Second to fourth digit (2D:4D) ratio and their relationships among first-time mother-and-child population in Ghana

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Abstract

The study aimed to determine the 2D:4D digit ratios and their relationships in a paired mother-and-child population. This was a cross-sectional study from December 2020 to January 2021. Digit ratios were measured by computer-assisted analysis (GIMP). Outcome variables were compared by < mean versus ≥ mean of digit ratios. The study involved 84 mother-and-child pairs (male: 45). The mean ± SD age of mothers was 23.5 ± 3.58 years. The median (IQR) age of female children was 111(51–180) days and males, 74 (44–190) days. The mean ± SD right-hand 2D:4D ratio was 0.94 ± 0.04 for mothers, 0.91 ± 0.04 for female and 0.90 ± 0.04 for male children. The mean ± SD left-hand 2D:4D ratios were 0.93 ± 0.04 for mothers, 0.92 ± 0.04 for female and 0.93 ± 0.05 for male children. Male and female children did not differ in their 2D:4D digit ratios, but males showed leftward bias. Mothers' right-hand digit ratio correlated with that of daughters' (r = 0.52, P = 0.001) and sons' (r = 0.38, P = 0.011). Serum alanine transferase (ALT) levels were positively associated with ≥ mean 2D:4D ratios of the right [aOR: 1.081(1.009–1.159)] and the left-hand [aOR:1.198(1.084–1.325)] of mothers. A mother's height could be predicted from their 2D:4D ratios. These findings support the heritability of 2D:4D ratios. We, however, recommend further studies.

Introduction

The second to fourth digit (2D:4D) ratio is a putative biomarker of prenatal testosterone and oestrogen exposure [1,2]. Prenatal testosterone exposure is has a permanent masculinizing effect on brain organization and personality and it is inversely correlated to the 2D:4D digit ratio [3]. It is an easy, simple and non-invasive method of investigating in utero androgen action [4].

Previous studies have sought to investigate the sexually dimorphic nature of the 2D:4D ratio but with varied outcomes. While some studies have found reduced digit ratios in males compared to females, others have not [5,6]. The association between age and digit ratios have also been studied. While Manning, et al. [7] earlier hypothesized that the 2D:4D ratio fluctuates and only gains stability after 2 years of age, other longitudinal studies have found that 2D:4D digit ratios increase with age [8,9]. Also, studies have shown that directional asymmetry which is defined as the right-left difference in digit ratio (Dr-l) are frequently leftward in males and rightward in females [10].

Previous familial studies on digit ratios have indicated that the heritability of 2D:4D digit ratio was up to 57% for the right-hand and 48% for the left -hand [11]. Although the process of digit ratio heritability is not well understood and will require further studies, genetic factors have been suggested [11,12]. Offspring sex ratios have also been linked to the 2D:4D ratio where reduced maternal digit ratios are mostly associated with sons than daughters (low 2D:4D)[6,13,14]. The relationship between 2D:4D digit ratios and height [15], serum cortisol [16] and lipids [17] have also been examined in previous studies.

The 2D:4D ratio shows genetic and environmental variability such that findings from one population may not be extrapolated to another population. There is therefore the need for population-specific studies of digit ratios and their relationship with outcome variables. This study, therefore, aimed to determine the 2D:4D ratios and how they are related in mothers and their children. Very few studies have examined digit ratios in Ghana, especially in a mother-and-child pair. This study is among the first in Ghana to examine the relationships between digit ratios, birth outcomes, age and height.

Results

Background information

The demographic and anthropometric information of the study population is summarized in Table 1. The study included a total mother-and-child paired sample of 84 (male = 45). The ages of the mothers ranged from 18–36 years with a mean ± SD of 23.5 ± 3.58 years. Majority of the mothers belonged to the Mole-Dagomba ethnic group [95.2% (80/84)] and most of them were also Moslem [86.9% (73/84)]. The right-hand 2D:4D digit ratio ranged from 0.83–1.01 with a mean ± SD of 0.94 ± 0.04 while the left-hand 2D:4D digit ratio ranged from 0.84-1.00 with a mean ± SD of 0.93 ± 0.04. The median (IQR) age of the female children was 111(51–180) years and the males, 74(44–190) years. Right-hand 2D:4D digit ratio ranged from 0.81–0.99 in female children with a mean ± SD of 0.91 ± 0.04 and 0.83–0.98 in male children with a mean ± SD of 0.90 ± 0.04. The female and male children left-hand 2D:4D digit ratios ranged from 0.86–1.03 and 0.84–1.05 respectively with their corresponding mean ± SD of 0.92 ± 0.04 and 0.93 ± 0.05. A significant difference between female and male children was only observed in the gestational age in weeks which was higher in females than in males (P = 0.014).

Table 1
General characteristics of the study population

Variable	Mother	Variable	Children		
	n (84)		Female n (39)	Male n (45)	P-value
Demographic					
Age (yrs.) *	23.0 (18–36), 23.5 ± 3.58	Age (days)†	111(51–180)	74(44–190)	0.864
Ethnicity		**Ethnicity**			0.681
Mole-Dagomba	80 (95.2)	Mole-Dagomba	37(47.4)	41(52.6)	
Other-ethnicity	4 (4.8)	Other	2(33.3)	4(66.7)	
Religious affiliation		Gestational age (weeks)	38.7 ± 2.01	37.6 ± 2.13	0.014
Islam	73 (86.9)	Birth weight (Kg)	2.9 ± 0.37	2.7 ± 0.62	0.181
Christianity	11 (13.1)	Foetal length (cm)	49.3 ± 2.88	48.8 ± 2.41	0.342
Marital status		Head circumference (cm)	32.5 ± 1.80	32.6 ± 1.60	0.862
Married	80 (95.2)	**Condition at birth**			0.867
Other partnership	4 (4.8)	Satisfactory	21(48.8)	22(51.2)	
Education		Fair	4(40.0)	6(60.0)	
None	10(11.9)	Good	14(45.2)	17(54.8)	
Basic/secondary	54(64.3)	**Mode of delivery (MOD)**			0.509
Post-secondary	20(23.8)	Vaginal delivery (VD)	31(48.4)	33(51.6)	
Employment status		Caesarean section (CS)	8(40.0)	12(60.0)	
Unemployed	45 (53.6)				
Self-employed	29 (34.5)				
Salaried work	10 (11.9)				
Exercise (≥ 30min/w)					
No	76 (90.5)				
Yes	8 (9.5)				
Anthropometric					

Variables in asterisks (*) were presented as median (min-max), mean ± SD; †Results were presented as median (IQR) and the rest were presented as either mean ± SD for continuous variables or n (%) for categorical variables.

Variable	Mother	Variable	Children		
	n (84)		Female n (39)	Male n (45)	P-value
Height (cm)	163.0 ± 5.42				
Weight (Kg)	62.9 ± 10.04				
BMI (Kg/m2)	23.6 ± 3.6				
2D:4D (right-hand) *	0.94 (0.83–1.01), 0.94 ± 0.04	2D:4D (right hand) *	0.91(0.81–0.99), 0.91 ± 0.04	0.89(0.83–0.98), 0.90 ± 0.04	0.111
2D:4D (left-hand) *	0.93 (0.84-1.00), 0.93 ± 0.04	2D:4D (left hand) *	0.91(0.86–1.03), 0.92 ± 0.04	0.92(0.84–1.05), 0.93 ± 0.05	0.802
Dr-l	0.01 ± 0.028	Dr-l (right-left 2D:4D)	-0.010 ± 0.05	-0.027 ± 0.06	0.153

Variables in asterisks (*) were presented as median (min-max), mean ± SD; †Results were presented as median (IQR) and the rest were presented as either mean ± SD for continuous variables or n (%) for categorical variables.

Digit ratios (2D:4D) and outcome variables

Supplementary Table 1 shows the summary of maternal characteristics separately for both hands by < mean versus ≥ mean 2D:4D digit ratio. There was no association between digit ratios (2D:4D) and a mother's demographic characteristics. In Table 2, Serum alanine transferase (ALT) levels were positively associated with ≥ mean 2D:4D ratios of the right [aOR: 1.081(1.009–1.159)] and the left-hand [aOR:1.198(1.084–1.325)] of mothers. Birth outcomes were compared by < mean versus ≥ mean 2D:4D digit ratio separately for both hands of the mother in Table 3. Birth weight was significantly increased among mothers with left-hand 2D:4D digit ratio ≥ mean (P = 0.020), but disappeared after adjusting for maternal demographic characteristics. Birth outcomes by below mean versus ≥ mean digit ratio for each hand of a female and male children are shown in Tables 4 and 5 respectively. The unadjusted birth weight was significantly higher among male children who's right-hand 2D:4D digit ratio was ≥ mean (P = 0.029). Directional asymmetry (Dr-l), sex and mother-child variations were assessed and the results summarized in Table 6. The Dr-l was significantly higher in mothers as compared to either female (p < 0.01) or male children (P < 0.001). Also, the Dr-l was significantly higher in male children as compared to mothers (P < 0.001). There was directional leftward bias in male children and rightward bias in mothers (P < 0.01). Correlations between digit ratios and the age of mothers, male and female children were investigated (Supplementary Fig. 1). There were no substantial correlations between digit ratios and age either among mothers, male or female children. In Fig. 1, the familial characteristics of digit ratios were explored. There were moderately strong and fairly strong positive correlations between a mothers' right-hand digit ratio and that of female children (r = 0.52, P = 0.001), and also, male children (r = 0.38, P = 0.011). Univariable and multivariable linear regression models for mothers' height were derived based on their 2D:4D digit ratios. In the univariable model (1), the 2D:4D digit ratio of the right-hand accounted for only 1.7% (R^2 = 0.017, P = 0.238) of a mother's height with a standard error of estimation (S.E.E) of 5.407. Left-hand digit ratio accounted for 0.8% (R^2 = 0.008, P = 0.416; S.E. E = 5.431) of a mother's height in the model (2), while in the multivariable model (3), the combined digit ratios accounted for only 1.7 % (R^2 = 0.017, S.E. E = 0.440) of a mother's height. Multicollinearity between digit ratios was determined by way of the variance inflation factor (VIF) which was 2.168:

Table 2

Maternal liver function test indices by equal or above versus below mean digit ratio for each hand of mother

Variables	Right 2D:4D Digit Ratio				Left 2D:4D Digit Ratio			
	< mean n (35)	≥ mean n (49)	P-value	aOR(95%CI) †	< mean n (36)	≥ mean n (48)	P-value	aOR(95%CI) †
Total Protein (g/l)	73.3 ± 6.05	72.5 ± 8.55	0.629	0.985(0.921–1.053)	72.3 ± 7.61	73.2 ± 7.61	0.581	1.020(0.953–1.091)
Albumin (g/l)	49.3 ± 5.31	48.6 ± 6.91	0.623	0.977(0.905–1.055)	48.2 ± 5.58	49.3 ± 6.78	0.448	1.024(0.945–1.109)
Globulins (g/l)	23.7 ± 7.15	23.7 ± 8.09	0.992	1.004(0.942–1.069)	23.5 ± 8.78	23.8 ± 6.80	0.870	1.015(0.948–1.085)
AST (UI/l)	22.5 ± 6.68	22.4 ± 6.56	0.952	1.002(0.930–1.080)	22.4 ± 7.03	22.4 ± 6.28	0.995	1.029(0.952–1.111)
ALT (UI/l)	17.4 ± 8.26	21.0 ± 8.31	0.054	1.081(1.009–1.159) *	16.3 ± 6.49	21.8 ± 9.00	0.003	1.198(1.084–1.325) **
AST/ALT	1.5 ± 0.73	1.3 ± 0.68	0.075	0.476(0.224–1.008)	1.5 ± 0.68	1.2 ± 0.71	0.056	0.432(0.205–0.913)
ALP (UI/l)	198.6 ± 48.93	198.7 ± 62.19	0.995	1.000(0.991–1.008)	200.5 ± 49.21	197.2 ± 62.23	0.794	0.998(0.990–1.007)
GGT (UI/l)	25.7 ± 11.00	26.6 ± 11.73	0.713	1.010(0.965–1.058)	25.9 ± 12.11	26.4 ± 10.90	0.844	1.026(0.978–1.077)
Total bilirubin (mmol/l)	11.7 ± 3.68	11.5 ± 4.13	0.760	1.006(0.889–1.138)	12.2 ± 3.85	11.2 ± 3.98	0.247	0.949(0.837–1.077)
Direct bilirubin (mmol/l)	5.2 ± 1.85	5.6 ± 2.00	0.473	1.028(0.795–1.330)	5.4 ± 1.79	5.4 ± 2.04	0.910	1.004(0.766–1.314)

Results were presented as mean ± SD unless otherwise stated. AST; aspartate transferase, ALT; alanine transferase, ALP; alkaline phosphatase, GGT; gamma-glutamyl transferase, aOR; adjusted odds ratios. †variables were adjusted for mother's age, religion, education, job status, ethnicity and BMI and exercise. *P < 0.028, **P < 0.001

Table 3
Birth outcomes by equal or above versus below mean digit ratio for each hand of mother

Variables	**Right 2D:4D Digit Ratio n (84)**				**Left 2D:4D Digit Ratio n (84)**			
	< mean n (35)	**≥ mean n (49)**	**p-value**	**aOR (95%CI) ***	**< mean n (36)**	**≥ mean n (48)**	**p-value**	**aOR (95%CI) ***
Gestational age (week)	38.3 ± 2.02	38.0 ± 2.24	0.650	0.889(0.694–1.140)	38.0 ± 2.22	38.3 ± 2.09	0.559	0.993(0.790–1.247)
Foetal length (cm)	49.0 ± 3.12	49.0 ± 2.26	0.906	0.995(0.833–1.190)	48.9 ± 3.17	49.1 ± 2.19	0.840	0.989(0.826–1.185)
Head circumferences (cm)	32.6 ± 1.58	32.5 ± 1.78	0.914	1.023(0.768–1.363)	32.5 ± 1.76	32.6 ± 1.65	0.824	1.041(0.776–1.396)
Birth weight (Kg)	2.8 ± 0.44	2.9 ± 0.57	0.391	1.140(0.414–3.142)	2.7 ± 0.46	2.9 ± 0.54	0.020	2.907(0.880–9.604)
Mode of delivery			0.225				0.767	
Vaginal	29(45.3)	35(54.7)		1	28(43.8)	36(56.3)		1
Caesarean	6(30.0)	14(70.0)		3.321(0.847–13.025)	8(40.0)	12(60.0)		2.141(0.537–8.540)
Condition at birth			0.633				0.769	
Satisfactory	20(46.5)	23(53.5)		1	19(44.4)	24(55.8)		1
Fair	4(40.0)	6(60.0)		2.449(0.412–14.552)	3(30.0)	7(70.0)		4.344(0.418–45.178)
Good	11(35.5)	40(64.5)		1.319(0.475–3.663)	14(45.2)	17(54.8)		0.779(0.279–2.202)
Child Sex			0.739				0.449	
Female	17(43.6)	22(56.4)		1	15(38.5)	24(61.5)		1
Male	18(40.0)	27(60.0)		1.299(0.508–3.319)	21(46.7)	24(53.3)		0.829(0.317–2.169)

Results were presented as mean ± SD for continuous variables and the n (%) for categorical variables. aOR; adjusted odds ratios, CI; confidence interval

*Variables was adjusted for mother’s age, religion, education, job status, ethnicity and BMI and exercise

Table 4
Birth outcomes by equal or above versus below mean digit ratio for each hand of female children

Variables	**2D:4D ratio (female child)**							
	Right-hand				**Left-hand**			
	< mean **n (15)**	**≥ mean** **n (24)**	**P-value**	**aOR(95%CI) ***	**< mean** **n (20)**	**≥ mean** **n (19)**	**P-value**	**aOR(95%CI) ***
Gestational age (weeks)	38.2 ± 2.11	39.1 ± 1.91	0.185	1.460(0.745–2.862)	39.2 ± 1.94	38.3 ± 2.02	0.148	0.710(0.349–1.448)
Birth weight (Kg)	3.0 ± 0.31	2.9 ± 0.41	0.431	0.100(0.005–1.974)	3.0 ± 0.41	2.8 ± 0.31	0.266	0.599(0.047–7.673)
Foetal length (cm)	49.7 ± 2.69	49.0 ± 3.01	0.472	1.042(0.683–1.590)	50.0 ± 2.58	49.1 ± 3.21	0.596	0.728(0.433–1222)
Head Circumference (cm)	32.5 ± 1.88	32.5 ± 1.79	0.901	0.896(0.502-1.600)	32.7 ± 1.76	32.4 ± 1.89	0.633	0.915(0.524–1.599)
Condition at birth%			0.126				0.293	
Satisfactory	9(42.9)	12(57.1)		1	13(61.9)	8(38.1)		1
Fair	3(75.0)	1(25.0)		1.184(0.042–33.358)	1(25.0)	3(75.0)		2.625(0.088–78.279)
Good	3(21.4)	11(78.6)			6(42.9)	8(57.1)		5.891(0.554–62.626)
Mode of delivery %			0.686				0.235	
Vaginal delivery (VD)	11(35.5)	20(64.5)		1	14(45.2)	17(54.8)		1
Caesarean section (CS)	4(50.0)	4(50.0)		0.241(0.015–3.791)	6(75.0)	2(25.0)		0.658(0.059–7.367)

Results were presented as mean ± SD for continuous variables and the rest as n (%). aOR; adjusted odds ratios, CI; confidence interval. *Variables were adjusted for mother’s age, religion, education, job status, ethnicity and BMI and exercise

Table 5
Birth outcomes by equal or above versus below mean digit ratio for each hand of male children

Variables	**2D:4D ratio (male child)**							
	Right-hand				**Left-hand**			
	< mean **n (24)**	**≥ mean** **n (21)**	**P-value**	**aOR(95%CI) ***	**< mean** **n (28)**	**≥ mean** **n (17)**	**P-value**	**aOR(95%CI) ***
Gestational age (weeks)	37.0 ± 2.42	38.3 ± 1.46	0.029	1.436(0.916–2.250)	37.8 ± 1.87	37.2 ± 2.51	0.376	0.963(0.620–1.496)
Birth weight (Kg)	2.8 ± 0.73	2.7 ± 0.46	0.455	0.706(0.116–4.281)	2.7 ± 0.51	2.9 ± 0.77	0.258	2.025(0.311–13.171)
Foetal length (cm)	49.2 ± 2.19	48.2 ± 2.61	0.181	0.733(0.491–1.096)	49.0 ± 2.85	48.4 ± 1.46	0.463	0.874(0.607–1.258)
Head Circumference (cm)	32.5 ± 1.67	32.6 ± 1.56	0.874	1.022(0.657–1.590)	32.2 ± 1.70	33.0 ± 1.37	0.171	1.361(0.763–2.427)
Condition at birth%			0.768				0.801	
Satisfactory	11(50.0)	11(50.0)		1	14(63.6)	8(36.4)		1
Fair	4(66.7)	2(33.3)		0.273(0.009–8.418)	3(50.0)	3(50.0)		3.862(0.169–88.305)
Good	9(52.9)	8(47.1)		0.830(0.182–3.785)	11(64.7)	6(35.3)		1.088(0.198–5.985)
Mode of delivery %			0.280				0.743	
Vaginal delivery (VD)	16(48.5)	17(51.5)		1	21(63.6)	12(36.4)		1
Caesarean section (CS)	8(66.7)	4(33.3)		0.031(0.001–1.320)	7(58.3)	5(41.7)		0.892(0.075–10.645)
Results were presented as mean ± SD for continuous variables and the rest as n (%). aOR; adjusted odds ratios, CI; confidence interval.								
*Variables were adjusted for mother’s age, religion, education, job status, ethnicity BMI and exercise								

Table 6
Directional asymmetry and differences between the sexes and mothers' digit ratios

Variable	**2D:4D digit ratio**				
	Mother n (84)	**Children**			
		Female n (39)	**Male** n (45)	**F**	**P-value**
Right-hand 2D:4D ratio	0.94 ± 0.04	0.91 ± 0.04*	0.90 ± 0.04**	16.09	< 0.001
Left-hand 2D:4D ratio	0.93 ± 0.04†	0.92 ± 0.04	0.93 ± 0.05†	0.37	0.694
Asymmetry (Dr-l)	0.01 ± 0.03	-0.01 ± 0.05	-0.03 ± 0.05**	10.26	< 0.001

Results were presented as mean ± SD. *P < 0.01, **P < 0.001 compared to mother (1-Way ANOVA), †P < 0.01 compared to the right hand (paired t-test, 2-tailed)

y (cm) = 180.733–18.853*2D:4D (right-hand) (1)

y (cm) = 174.263–12.453*2D:4D (left-hand) (2)

y (cm) = 180.380 + 1.685*2D:4D (left-hand) – 20.147*2D:4D (right-hand) (3)

The relationship between the observed and predicted height was assessed with Spearman rank correlation plots while the degree of agreement between the observed and predicted height were assessed by Bland-Altman scatter plots as shown in Fig. 2. There were no substantial differences between the predicted height and the observed height in mothers.

Discussion

The study aimed to determine 2D:4D digit ratios and their relationships in first-time mothers and their children in Ghana. The study did not find any considerable differences in digit ratios between male and female children and there was no association between digit ratios and age. Also, mothers' right-hand digit ratio was markedly higher compared to their children but did not determine offspring sex. There was rightward directional bias in mothers and a leftward directional bias in male children with the observation of a positive association in the right-hand digit ratios between mothers and their children. Lastly, increased digit ratio in mothers was associated with increased blood serum ALT and there were no substantial differences between the actual height of mothers and height predicted using regression models based on their digit ratios.

The prove of the effect of prenatal androgen exposure on digit ratio is indicated by the occurrence of sexual dimorphism in digit ratios at an early age, according to Manning, et al. [7]. This current study, however, did not find substantial differences in both the left and the right-hand digit ratios between male and female children. This finding was consistent with a previous study by Yamada, et al. [5], who studied 1,045 children aged 1½ years from the JECS-A (the Aichi regional sub-cohort of the Japan Environment and Children's Study) cohort study in Japan. The authors adopted an easy-to-use photographic method to measure digit lengths. They explained that their findings may be due to difficulties in digit measurements at that age or the rapid growth that occurs at that stage of human development that may have neutralized the in utero sexual dimorphism [5]. A similar study by Barrett, et al. [18] among 321 children from the Infant Development and the Environment Study (TIDES) in America found no significant differences in digit ratios between male and female children. The children in their study were, however, 4-year-olds and the researchers directly measured digit lengths with Vernier dial callipers. They explained that sex differences in digit ratios in children, tended to be less consistent and the effect sizes, smaller compared to adults. They also suggested that method variation in digit measurements may have accounted for the inconsistencies in the results of previous studies. In contrast to this current study, Ventura, et al. [6] studied 106 newborn babies in a prospective study conducted at the maternity of Dona Estefânia Hospital (HDE) in Lisbon, where they found reduced digit ratio in the left-hand of boys, which was contrary to the popular belief of right-hand sexual dimorphism. The authors' measured digit lengths from photocopies of the ventral palmar surfaces, and observed substantial overlap between male and female babies with only subtle differences. Similar to the study of Ventura, et al. [6], a study by Ertuğrul, et al. [19], involving 225 newborn infants, found reduced digit ratios in both hands of males regardless of whether the infants were inbred or outbred. In their study, however, digit lengths were directly measured with Vernier callipers and not by computer-assisted analysis.

Although considerable differences in digit ratio were not found between male and female children, there was, however, directional asymmetry in mothers and male children. The left-hand 2D:4D digit ratio in male children was markedly higher than the right-hand (leftward bias) but the reverse was true for the mothers (rightward bias). This was consistent with a study by Richards, et al. [20] who found that left-hand 2D:4D digit ratio was considerably higher than the right-hand digit ratio but found no differences in female children. This study used data from a previous study by Ventura, et al. [6] where digit ratios were estimated from photocopies of 106 newborn babies. Another study involving 1,013 participants from 4 countries, found asymmetry in digit lengths. The age range in this study was, however, between 2–90 years and digit lengths were directly measured using Vernier callipers. Further confirmation of the finding in this study can be found in the work of Voracek, et al. [10], who studied digit ratios in a sample of about 3,000 participants and found that leftward bias was more frequent in males while rightward bias was more frequent in females. The study by Voracek, et al. [21], was a replication of the findings of a previous study by Puts, et al. [22] who analysed data from about 500 individuals. Differences in directional asymmetry are a further indication of the effect of prenatal androgen exposure and its influences on digit ratios in males and females [10].

There were no considerable correlations between age and digit ratios in both the mothers and their children in this study. However, Körner, et al. [23] who also used scanned images in a cohort study involving 274 children in Düsseldorf, Germany measured digit ratios in both hands in males and females at ages 5, 9, 20 and 40 months. The authors reported that age did not have an impact on digit ratios from 9–20 months after birth but had an effect from 20–40 months. Their study population was predominantly Caucasian. Manning, et al. [7] earlier on hypothesized that digit ratios were established in utero and only gain stability about 2 years of age after the postnatal testosterone surge. In contrast to Manning, et al. [7], previous longitudinal studies, one from the Jamaican Symmetry Project, have reported that 2D:4D digit ratios increased from infancy to adulthood [8,9]. A 2D:4D digit ratio associations studies in Wales by Richards, et al. [24] found a positive correlation between age and digit ratios in children but a negative correlation in adults. In their study, however, digit lengths were measured from hand scans in 585 parent-child pairs who were mostly White European, aged from 5–89 years. Longitudinal variations in digit ratios might have also accounted for the observed higher digit ratios in mothers than their children, consistent with the findings in a study by Ventura, et al. [6].

Correlational analysis in this study found a positive association between mother and child but only in the right-hand digit ratio. In line with our findings, a study involving 673 mother-child pairs, whose hands scans were studied for 2D:4D found positive associations between mother and child digit ratios. However, this study involved children who were 2–5-year-old from the MIREC (Maternal-Infant Research on Environmental Chemicals) cohort study in Canada [12]. Also, a study among families of the Chuvasha and Bashkortostan Autonomies of the Russian Federation revealed parent-offspring correlations in 2D:4D digit ratios. Instead of hand scans, the authors' measured digit ratios from X-ray radiographic images in 1,541 people [25]. A positive correlation between 2D:4D digit ratio of mothers and newborn daughters have been reported by Ventura, et al. [6] and Richards, et al. [24]. Previous familial studies on digit ratios have indicated that the heritability of 2D:4D digit ratio was up to 57% for the right-hand and 48% for the left -hand [11]. Although the process of digit ratio heritability is not well understood and will require further studies, genetic factors have been suggested [11,12].

There was no association between mother's digit ratio and sex of the child in this study. This was, however, contrasted by a study by Ventura, et al. [6] who observed that mothers with reduced 2D:4D ratios bore male children. Previous studies have reported a negative correlation between 2D:4D digit ratios and the proportion of their male offspring which is in line with the hypothesis that the male sex at conception in mammals correlates with high parental testosterone level (low 2D:4D)[6,13].

Digit ratios were associated with some phenotypic traits of the mothers. Increased blood serum ALT was positively associated with digit ratio of both the left and the right-hands. Previous studies have drawn some levels of association between digit ratios and blood serum analytes such as cortisol [16] and lipids [17]. Although there was no correlation between the observed and predicted height of mothers, there were no significant differences between them. This indicated an agreement between the observed and predicted height such that the height of the mothers in the study population could be accurately predicted from regression models based on 2D:4D digit ratio [26]. A previous study by Barut, et al. [15] in a 386 study population, had indicated an association between directly measured 2D:4D digit ratios and height in right-handers. This is a significant finding that will be useful in medico-legal investigations where only fragmented body parts may be the only evidence available for height estimation.

This current study has many strengths. One of them is that this study is among the very few studies on digit ratios and their relationships in a mother-and-child population in Ghana and maybe the first in children under 2 years of age in the northern part of the country. Also, the study adopted a computer-assisted image analysis for digit measurements which has been found, by previous studies, to be more reliable than direct measurements, photocopies or printed scanned images [27,28]. Another strength of this study is the use of the Bland-Altman method to estimate the level of agreement between the repeat measurements even after calculating the intraclass correlation coefficients (ICCs). The correlation between two variables only quantifies the degree to which the variables are related but does not usually imply their level of agreement [26]. Despite the many strengths of this study, the authors acknowledge some weaknesses. The study may have been underpowered which may not allow for the generalization of the findings. Also, there was under-representation of minority ethnic groups, as the setting of the study was mainly in an area that is dominated by people of the Mole-Dagomba ethnic group. We conclude that the 2D:4D digit ratio was not significantly different between male and female children but exhibited directional asymmetry and familial associations. Also, the 2D:4D digit ratio was associated with blood serum ALT levels. The height of first-time mothers can be predicted from regression models derived from digit ratios. To support our finding, the authors will recommend further studies involving a larger sample size with equitable ethnic representations.

Methods

Study design and population

This was a cross-sectional study that was conducted from December 2020 to January 2021. The study recruited first-time mothers, and their children, who were receiving postnatal services at the Reproductive and Child Health (RCH) clinic, located in the Tamale Metropolis in the Northern region of Ghana. The RCH is well patronized by young mothers mostly between the ages of 15–19 years and was therefore suitable for mother-and-child pair studies [29]. The inclusion and exclusion criteria were; a first-time non-menstruating mother (natural), singleton births ≤ 730 days (≤ 2 years) old. All participants were to be devoid of limb, finger and spinal deformities and also without any known medical history of congenital adrenal hyperplasia (CAH), chronic hepatitis, hormone treatment or medications that could interfere with laboratory results. The authors, however, could not have excluded participants with a previous history of fractures that had healed and not apparent to the observers. This was because X-ray images were not available.

Study variables

The 2D:4D ratio was the independent variable and was measured by computer-assisted analysis of scanned hand images following the guidelines proposed by Neyse and Brañas-Garza [30]. Participants were asked to remove all objects including rings that could mask creases or reflect light during the scanning process. The person was then guided to place the ventral palmar surface of each hand on the flatbed surface of an HP desk jet 2620 series 3-in-1 printer scanner (HP Inc. 1501 Page Mill Road Palo Alto, CA 94304 United States). The participant was asked to press the hand firmly enough making the fingers straight and visible to obtain a good scan but not push the glass with the fingertips. The hand should not be moved during the scanning process. A unique identification number, e.g., LH-001M for the left-hand of the first mother or LH-001C for the left-hand of her child was boldly written on a piece of paper and placed on the flatbed of the scanner alongside the hand. When scanning the right-hand, 'RH' was used in place of 'LH'. The hands were then scanned at a resolution of 150 dpi. In the case of the children, one observer had to hold the hands and place it as appropriate on the scanner while the second observer issued the command to scan the hand. The scanned images were then stored with the ID number on a laptop for analysis. The scanned images were later exported into GIMP (v 2.10.22), an image manipulation program (www.gimp.org) for digit measurements. The resolution of the image was adjusted as appropriate to ensure the proper delineation and visibility of creases. The calliper in GIMP was controlled with the mouse pointer. The pointer was placed on the proximal crease and then extend to the tip of the finger. The length was adjusted as appropriate before the results were read from the results window to the nearest 0.01 mm (Supplementary Fig. 2). The process was repeated by the same observer after 1 week. The digit ratio was calculated by dividing the 2D by the 4D for the first and second measurements and the 2 were then averaged to obtain the final results. The reliability of the repeat measurements was assessed by calculating the intraclass correlation coefficients (two-way mixed, single measures with absolute agreement) and the degree of agreement was confirmed with the Bland-Altman method [31]. The left-hand 2D:4D ratio had an ICC of r = 0.99 (95%CI:0.99-1.00), with an arithmetic mean = 0.0004(95%CI: -0.0003 to 0.0013, P = 0.470) while the right-hand 2D:4D ratio ICC was r = 0.98(95%CI:0.97–0.99), with an arithmetic mean = 0.0019 (95%CI: -0.0002 to 0.0040, P = 0.077). The other anthropometric variables; weight and height were measured following the recommendations of Best and Shepherd [32] using a stadiometer for height and bathroom scale for body weight. Socio-demographic data, clinical information and birth outcomes were collected using a structured questionnaire and interview and from their medical records. Socio-demographic variables included; age, ethnicity, religion, marital status, employment status, educational level and exercising habits. Birth outcomes included; gestational age at delivery, birth weight, foetal length, head circumference, condition at birth and mode of delivery. A 5 ml venous blood sample was collected into a gel separator tube for liver function test using BT 1500 automated biochemistry analyzer (Biotechnica Instruments, SPA, Italy). All data were collected between 8 am and 12 noon to avoid diurnal variations in measurements.

Statistical analysis

The data were entered into an Excel spreadsheet and then exported to SPSS (v23), GraphPad Prism (v 8) and MedCalc statistical software for analysis. Output variables were compared by below mean versus equal or above mean 2D:4D ratio. Associations between digit ratios and outcome variables were established using t-test for continuous variables and Chi-square (Fisher's exact test as appropriate), for categorical variables. Correlation between mother and child digit ratios or age used Spearman scatter plots and predictive models were derived using univariate and multivariate regression. The measurement of agreement between estimates was done using the Bland-Altman method. All analyses were two-sided with a P-value set at < 0.05.

Ethics declarations

All methods were carried out following the relevant international, national and institutional guidelines and regulations. The study received approval from the Institutional Review Board of the University for Development Studies, Tamale. Informed consent was obtained from all the mothers and also, informed parental consent was obtained for each child.

Declarations

Data Availability

Available on request

Competing interest statement

The authors declare no competing interest

AUTHOR CONTRIBUTIONS

N.A. and L.Q. conceived the idea and designed the experiment; M.B. performed the experiments, collected and analyzed the data and also wrote the first draft; N.A. and L.Q. provided the interpretation of the results. All authors reviewed the final draft and approved it.

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Figures

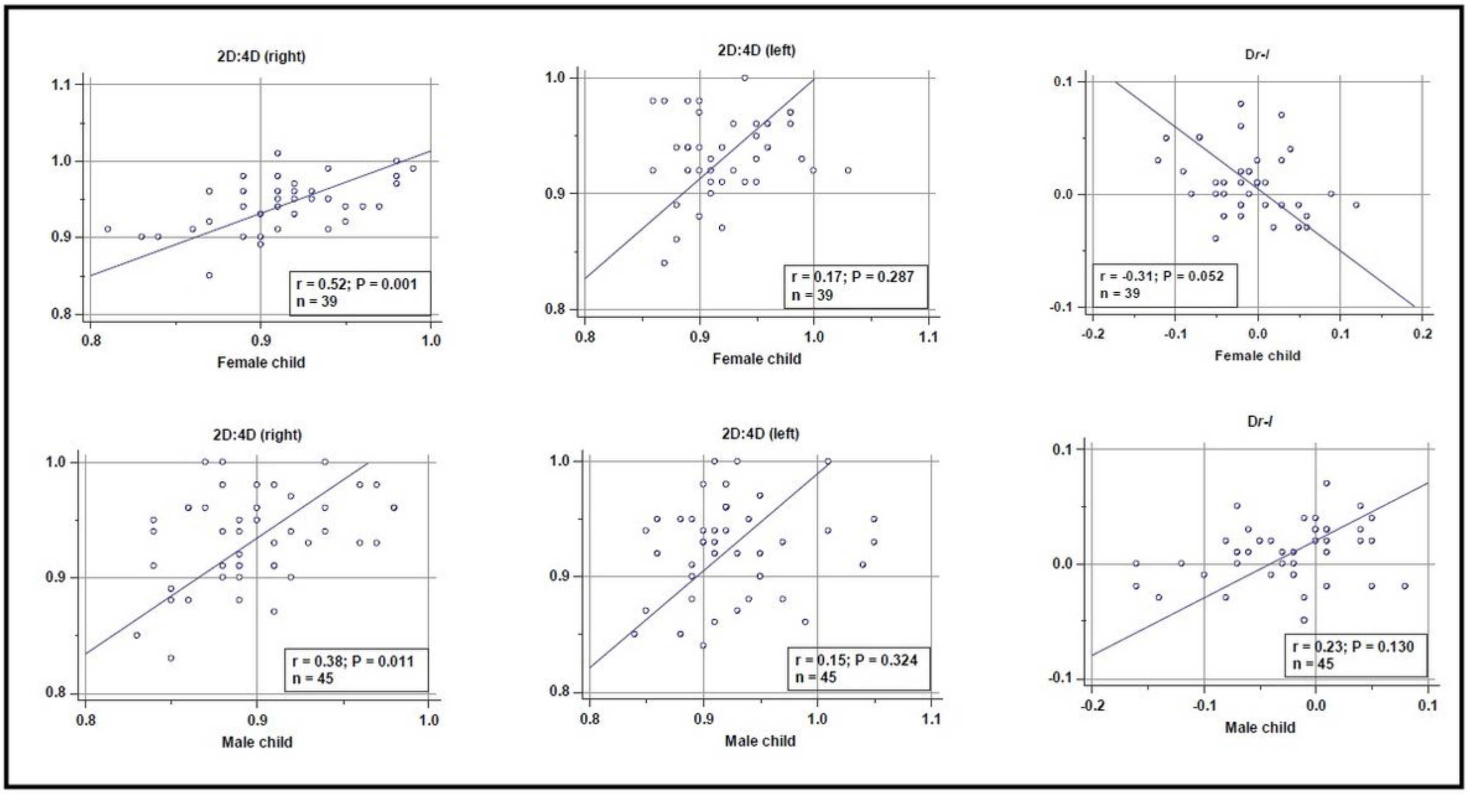

Figure 1

Spearman rank correlation plots between same hand digit ratios (2D:4D) of the mothers and their children for female children (top row) and male children (bottom row). There were significant correlations between the right-hand of mothers and that of male and female children.

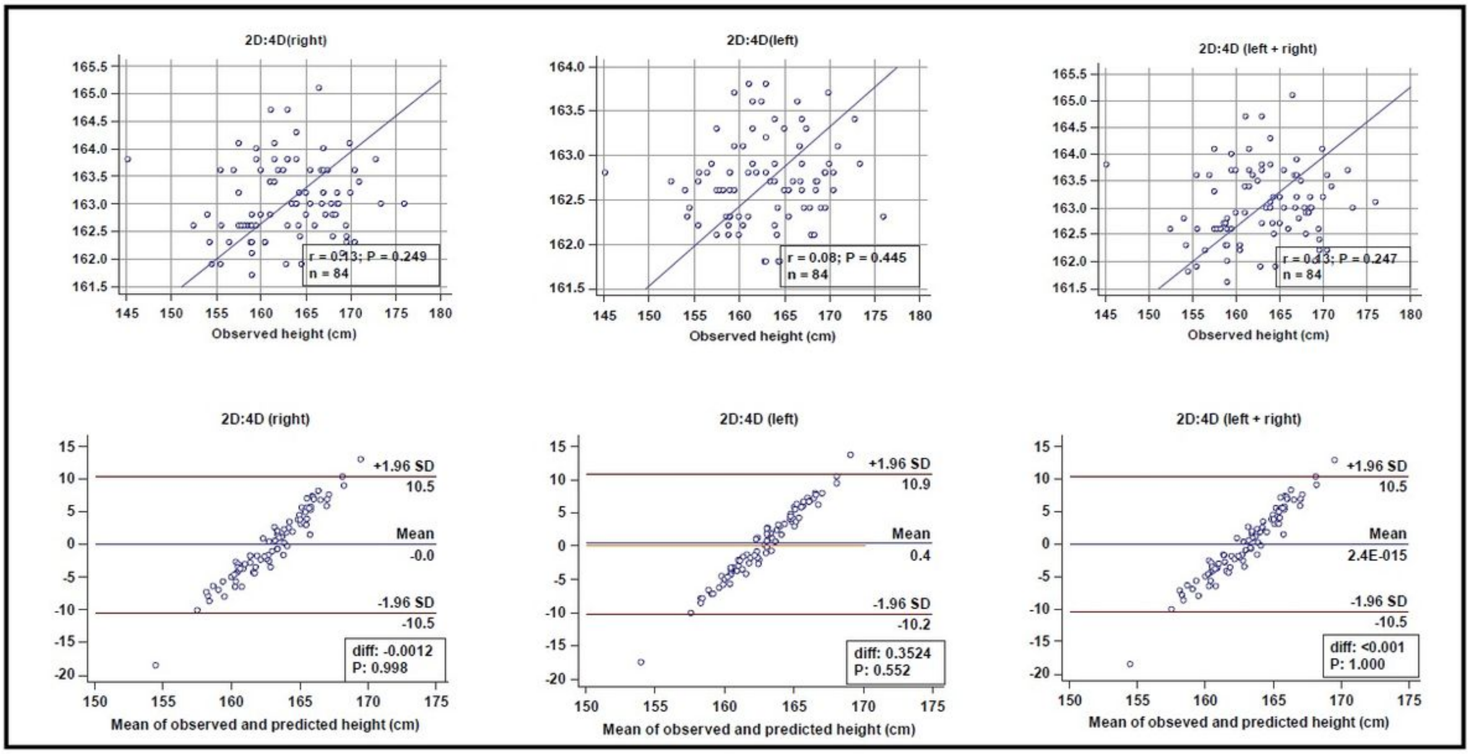

Figure 2

The observed and predicted height (2D:4D ratio) of mothers compared: Spearman correlation graphs (top row) and Bland-Altman scatter plots (bottom row). There were no significant correlations and no significant differences were found between the observed and predicted.

Supplementary Files

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