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2nd TO 4th DIGIT RATIO (2D:4D) AND MATHEMATICS PERFORMANCE AMONG SECONDARY SCHOOL STUDENTS IN KADUNA, NIGERIA

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Abstract

Humans, non-human primates, birds and reptiles have demonstrated sexually dimorphism in the length of their 2nd and 4th digits otherwise known as 2D:4D, with males on the average having lower values than females. This difference has been associated with the differential exposure of prenatal testosterone relative to estrogen during intrauterine life. This present study investigated the association between 2D:4D and Mathematics performance among secondary school students in Kaduna metropolis, Kaduna state. A total of 462 students of (males n=239 and females n=223 with mean age 16.84 ± 1.94) participated in the study from 3 secondary schools in Kaduna metropolis. The length of 2nd and 4th finger were measured with digital Vernier caliper from the basal crease to the tip of the finger, and 2nd digit length 2D was divided by 4th digit 4D to obtain 2D:4D ratio. Mathematics performance of the participated students was assessed from the terminal examination results obtained from the schools authorities. The study established significant relationship between 2D:4D and performance in mathematics with right hand r= 0.22 P<0.01 and left

hand 0.16 P<0.01 in females but not in males. The study also agree with the existing literature that stated 2D:4D is more on the right hand than the left.

Keywords: 2D:4D, Digit length, Secondary School, Performance, Mathematics, Kaduna.

INTRODUCTION

Sexual dimophism has been known to exist in the ratio of the second to forth finger length otherwise known as second digit to fourth digit ratio,(2D:4D) for over 100 years(Baker, 1888), with men, on the average, having lower 2D:4Ds than women do. Digit ratios are determined in the utero and will then remain the same without change during the individual development (Mannimg *et al.,* 1998) and appeared to be universal across ethnic groups (Manning, 2002) and has been shown to exist in mammals and other primates (Burley and Foster 2004; Brown *et al*., 2002). Based on a large number of studies, it has been concluded that 2D:4D is positively associated with prenatal estrogen and negatively associated with prenatal testosterone(Manning, 2002; Danborno *et al*., 2007 and Breedlove 2010), recently Lu *et al.,* (2017) were able to show that 2D:4D ratio is a good measure of hand grip strength in men, but is not a robust measure of hand grip strength in women. Moreover birth weight can also be predicted using 2D:4D ratio (Danborno *et al*., 2010)

2D:4D has been found to be associated with a variety of physical and psychological characteristics. For example, men with lower 2D:4D are more aggressive, more athletic, less feminine, and more musically talented (Bailey and Hurd, 2005; Frick *et al.,* 2017, Manning and Taylor, 2001; Rammsayer and Troche, 2007; Sluming and Manning, 2000). Women with lower 2D:4D have higher waist-to-hip ratio, are more masculine, and are more athletic (Csathó *et al.,* 2003a; Manning *et al.,* 2000; Pokrywka *et al*., 2005). Among both men and women, 2D:4D is correlated positively with verbal intelligence and agreeableness, and negatively with numerical intelligence and physical fitness (Hönekopp *et al*., 2006; Luxen and Buunk, 2005).Autistic individuals have also been found to be gifted in identifying recurrent patterns, processing perceptual information, andoften have exceptional memories and are less likely to misremember data (Mottron, 2011). These are characteristics that are usefulin order to perform well in practical and theoretical examinations. Reports of digit ratio in relation to aspects of mathematical performance are less common. Luxen and Buunk (2005) found a significant correlation between right hand digit ratio and numerical skills, with numerical skills being higher in individuals with lower masculinised digit ratios. Kempel *et al.,* (2005) also found that females with more masculinised digit ratios performed better on a numerical IQ task (continuing numerical series). In the mathematical cognition literature, it has been argued that mathematical thinking depends in part on an underlying "number sense" (Dehaene *et al.,* 2003), which is biologically determined and has a long evolutionary history. This number sense allows us to compare and approximate numerical quantities, and such abilities have been repeatedly demonstrated in studies with very young infants (Lipton and Spelke, 2003; Xu, 2003).

Hopp *et al*., (2012) have found that low 2D:4D is related to practical and theory examination marks in Brazilian male dental students. They suggest that their finding supports a theoretical link between high prenatal testosterone and high intelligence. The lack of a relationship between2D:4D and examination marks in female dental students indicate that prenatal testosterone does not influence female intelligence in the same manner as that in males, even though the studies is consistent with that ofCoco *et al.,* (2011), who evaluated a group of Italian male students, and found a significant correlation between 2D:4D and success in admission tests for a medical school.Their is paucity of data and gap in knowledge regarding what one part of a body entails aboutthe other parts in Nigeria. Therefore this study is aimed to add to the pool of data regardingmathematical performance and the 2D:4D ratio.

MATERIALS AND METHODS

Data for this study were obtained from secondary school students of Kaduna, Kaduna State, Nigeria.462 both male and female students participated in the study (n=462, mean age 16.84 ±1.94 years). The schools were randomly selected in Kaduna metropolis, namely Federal Government College, Kaduna, Capital School and Technical College, Kaduna. The work was carried out in accordance with The Code of Ethics of the World Medical Association for experiments involving humans, and approved by the health research ethics committee of Ahmadu Bello University Teaching Hospital, Shika, Zaria. In each of the school, an informed written and verbal consent was also sought from the school authority as well as the participating students. In order to encourage more candidates and reliable responses, participants were made to complete the self-administered questionnaire in confidence with their peers unable to see their questinnaire. Digit lengths (the length of 2nd digit otherwise known as index finger and that of the 4th digit also known as ring finger) was measured on the ventral surface of the hand from the basal crease of the digit to the tip of the finger using a digital venier caliper measuring to 0.05mm. In order to reduce observation errors, Digit length measurements were read twice independently and the mean of the two measurements was taken as the actual value. Students with a history of fractures in the fingers or any form of deformity on the digits that could hinder accurate measurement, and those with incomplete academic records with the school management were restricted from the study.

Terminal results of the first and second terms of the students were collected from the schools examination officers for Mathematics performance correlations in each of the school visited. Mathematics results of the two terms of each student were added and the average of the two results was taken as the actual real value of Mathematics academic performance.

Data were expressed as means ±standard deviations (SD). Statistical analysis used Student's t test for male versus female digit ratio comparison, and to check for the difference in 2D:4D in the right and left hands of subjects. Pearson's correlation coefficient was applied to test

the relationship between 2D:4D and Mathematics performance. Finally linear multiple regression for 2D:4D was used to generate equations for predicting Mathematics performance from digit ratio and digit lengths.Statistical significance difference was deemed acceptable at $P < 0.05$. SigmaStat 2.0 for Windows (San Rafael, CA) was used for the statistical analyses, MS Excel 2010.

RESULTS

After exclusion criteria, 462 students were selected to participate in the study (Males n = 239 and Females n = 223). Table 1 highlight the mean age for the participants 17.44 ± 2.30 years for males and 16.20 ± 1.17 years for females. Mean 2D:4D for males was 0.96 ± 0.04and for females 0.95 ± 0.04. This sex difference in 2D:4D was in the unexpected direction as most digit ratio studies reported lower ratios in favour of the male subject. Figure 1 shows sexual dimophism,Mathematics performance is higher in female student subjects than in male students counterparts. Student t-test indicates significant difference, $p < 0.05$.

With regard to sex differences in the Mathematics performance, males and females differ in their examination marks (males 46.92 ± 16.30, females 51.03 ± 14.63 , $t = 2.84$, $p = 0.005$), however, females scored significantly higher examination marks than their male counterparts. Pearson's correlation matrix (Table 2) analysis showed that the relationship between 2D:4D and Mathematics performance remained significant. It is to be noted that the correlations between 2D:4D and Mathematics performance are of similar strength, and this was confirmed by an examination of the correlation between 2D:4D and the ratio between Mathematics marks ($r = 0.22$, $p = 0.01$ for right hand and $r = 0.16$, $p = 0.05$ for the left hand). With regard to males (Table 3), there was no significant correlation between 2D:4D and Mathematics marks ($r = 0.06$, p = for right hand and $r = 0.09$, p = for the left hand)

Table 4 shows predictive equations (Linear regression models) for predicting performance in Mathematics using digit lengths of R2D (length of Right 2nd digit), L2D (length of Left 2nd digit), R4D (length of Right 4th digit) and L4D (length of Left 4th digit) and digit ratios (2D:4D), statistics shows significance for estimating Mathematics performance. From this linear regression one can be able to predict how well a student can performe in Mathematics, based on the records of the digit ratio or digit length of that student.

Table 1.0: Mean and standard deviation of digit lenght, digit ratio and Mathematics performance of overall sample population and according to sex (n = 462)

	All subjects		Female		Male			
Parameters	Mean ± SD	Min – Max	Mean ± SD	Min – Max	Mean ± SD	Min – Max	t	p
N	462		223		239			
Age (yrs.)	16.84 ± 1.94	13.00 – 26.00	16.20 ± 1.17	13.00 – 21.00	17.44 ± 2.30	13.00 – 26.00	-7.22	0.001
R2D (cm)	6.79 ± 1.05	2.50 – 8.89	6.49 ± 1.12	2.50 – 8.30	6.49 ± 1.12	2.50 – 8.89	-6.00	0.001
R4D (cm)	7.10 ± 1.05	2.93 – 9.09	6.82 ± 1.12	2.93 – 8.25	7.37 ± 0.90	2.93 – 9.09	-5.84	0.001
R2D:4D	0.95 ± 0.04	0.78 – 1.10	0.95 ± 0.04	0.79 – 1.08	0.96 ± 0.04	0.78 – 1.10	-1.73	0.084
L2D (cm)	6.87 ± 1.04	2.91 – 8.58	6.58 ± 1.10	2.91 – 8.06	7.13 ± 0.89	2.91 – 8.58	-5.92	0.001
L4D (cm)	7.08 ± 1.05	0.84 – 1.10	6.80 ± 1.12	3.22 – 8.33	7.34 ± 0.91	3.22 – 9.01	-5.77	0.001
L2D:4D	0.97 ± 0.04	0.85 – 1.10	0.97 ± 0.04	0.85 – 1.08	0.97 ± 0.04	0.85 – 1.10	-1.16	0.245
Mathematics (%)	48.90 ± 15.63	5.00 – 90.00	51.03 ± 14.63	12.00 – 89.00	46.92 ± 16.30	5.00 – 90.00	2.84	0.005

Table 2.0: Pearson's correlation matrix of digit lenght,digit ratio and Mathematics academic performance of females study participants

	R2D	**R4D**	**L2D**	**L4D**	**R2D:4D**	**L2D:4D**	**Maths**
R2D	-	0.97[a]	0.99[a]	0.97[a]	0.40[a]	0.96[a]	0.39[a]
R4D		-	0.97[a]	0.99[a]	0.17[a]	0.13	0.36[a]
L2D			-	0.98[a]	0.33[a]	0.28[a]	0.39[a]
L4D				-	0.22[a]	0.08	0.37[a]
R2D:4D					-	0.56	0.22[a]
L2D:4D						-	0.16[b]
Maths							-

R2D = right second digit (cm), R4D = right fourth digit (cm), R2D:4D = right-second-to-fourth digit ratio, L2D = left second digit (cm), L4D = left fourth digit (cm), L2D:4D = left-second-to-fourth digit ratio, Maths = Mathematics (%), a: correlation statistically significant at $p < 0.01$, b: correlation statistically significant at $p < 0.05$

Table 3.0: Pearson's correlation matrix of digit lenght,digit ratio and Mathematics academic performance of males study participants

	R2D	R4D	L2D	L4D	R2D:4D	L2D:4D	Maths
R2D	-	0.95[a]	0.96[a]	0.93[a]	0.22[a]	0.24[a]	0.20[a]
R4D		-	0.96[a]	0.97[a]	-0.09	0.10	0.18[a]
L2D			-	0.98[a]	0.33[a]	0.27[a]	0.18[a]
L4D				-	0.22[a]	-0.03	0.16[a]
R2D:4D					-	0.48[a]	0.06
L2D:4D						-	0.09
Maths							-

R2D = right second digit (cm), R4D = right fourth digit (cm), R2D:4D = right-second-to-fourth digit ratio, L2D = left second digit (cm), L4D = left fourth digit (cm), L2D:4D = left-second-to-fourth digit ratio, Maths = Mathematics (%), a: correlation statistically significant at $p < 0.01$, b: correlation statistically significant at $p < 0.05$

Table 4.0: Linear regression models for predicting performance in Mathematics using digit lengths and digit ratios (2D:4D)

Parameters	*Predictive equation*	*SEE*	*R*	R^2	*P*
R2D (cm)	MATH = 19.636 + 4.310 × R2D	14.981	0.289	0.084	0.0001
R4D (cm)	MATH = 20.784 + 3.960 × R4D	15.088	0.265	0.070	0.0001
R2D:4D	MATH = (-7.166) + 58.719 × R2D:4D	15.465	0.153	0.024	0.0010
L2D (cm)	MATH = 20.182 + 4.180 × L2D	15.035	0.278	0.077	0.0001
L4D (cm)	MATH = 21.822 + 3.830 × L4D	15.126	0.257	0.066	0.0001
L2D:4D	MATH = (-2.026) + 524.980 × L2D:4D	15.530	0.123	0.015	0.0080

SEE Standard Error of the Estimate, R2D = right second digit (cm), R4D = right fourth digit (cm), R2D:4D = right-second-to-fourth digit ratio, L2D = left second digit (cm), L4D = left fourth digit (cm), L2D:4D = left-second-to-fourth digit ratio, MATH = Mathematics (%),

DISCUSSION

Contrary to most studies that reported lower 2D:4D in favor of the males and higher ratio to females, this present study found lower 2D:4D ratio in favour of females and higher ratio to males this explained why the females students perform better in Mathematics than their males counterpart. Mathematics scores were positively statistically significant with 2D:4D for both hands in females and not in males. The study agrees with other works that reported that 2D:4D is negatively associated to prenatal testosterone and that the relationship is particularly strong for the right hand and also shows sex difference (Manning *et al.,* 2004),although this present study shows that women are having higher 2D:4D ratio than the male counter part as in previous study. Males tend to have lower values of 2D:4D than females (Manning *et al.,* 2004, 2007), Therefore the 2D:4D is a sexually dimophic trait (Zheng *et al.,* 2011). Academic performance in Mathematics showed sex differences such that females students had higher performance in Mathematics. This could be due to organizational effects of sex hormone on the brain and this is consistent with the study of Keogh, (2011) and Brosnan, (2006) who reported positive correlation between digit ratio and numeric capabilities and ability to understand information communication technology (Brosnan, 2006 and Keogh, 2011),

In line with our present study, Nye *et al.,* (2012) show that for academic achievement as measured by grades or school GPA, 2D:4D seems to have a clear and significant quadratic effect for women, but the effects are either mildly linear or even insignificant for men.
Luxen and Buunk (2005) also found a significant correlation between right hand digit ratio and numerical skills, with numerical skills being higher in individuals with lower masculinised digit ratios. Kempel *et al.,* (2005) also found that females with more masculinised digit ratios performed better on a numerical IQ task (continuing numerical series). In agreement with our study to some extend, Hopp *et al,* (2012) also found that right hand 2D:4D is negatively related to theory and practical marks in male dental students. But there is lack of a relationship between 2D:4D and examination marks in female dental students. Improved Mathematical performance in relation to lower 2D:4D, also agree with the finding of no sex differences in the areas of number, counting, and basic mathematics (Geary, 1996). Significant relationship were also reported to exist between digit ratio i.e lower ratio potentially indicating higher prenatal testosteron was associated with better performance on the numerical measures and number, counting or simple numerical abilities in boys but not girls (Fink 2006). Recently, Coco *et al.* (2011) evaluated a group of male medical students in Italy, and found a significant correlation between 2D:4D and success in admission tests.

Correlational evidences reported that digit ratio (2D:4D), is negatively associated with prenatal testosterone and the ratio between prenatal testosterone and prenatal oestrogen (Breedlove, 2010; Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer and Manning, 2004; Manning, 2002; Manning and Fink, 2008; Manning et *al.,* 1998). Also, experimental manipulation (including loss of androgen and oestrogen receptors and addition of androgen

and oestrogen blockers and testosterone and estradiol) of sex steroids in the mouse has shown that 2D:4D is dependent on the ratio of prenatal testosterone and prenatal oestrogen (Zheng and Cohn, 2011). That is, when prenatal testosterone is high and prenatal oestrogen is low then 2D:4D is low and vice versa. Therefore, our findings suggest that females students with high prenatal testosterone (in comparism to other females) have high intelligence. We suggest that this supports the hypothesis of Mrazik and Dombrowski (2010), who have suggested that high intelligence is linked to high prenatal testosterone through the latter's influence on neuronal proliferation, migration, differentiation, and apoptosis. However, we have not found a correlation between 2D:4D and Mathematics performance in male subjects. This may be because males have higher 2D:4D which may be suggested that the males were exposed to an elevated level of estogen (in comparism to other males) prenatally and this indirectly affected their intelligence and the link between prenatal testosterone and intelligence is particularly strong when prenatal testosterone is high (as it is in most males).Prenatal testosterone exposure may directly influence intelligence, by altering neuronal migration, leading to greater righthemisphere development (Geschwind and Behan, 1982), as well as greater coordination within and between the hemispheres (Alexander, O'Boyle, and Benbow, 1996; Anderson and Harvey, 1996),resulting in males becoming more strongly lateralized than females on certain tasks (Wisniewski, 1998). This could lead to dense neuronal networks in areas related to cognition, learning and memory, either by decreasing apoptosis of brain cells during development, or increasing migration of cells to one of those areas (Mrazik and Dombrowski, 2010). If so, then significant relations between the 2D:4D ratio and performance on Mathematics may be found in females who exhibit male typical digit ratio (with lower 2D:4D).

CONCLUSION

Females students with lower 2D:4D ratio (male typical ratio) performs better academically and Mathematically than their male counterparts with higher 2D:4D (female typical ratio).

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