0.00) for all participants. When analysed separately for different sexes, males had 0.60 (p=0.00) intra-class coefficient for right and left 2D:4D, while the coefficient for females was 0.33 (p=0.02).

**Table 1: Sex difference in right and left hand digit ratio (2D:4D)**

| Sex difference | | Digit ratios | | | |
|---|---|---|---|---|---|
| Total | Males (N=125) | 0.93 ± 0.06 | t=0.73 | 0.94 ± 0.04 | t=1.01 |
| | Females (N=108) | 0.93 ± 0.04 | NS | 0.94 ± 0.03 | NS |
| Right-handers | Males (N=115) | 0.94 ± 0.06 | t=0.72 | 0.95 ± 0.04 | t=0.65 |
| | Females (N=96) | 0.93 ± 0.04 | NS | 0.94 ± 0.03 | NS |
| Left-handers | Males (N=10) | 0.93 ± 0.04 | t=0.51 | 0.94 ± 0.04 | t=0.06 |
| | Females (N=12) | 0.93 ± 0.04 | NS | 0.92 ± 0.03 | NS |
| Athletes | Males (N=78) | 0.93 ± 0.07 | t=0.23 | 0.95 ± 0.05 | t=0.16 |
| | Females (N=62) | 0.93 ± 0.05 | NS | 0.94 ± 0.03 | NS |
| Non-athletes | Males (N=47) | 0.92 ± 0.04 | t=2.31 | 0.94 ± 0.03 | t=1.44 |
| | Females (N=46) | 0.94 ± 0.03 | NS | 0.93 ± 0.03 | NS |

**Table 2: Handedness difference in right and left hand digit ratio (2D:4D)**

| Sample | Handedness | Right hand digit ratio | | Left hand digit ratio | |
|---|---|---|---|---|---|
| Total | Right-handers (N=211) | 0.93 ± 0.06 | t=0.19 | 0.94 ± 0.04 | t=0.94 |
| | Left-handers (N=22) | 0.93 ± 0.04 | NS | 0.93 ± 0.03 | NS |
| Male | Right-handers (N=115) | 0.93 ± 0.07 | t=0.01 | 0.95 ± 0.04 | t=0.72 |
| | Left-handers (N=10) | 0.93 ± 0.04 | NS | 0.94 ± 0.04 | NS |
| Female | Right-handers (N=96) | 0.93 ± 0.04 | t=0.27 | 0.94 ± 0.03 | t=0.55 |
| | Left-handers (N=12) | 0.93 ± 0.04 | NS | 0.93 ± 0.03 | NS |
| Athletes | Right-handers (N=132) | 0.93 ± 0.06 | t=0.29 | 0.94 ± 0.03 | t=1.65 |
| | Left-handers (N=8) | 0.93 ± 0.03 | NS | 0.92 ± 0.03 | NS |
| Non-athletes | Right-handers (N=79) | 0.93 ± 0.04 | t=0.08 | 0.94 ± 0.04 | t=0.07 |
| | Left-handers (N=14) | 0.93 ± 0.04 | NS | 0.94 ± 0.03 | NS |

**Table 3: Athlete-sedentary difference in right and left hand digit ratio (2D:4D)**

| Sample | Athlete-Sedentary | Right hand digit ratio | | Left hand digit ratio | |
|---|---|---|---|---|---|
| Total | Athlete (N=140) | 0.93 ± 0.06 | t=0.27 | 0.94 ± 0.03 | t=0.43 |
| | Sedentary (N=93) | 0.93 ± 0.04 | NS | 0.94 ± 0.03 | NS |
| Right-handers | Athlete (N=132) | 0.94 ± 0.06 | t=0.31 | 0.94 ± 0.04 | t=0.2 |
| | Sedentary (N=79) | 0.93 ± 0.04 | NS | 0.94 ± 0.03 | NS |
| Left-handers | Athlete (N=8) | 0.93 ± 0.03 | t=0.31 | 0.92 ± 0.03 | t=1.47 |
| | Sedentary (N=14) | 0.93 ± 0.04 | NS | 0.94 ± 0.03 | NS |
| Males | Athlete (N=107) | 0.93 ± 0.07 | t=1.01 | 0.94 ± 0.03 | t=1.57 |
| | Sedentary (N=18) | 0.92 ± 0.04 | NS | 0.96 ± 0.06 | NS |

| | | | | | |
|---|---|---|---|---|---|
| Females | Athlete (N=33) | 0.93 ± 0.04 | t=0.17 | 0.94 ± 0.03 | t=0.17 |
| | Sedentary (N=75) | 0.94 ± 0.04 | NS | 0.94 ± 0.03 | NS |

## DISCUSSION

Over the past decades digit ratio as a priori marker of fetal testosterone exposure *in utero* has been widely debated on [3,11]. These arguments were based on initial data reported by Manning et al. [13] who observed that digit ratio could be a marker of the quantity of testosterone exposure of the fetus *in utero*, and that testosterone level *in utero* was related to the quantity of postnatal circulating testosterone [14]. Subsequent studies identified that digit ratio substantially varies between males and females [20,23]. Although the ethnic differences in digit ratio are only becoming recently acknowledged [18-20], digit ratio is generally smaller for males compared to females [11]. The results of our study did not identify any sex related difference in both right and left hand digit ratios, which is a direct contradiction to previous studies, which reported significant sex differences in digit ratio, such that males had lower 2D: 4D than females [20,24-28].

A very few studies, conducted in Africa have shown that digit ratio is sexually dimorphic [24-29]. In a study conducted in Ilorin, Nigeria, Oyeyemi et al., revealed significant sex-related differences in 2D:4D [26]. Furthermore, the authors showed that 2D:4D was lower in males compared to females [26]. Interestingly, they also reported correlation between 2D:4D, metabolic syndrome and cardiovascular risk factors in the Ilorin inhabitants [26]. In another study, Gwunireama et al. investigated digit ratio of Andoni and Ikwerre ethnic groups in the Niger Delta region of Nigeria [27]. The results showed significant sex-related differences in digit ratio in both ethnic groups [27]. However, within same geographical location, there were both sexual and ethnic differences in digit ratio, suggesting that in addition to geographical influences, digit ratio may be inherited [27]. In a study conducted in Zaria (Nigeria), Danborno et al., also reported sexual dimorphism in digit ratio [28]. Similar results had been reported in Namibia [29].

Manning et al. found that sex related difference in 2D:4D was consistent across ethnic and country groupings [20]. However, the mean 2D:4D varied across ethnic groups with higher ratios for non-Chinese Asians, mid-Easterners, and whites, but lower ratios in Chinese and blacks [20]. However, in contrast to the results of Manning et al. [20] and other authors [3-12,16], Marczak et al. recently reported absence of sex differences in digit ratio among Yali people of Papua, Indonesia [19]. It has been previously suggested that the absence or differences in digit ratio may be due to such factors as latitude, which determines length of day and night as well as duration of exposure to sunlight-are important factors that might shape differences in digit ratios [18,19]. In the case of Yali people, the environment is temperate, high-mountain, and is almost on the equator [19]. Indeed, a weak 2D:4D between males and females had been previously documented [24]. This suggests that the degree of association in sex differences in digit ratio may vary from strong [20], to weak [30] and in some cases absence of any association [19,31].

Digit ratio is widely known to be associated with traits like left-handedness [11], and the association between prenatal testosterone with left-handedness was first reported almost three decades ago [32]. Prenatal testosterone levels appear to have substantial effect on development of cerebral hemispheres, which in turn determines handedness. A higher 2D:4D of the left hand in comparison to the right hand is associated with left handedness in both males and females. Similarly, a higher 2D:4D of the right hand in comparison with the left hand is associated with right handedness in both genders [33]. Stoyanov et al. found that the difference in digit ratio between the right and left digit ratios in left-handers was significantly lower than similar index in right-handers, suggesting that left-handers had exposure to greater levels of testosterone *in utero* [34]. A low value of difference between right and left digit ratios was associated with left hand preference [33]. Similar findings were reported by Beaton et al. [16]. However, in this study, handedness related differences in digit ratio could not be ascertained among the young Africans. These findings are consistent with very recent data reported by Marczak et al. [19].

It should be noted that differences in gene pools in a given ethnic milieu may play a stronger role in shaping the sex differences related to digit ratio and handedness [18]. Warrington et al. found only a weak evidence for association between digit ratio and sensitivity to testosterone exposure *in utero* [17]. Similar findings were reported by Kaltwasser et al. [35].

Overall, the results of the present study and data reported by other authors [17,19] suggested that sexual dimorphism and handedness related differences in digit ratio are not universal in humans. Furthermore, the relationships among digit ratio, physical ability and strength, and sportive performance may vary with racial and ethnic factors.

## CONFLICT OF INTEREST

The authors declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

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