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Handedness, Eyedness, Footedness, Crossed Dominance and Digit Ratio in Nigerian People

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ABSTRACT

Background: Proxy measures of cerebral lateralization such as handedness, eyedness, footedness and crossed dominance are associated with digit ratio. Cerebral lateralization and digit ratio are believed to serve as potential biomarkers of effectiveness of performance in several spheres of human endeavors, and are also related to development of certain diseases that affect mankind. Both cerebral lateralization and digit ratio vary with different genders, ethnic groups and geographical locations. There is lack of data on digit ratio and cerebral lateralization among the Nigerian people. Furthermore, gender differences in digit ratio and cerebral lateralization are not known in the Nigerian population. The aim of this study was to investigate the gender differences in handedness, footedness, eyedness, and digit ratio among young Nigerian people. The effects of crossed dominance on digit ratio for right and left hands were also investigated.

Methods: A total of 107 Nigerians (52 males and 55 females, age range: 17-27 years) volunteered for the study.

Results: The percentage of left handedness was higher in males, whereas females had higher percentage of right handedness. There was no gender difference in eyedness, footedness and digit ratio. Digit ratio for the right hand was higher in subjects having crossed hand-eye dominance, while the left hand digit ratio was higher in subjects having crossed hand-foot dominance.

Conclusions: Among the proxy measures of cerebral lateralization, Nigerians showed gender variation for handedness only. Gender differences in digit ratio and cerebral lateralization are not universal across nationalities or geographical regions.

Key words: Laterality, Cerebral lateralization, Dominance, Handedness, Eyedness, Footedness, Crossed dominance, Digit ratio

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INTRODUCTION

Handedness, eyedness, footedness, and eardness are used to describe cerebral lateralization or laterality, referring to the preferential use of the right or left hemisphere of the brain to control bodily activities or tasks. In other words, cerebral lateralization allows humans to preferentially use homologous body parts on one lateral half of the body over those on the other side. Thus one body part is functionally dominant over the other part during performance of a given task. It should be mentioned, however, that the preferential use of lateral homologous body part is not consistent for all activities. Thus, some individuals may use their right hand for writing, and their left hand for certain sporting activities [1-4]. Though very uncommon in the population, some individuals may exhibit mixed-handedness, mixed-eyedness, mixed-footedness, or mixed-eardness, which enable them to change preference for use of one body part over the other in specific task [1-6]. This phenomenon is known as crossed dominance or crossed laterality. Therefore, individuals are not consistently or uniformly right- or left-sided [5].

Over the past decades accumulating research data have steadily showed a relationship between cerebral lateralization and effectiveness of performance in several spheres of human endeavors [7,8]. For instance, Petersen et al. observed that right handedness was associated with higher physical performance on a dynamometer [9]. Similar findings were reported elsewhere [10]. Non-right-handedness (i.e. left handedness and mixed-handedness) is thought to be related to neuropsychological pathology [11-13]. Papadatou-Pastou et al. reported a higher level of non-right-handedness in intellectually disabled than typically developing individuals [11]. Indeed left handedness and mixed-handedness occur with a higher frequency in patients suffering from schizophrenia, compared to healthy individuals [13]. In contrast to females, male schizophrenics were reported to have increased frequency of left eyedness and crossed hand-eyedness, compared to their healthy counterparts [13]. Similar findings were reported in previous studies [14,15]. In another study, Aygül et al. investigated cerebral lateralization in male patients with migraine headache and showed higher incidence of left-eyedness in the patients compared to healthy controls [16]. Importantly, aura, defined as a neurological disorder that precedes or appears during the onset of a migraine, was associated with left-eyedness and crossed hand-eye dominance [16,17]. In heroin addicts, increased left-eyedness and the crossed hand-eye dominance, compared to healthy controls were reported (heroin addiction is, arguably, a brain disease, characterized by relapse, impulsive heroin seeking behaviour and use, despite harmful consequences) [18-20]. It is now increasingly believed that disorder in developmental programming of cerebral hemisphere connectivity at certain points in ontogenesis may lead to anomalous cerebral dominance, which may necessarily lead to neuropsychological disorders [21,22] such as schizophrenia [12], epilepsy [23], autism [24], deafness [11], and Klinefelter's syndrome [25]. Though the mechanisms of cerebral lateralization and its disorders are yet to be fully understood, recent investigations have identified genetic markers that control cerebral lateralization [26-28]. *PCSK6* and *LRRTM1* genes have been identified as key regulators of signalling pathways that control development of cerebral lateralization [26,29]. Certain variants of these genes have been implicated as possible causes of autism and schizophrenia [26,29].

Thus cerebral lateralization parameters may serve as potential biomarkers of risk stratification in several diseases or propensity of development of certain diseases [30-33]. But cerebral lateralization varies with different ethnic groups and geographical locations. There is lack of data on cerebral lateralization in the Nigerian population. In particular, the frequency of left-, right-handedness, -eyedness, -footedness and crossed dominance have not been investigated among the Nigerian people. Furthermore, gender differences in cerebral lateralization are not known in the Nigerian population.

Interestingly, proxy measures of cerebral lateralization such as handedness, eyedness, footedness, eardness and crossed dominance are related to anthropometric measures, in particular, digit ratio [34,35]. Digit ratio refers to the ratio of the length of the 2nd digit (2D or index finger) and the 4th digit (4D or ring finger), i.e. 2D: 4D. Over the past decades, a couple of studies conducted in different parts of the globe have continuously reported sex differences in 2D:4D [32,36]. Research data have shown that males have longer 4D relative to 2D than females-meaning that males have lower 2D:4D compared to females. Consequently digit ratio can be said to be sexually dimorphic [37-39]. It is believed that sex difference in 2D:4D is determined by differential activity of sex steroids, particularly, testosterone and estrogen, early during the period of ontogenesis [37,39] and a developmental period before puberty [40]. If 2D:4D is an indication of hormonal influences during early pregnancy, then it is possible to use 2D:4D to explain the etiological basis of sexually dimorphic behaviours such as risk-taking, aggression; and physical abilities such as strength and speed [36,41,42].

So, lower digit ratio is associated with greater strength, better sporting performance, and a propensity towards jobs demanding greater physical ability, and possibly, better financial standing [43,44] in both males [45] and females [46]. Interestingly, Coates et al. revealed in their study, conducted in London (United Kingdom), that digit ratio can predict financial success and long-term profitability in business [47]. But, digit ratio also varies with different ethnic groups and geographical locations [48-50]. Unfortunately, however, there is a paucity of data on gender differences in digit ratio in Nigerians. Moreover, recent data indicate that digit ratio can be harnessed as a marker of some behavioural contingencies, life experiences and outcomes [38] as well as propensity to develop disorders such as Alzheimer's disease, amyotrophic lateral sclerosis, and multiple sclerosis [51-53].

The aim of this study was to investigate the gender differences in handedness, footedness, eyedness, and digit ratio among young Nigerian people. The effects of crossed dominance on digit ratio for right and left hands were also investigated.

MATERIALS AND METHODS

Ethical statement

The experimental protocol for this study was in accordance with the Helsinki Declaration (1975, revised in 1996-2013). Informed consent was obtained from the participants after the aims and objectives of the study had been explicitly explained. Only those who agreed and gave their consent were involved in the study.

Participants

The study involved a total of 107 young Nigerians in Federal Capital Territory-Abuja (Nigeria), who had no known illness. Of them, 52 participants were males (age range: 17-27 years, mean age: 19.73 years, SD: 3.77) and 55 were females (age range: 17-27 years, mean age: 17.86 years, SD: 1.56).

Handedness

Handedness was ascertained using the Edinburgh Handedness Inventory [54]. The test yielded scores from -100 to 100. A subject could only have scores from -100 to 0 or from 0 to 100. Left-handed subjects were those who scored from -100 to zero, while right-handed subjects scored from zero to 100.

Eyedness

Eye dominance, also known as ocular sighting dominance, was determined by near-far alignment test (modified Miles test) [55]. To carry out this test, two points were first determined. The first point, also called near point, was designated as the tip of a stick located 40 cm away from a jaw support. The second point, also called far point, was designated as a wall located 3 m away from the near point. Each participant was requested to fix his or her jaw on the support, and then focus on both right and left eyes on the far point. Thereafter, the participant was requested to close one eye without moving the head or eyes. This process was done for the other eye. The closed eye was referred to as the dominant eye if the position of the tip of the stick on the horizontal plane changed from the far point when one of the eyes was closed. We repeated this test three times for each participant. The results were accepted as correct if the results of the three tests were same or closely similar [56].

Crossed dominance

Participants were considered to be crossed hand-eye dominant if they had right hand-left eye dominance or left hand-right eye dominance.

Footedness

Footedness was determined as foot preference with regard to kicking a ball to hit a target [57]. Participants who had preference to put the left foot forward in kicking the ball and completing task (hitting the target) were considered as left footed, while those that executed the task preferentially using the right foot were considered as right footed.

Digit ratio

The lengths of the 2^{nd} and 4^{th} digits (in cm) were determined by direct measurement using electronic digital caliper with an accuracy of ± 0.1 mm/0.01. Participants were asked to remove any rings on the fingers before the lengths of the 2^{nd} and 4^{th} digits were determined by the caliper, placed on the ventral surface of the hands from the basal crease to the tip of the digit. The most proximal crease was chosen in the presence of band of creases at the digit base. The measurement was first taken from the right hand before the left hand. Digit lengths were measured three times by different observers and the average was calculated. The values of 2D: 4D were computed by dividing the lengths of the 2^{nd} digit by the 4^{th}.

Height and weight measurement

The height and weight measurements were recorded using floor type weighing machine (RGZ-120 size: 385 × 280 mm, dimensions: 900 × 350 × 305 mm, weight: 24 kgs). Participants were asked to keep their shoes, bags and any load interfering objects before mounting on the machine. The measurements of the height and weight were carried out simultaneously using the manufacturer instructions.

Statistical analysis

The SPSS statistical software package (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 comparison. Cross-tabulation with Pearson chi square test was also performed. Differences were considered statistically significant at $p<0.05$.

RESULTS

Of the 52 males that participated in the study, 42 (80.8%) were right-handed, while 10 (19.2%) were left-handed. Among the 55 female participants, 52 (94.8%) were right-handed and only 3 (5.5%) were left-handed. The difference in rate of left-handedness between male and female participants was statistically significant (X2=4.75, p=0.03). But, there was no gender difference in eyedness and footedness. Regarding anthropometric measures, no statistically significant gender difference was observed in BMI and digit ratio (Table 1). However, height and weight were statistically higher among the males compared to the females (Table 2).

Table 1: The gender differences in some body sizes and digit ratios

Parameters	Males (N=52)	Females (N=55)	t	p
Height (m)	1.76 ± 0.07	1.63 ± 0.08	10.22	0
Weight (Kg)	70.08 ± 12.34	64.12 ± 13.69	2.34	0.02
BMI (Kg/m^2)	22.68 ± 3.7	23.68 ± 5.52	1.08	NS
2D:4D (Right hand)	0.94 ± 0.04	0.96 ± 0.09	1.09	NS

2D:4D (Left hand)	0.95 ± 0.04	0.96 ± 0.09	1.6	NS

Table 2: The handedness differences in some body sizes and digit ratios

Parameters	Right-handers (N=94)	Left-handers (N=13)	t	p
Height (m)	1.69 ± 0.09	1.73 ± 0.07	1.54	NS
Weight (Kg)	66.91 ± 13.78	67.81 ± 9.89	0.22	NS
BMI (Kg/m^2)	23.28 ± 4.97	22.61 ± 2.65	0.47	NS
2D:4D (Right hand)	0.95 ± 0.07	0.94 ± 0.04	0.79	NS
2D:4D (Left hand)	0.96 ± 0.05	0.94 ± 0.03	1.09	NS

Of the 94 right-handed participants in the total sample, 80 (85.1%) were right-footed and 14 (14.9%) left-footed. Among the 13 left-handed participants in the general sample, 5 (38.5%) were right-footed and 8 (61.5%) were left-footed. The difference in frequency of left-footedness between right- and left-handed participants was statistically significant (X2=15.21, p=0.00). However, there was no difference in footedness between right and left eye dominant participants.

Digit ratio for the right hand was higher in subjects having crossed hand-eye dominance compared to congruent participants (t=2.31, p=0.02). The left hand digit ratio was higher in participants having crossed hand-foot dominance compared to congruent participants (t=2.27, p=0.03) (Table 3).

Table 3: The effects of crossed hand-eye and hand-foot dominances on digit ratios in right and left hands

Parameters	Congruent hand-eye dominant subjects (N=64)	Crossed hand-eye dominant subjects (N=43)	t	p
2D:4D (Right hand)	0.94 ± 0.07	0.97 ± 0.06	2.31	0.02
2D:4D (Left hand)	0.95 ± 0.04	0.96 ± 0.06	1.16	NS
Parameters	**Congruent hand-foot dominant subjects (N=88)**	**Crossed hand-foot dominant subjects (N=19)**	**t**	**p**
2D:4D (Right hand)	0.94 ± 0.07	0.97 ± 0.07	1.26	NS
2D:4D (Left hand)	0.95 ± 0.05	0.98 ± 0.07	2.27	0.03

DISCUSSION

This is the first study to investigate frequency of proxy measures of cerebral lateralization among young people in Nigeria, while also highlighting gender differences in handedness and related anthropometric indices.

Consistent with previous studies [58-62], the results of this study revealed higher percentage of left handedness in males. Similar to the results reported by Vlachos et al., percentage of right-handedness was clearly higher among females [63]. Though right handedness has been reportedly associated with higher strength in grip test [9,10], other researchers have observed that left-handers are more successful in sporting activities such as wrestling [64], tennis [65], and basketball [66]. Thus, in contrast to right hand dominance, left-handedness may be associated with superior performance in interactive sports [57]. This indicates that there are no clear-cut characteristics that differentiate anomalous hemispheric dominance (leading to left-handedness in neuropsychological disorders) from typical hemispheric dominance (leading to "normal" left-handedness). Therefore, further investigations on key characteristics of "pathological" handedness, which differentiate it from "normal" handedness, are necessary [67].

Consistent with the findings of other studies conducted in different geographical regions of the world [59,61,68], no gender difference in footedness and eyedness among young Nigerian people was observed. Footedness is a very important index in sports. Relatively recently, Tran et al. showed that mixed-footedness and left-footedness were beneficial in dancing, skiing, team sports, martial arts, fencing, and swimming [57]. It is believed that the superior motor abilities of mixed- and left-footedness are due to better cerebral inter-hemispheric connectivity, which may depend on hormonal (e.g. testosterone) induced effects [57,69]. Thus the absence of any gender difference in footedness in our study indicates that the testosterone hypothesis may not be universal for all nationalities or ethnic groups. It is therefore, imperative to investigate other factors that may determine the pattern of cerebral lateralization during early developmental periods of life. This may provide some information on the mechanisms of development of certain neuropsychological disorders.

Bourassa et al. observed 1.2 times higher incidence of left-eyedness for females than for males among 9,480 male and 8,899 female participants in 21 studies [70]. This further reiterates that gender differences in eyedness are not the same across geographical regions of the world. It is widely known that left eyedness occurs in about 30% of the population. The remaining 70% of people are right-eye dominant [71-75]. But a very small proportion of the population has mixed-eyedness [76]. Though the pathological aspects of eyedness have not been widely investigated, available evidences suggest that certain cases of left-eye dominance are associated with migraine and obsessive compulsive disorders [16,77].

In contrast to previous studies [36,38], no gender difference in digit ratio was observed in our study. Ethnic factors may be responsible for these inconsistencies in the literature. Indeed emerging data have indicated that sex differences in digit ratio may not hold in every ethnic and cultural groups [49,50]. As a key marker of endocrine interruption and its health consequences during early developmental period of life *in utero* [78], digit ratio is associated with behavioural and somatic disorders, and thus, can have important health consequences [79]. To this end, a recent study conducted by Bunevicius revealed that low digit ratio was associated with gastric cancer, prostate cancer, and brain tumors, while high digit ratio was associated with cervical dysplasia and breast cancer [80]. Consequently, the relationship between digit ratio and crossed hand-eye and hand-foot dominances may help us to have clinically important predictions about the development of certain diseases [13-16,48,51-53]. But digit ratio and crossed dominance are believed to be related to performance in certain activities. In a previous study conducted by Voracek et al., it was reported that tournament fencers had lower digit ratio, but had higher percentage in left-handedness compared to the local general population [81]. Crossed *versus* congruent hand-eye and hand-foot preferences were related to performance in fencing [81]. Our study revealed that crossed hand-eye dominance resulted to higher digit ratio for the right hand, whereas crossed hand-foot dominance was related to higher digit ratio for the left hand. This suggests that cross laterality may have some effects on digit ratio, ensuring ambidexterity independent on gender.

The implication of our findings on digit ratio and crossed dominance will be considered for future research on the clinical usefulness of digit ratio and crossed dominance in health and neuropathological diseases in the Nigerian population. The results of this study provide a basis for comparison with future investigations on digit ratio and cerebral lateralization in different age groups and categories of individuals in Nigeria. This study provides useful addition to the global discourse on the gender differences in digit ratio and cerebral lateralization.

CONCLUSIONS

The percentage of left handedness was higher in males, whereas females had higher percentage of right handedness. There was no gender difference in eyedness, footedness and digit ratio. Digit ratio for the right hand was higher in subjects having crossed hand-eye dominance, while the left hand digit ratio was higher in subjects having crossed hand-foot dominance. Gender differences in digit ratio and cerebral lateralization are not universal across nationalities or geographical regions.

FUTURE RESEARCH

Since gender differences in cerebral lateralization are not consistent across the proxy measures of laterality, it will be important for future research to investigate how similar parameters of cerebral laterality change in different neuropathological states and stages of disease progression in the Nigerian population. It will be important to investigate how gender differences in digit ratio and cerebral lateralization change across different age groups. Future investigations will also take in consideration the possibility of using digit ratio and cerebral lateralization as potential biomarkers of some behaviours, life experiences and outcomes as well as propensity to develop neuropathological disorders.

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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