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Carrying angle; Second and fourth digit ratio (2D:4D): A correlation study of University of Port Harcourt Students.

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ABSTRACT
The carrying angle is the angle (in the sagittal plane) formed by the axes of the arm and the forearm, with the elbow in full extension. Females have wider carrying angle due to a wider hip design for obstetric reasons. This study was carried out to determine the relationship between carrying angle and 2D-, 4D-length and ratio. One hundred and nine (109) subjects comprising 49 males and 60 females were randomly selected from the University of Port Harcourt. Carrying angle was measured using a goniometer (after the midpoint of the arm and forearm were determined using a flexicurve), while 2D-, 4D-length was measured using a digital vernier caliper. Data was analyzed using statistical package for the social science (SPSS version 22.0). The results showed that for males on the right, carrying angle (CA) significantly correlated with 2D length ($r = 0.461$, $R^2 = 0.21$, $p < 0.01$) and 4D length ($r = 0.474$, $R^2 = 0.22$, $p < 0.01$). While on the left, it correlated with 2D length ($r = 0.450$, $R^2 = 0.20$, $p < 0.01$) and 4D length ($r = 0.366$, $R^2 = 0.13$, $p = 0.05$). For females on the right, it significantly correlated, with 2D length ($r = 0.469$, $R^2 = 0.22$, $p < 0.01$) and 4D ($r = 0.357$, $R^2 = 0.13$, $p = 0.003$), 2D:4D ratio ($r = 0.285$, $R^2 = 0.08$, $p = 0.014$). While on the left, it correlated with 2D ($r = 0.449$, $R^2 = 0.20$, $p < 0.01$) and 4D ($r = 0.322$, $R^2 = 0.10$, $p = 0.006$). Females had higher CAs, while males had longer 2D and 4D. Significant differences were observed in all measured parameters between sex at $p < 0.05$, except for the right 2D, 2D:4D; and the left 2D:4D. The right 4D and 2D better were better predictors of CA in males and females respectively. The findings from this study will be useful for estimating CA from 2D, 4D and 2D:4D and also in surgical repair (management) of elbow fracture or dislocation.

Key Words: 2nd digit, 4th digit, length, ratio.

INTRODUCTION
Successful locomotion in humans and bipedals involves gait and arm swings. These activities are coordinated and complimentary movements which occurs involuntarily. The faster the gait, the faster the swing. Hence in terms of biomechanics, there is a need for space between the arm and the lower trunk, in other to reduce friction and encourage movement. An angle is therefore created (in the sagittal plane), by the axes of the arm and the forearm (Figure. 1), with the elbow in full extension. This angle is typically larger in females than males. [1] The wider female pelvis (for obstetric reasons) as well as pronounced fat deposits around the gluteal region, give females larger hips compared to the males (who have broad shoulders); hence making a larger carrying necessary in females. [2]

Carrying angle therefore allows space between the forearm and the lower trunk; encouraging unrestricted arm swings during gait and at the same time adding to the general aesthetic appearance of the female individual. The study therefore attempted to determine the relationship between carrying angle and 2D:4D ratio [i.e. the ratio of the lengths of the second and fourth digits measured from the midpoint of the bottom crease to the tip of the finger (Figure. 2)], with the understanding that proportionate relationship exist between body parts. Hence the study was carried out to correlate carrying angle and 2nd (2D) and 4th (4D) digit length as well as ratio. [3]

MATERIALS AND METHODS
One hundred and nine (109) volunteer students comprising of 49 males and 60 females who gave their consent after being verbally informed about the research were randomly selected from the University of Port Harcourt. Carrying angle was determined; first, students were asked to stand with their arms extended and in full supination. A flexible curve was used to get the mid-points of the arm and forearm (Figure. 3). These points were marked using a cosmetic pencil (AH, EM, EL, US, RS, Z, z) (Figure. 3). Carrying angle was then determined using a goniometer, which was placed following the marked points with the stationary part on the arm (line Y) and movable part on the forearm (line y) as shown in Figure. 3 and 4. However 2D and 4D length was measured using a digital vernier caliper, with the supinated palm, placed on a flat surface, and the wrist fixed in a neutral position. Measurements

were therefore made on the ventral surface of the second (2D) and fourth (4D) digits, with the fixed arm of the goniometer placed at the midline of the basal finger crease and the movable arm extended to the tip of the same finger without exerting pressure.

The ratio (2D:4D) was obtained using the following mathematical expression;

RESULTS

Data obtained are as presented in Tables 1-4. The descriptive statistics of the measured parameters are summarized in Table 1.

Mean values for the right in males were (CA = 7.53°, 2D = 76.43mm, 4D = 81.70mm and 2D:4D = 0.93), while for the left (CA = 7.53°, 2D = 77.90mm, 4D = 81.47mm and 2D:4D = 0.96).

For the female subjects on the right (CA = 10.72°, 2D = 73.28mm, 4D = 77.23mm and 2D:4D = 0.95), while for the left (CA = 10.77°, 2D = 73.70mm, 4D = 77.89mm and 2D:4D = 0.95).

Table 2, compares male and female CA and 2D, 4D lengths and ratio. Significant differences in mean values between male and female CA and 2D, 4D lengths and ratio were observed; Right CA ($t = -6.70$, $P<0.01$), Right 4D ($t = 3.03$, $P< 0.01$), Left CA ($t = -6.72$, $P<0.01$), Left 2D ($t = 2.83$, $P = 0.01$) and left 4D ($t = 2.32$, $P = 0.02$). However, there was no significant difference in the following; Right 2D ($t = 1.84$, $P = 0.07$), Right ratio ($t = -1.23$, $P = 0.22$) and Left ratio ($t = 0.74$, $P = 0.46$).

Table 3 compares the right and left CA, 2D, 4D and 2D:4D. Significant differences were observed in male subjects between the right and left 2D ($t = -3.87$, $P < 0.01$) as well as right and left 2D:4D ($t = -2.70$, $P = 0.01$). All parameters in female subjects did not show significant difference.

Correlation analysis and prediction model for carrying angle and digit parameters were presented in Table 4 the right 4D (22%) and right 2D (22%) had the highest predictability with carrying angle, while the left 4D (13%) and right 2D:4D (8%) has the lowest predictability in male and female respectively.

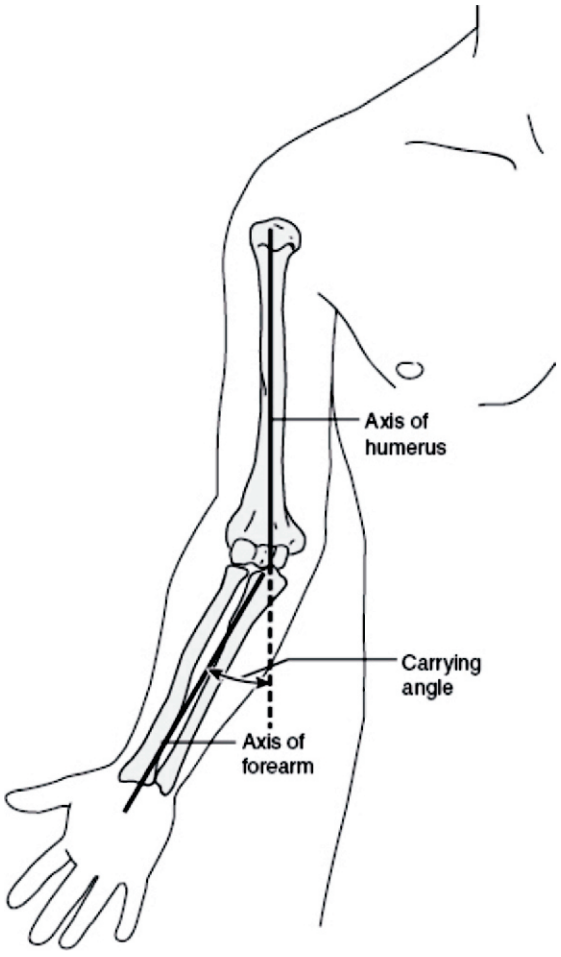


Figure 1: Schematic illustration of Carrying angle: Adopted from www.demosmedicalpublishing.com/carrying-angle/

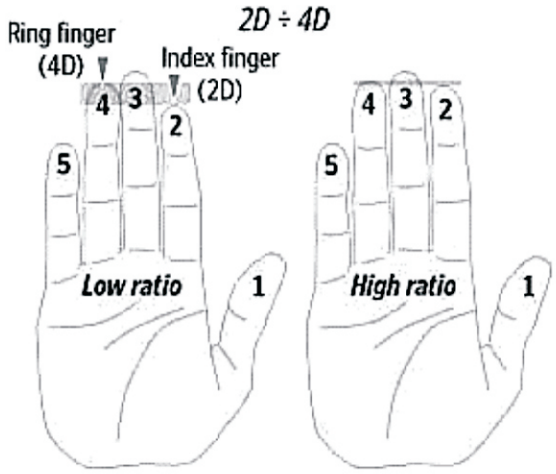
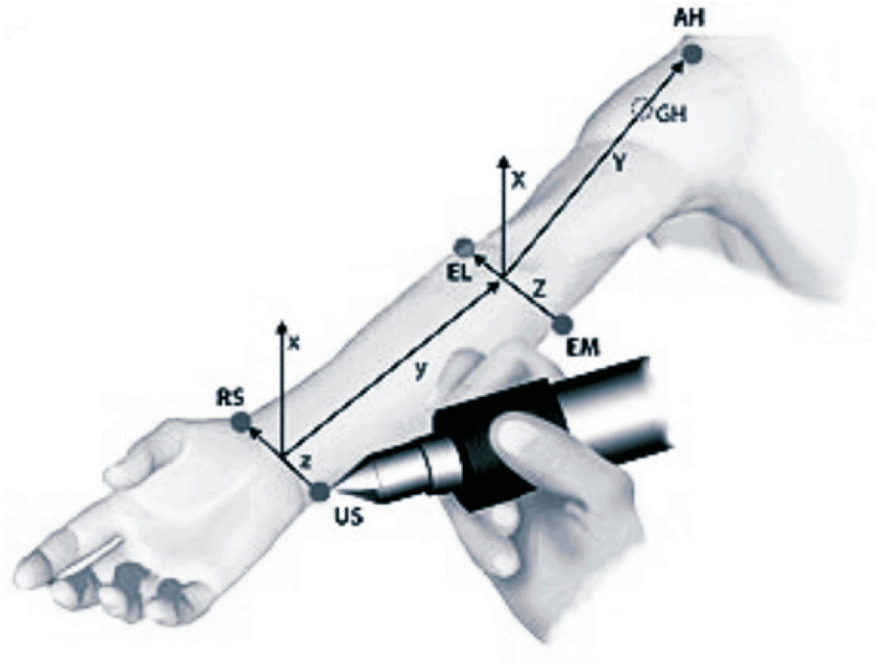


Figure. 2: Schematic illustration of Second digit (2D), fourth digit (4D) of the right hand: Adopted from www.demosmedicalpublishing.com/carrying-angle/



Key: AH = Gap between the acromium and humerus, EM = Most caudal point on the medial epicondyle, EL = Most caudal point on the lateral epicondyle, US = Most caudal-medial point on the ulnar styloid, RS = Most caudal-medial point on the radial styloid, Z = mid-point between EL and EM, z = midpoint between RS and US.
Figure. 3: Landmarks for measuring the carrying angle: Adapted from healio.com.

Table 1: Descriptive statistics of the measured parameters among the student population

	Male (49)			Female (60)			Total (109)		
Variables	*Range (min-max)*	*Mean*	*S.D*	*Range (min-max)*	*Mean*	*S.D*	*Range (min-max)*	*Mean*	*S.D*
Right CA (°)	4.00 - 12.00	7.53	2.16	5.00 - 17.00	10.72	2.69	4.00 - 17.00	9.28	2.93
Left CA (°)	4.00 - 13.00	7.53	2.07	5.00 - 19.00	10.77	2.94	4.00 - 19.00	9.31	3.04
Right 2D (mm)	55.86 - 92.22	76.43	8.90	53.44 - 92.00	73.28	8.88	53.44 - 92.22	74.69	8.99
Right 4D (mm)	61.74 - 95.01	81.70	7.13	58.48 - 93.00	77.23	8.08	58.48 - 95.01	79.24	7.95
Left 2D (mm)	60.43 - 94.21	77.90	8.35	54.68 - 88.00	73.70	7.18	54.68 - 94.21	75.59	7.97
Left 4D (mm)	57.06 - 96.00	81.47	8.12	57.06 - 95.00	77.89	7.96	57.06 - 96.00	79.50	8.19
Right 2D:4D	0.76 - 1.05	0.93	0.06	0.82 - 1.17	0.95	0.06	0.76 -1.17	0.94	0.06
Left 2D:4D	0.81 - 1.18	0.96	0.06	0.84 - 1.18	0.95	0.06	0.81 - 1.18	0.95	0.06

Min = minimum, Max = maximum value, SD = standard deviation, CA = Carrying angle, 2D = 2nd digit, 4D = 4th digit

Table 2: T-test comparing carrying angles and digit ratios between male and female students.

Variables	Levene's Test for Equality of Variances			t-test for Equality of Means					
	F-value	P-value (f)	Inference	t-value	df	P-value (t)	Inference	M.D	S.E.M.D
Right CA (°)	1.04	0.31	EVA	-6.70	107.00	<0.01	S	-3.19	0.48
Right 2D (mm)	0.02	0.89	EVA	1.84	107.00	0.07	NS	3.14	1.71
Right 4D (mm)	2.65	0.11	EVA	3.03	107.00	<0.01	S	4.47	1.48
Right ratio	1.77	0.19	EVA	-1.23	107.00	0.22	NS	-0.01	0.01
Left CA (°)	4.92	0.03	EVNA	-6.72	104.89	<0.01	S	-3.24	0.48
Left 2D (mm)	2.57	0.11	EVA	2.83	107.00	0.01	S	4.21	1.49
Left 4D (mm)	0.00	0.95	EVA	2.32	107.00	0.02	S	3.58	1.55
Left ratio	0.03	0.86	EVA	0.74	107.00	0.46	NS	0.01	0.01

EVNA = Equal variances not assumed, EVA = Equal variances assumed, M.D = mean difference, S.E.D = standard error of mean difference, F-value = Fisher's value, t-value = t-test value, P-value = Probability value, CA = Carrying angle, 2D = 2nd digit, 4D = 4th digit, S = significant, NS = Not Significant

Table 3: Paired sample T-test comparing side differences in carrying angles and digit ratios among male and female students.

Parameters	Female				Male			
	Mean	SD	t-value	P-value	Mean	SD	t-value	P-value
Right CA v Left CA	-0.05	0.96	-0.40	0.69	0.00	0.74	0.00	1.00
Right 2D v Left 2D	-0.41	3.43	-0.94	0.35	-1.48	2.67	-3.87	0.00**
Right 4D v Left 4D	0.01	7.68	0.01	0.99	0.23	4.11	0.40	0.69
Right ratio v Left ratio	-0.05	0.39	-0.91	0.37	-0.02	0.06	-2.70	0.01**

CA = Carrying angle, 2D = 2nd digit, 4D = 4th digit, S.D = standard deviation, t-value = t-test value, P-value = Probability value, ** = significant

Table 4: Correlation analysis and prediction model for carrying angle and digit parameters

Sex	Carrying angle	Digit parameters	r	R^2(%)	Regression equation	P-value
Male	Right CA	Right 2D	0.461**	21	CA = 0.1117 (2D) - 1.0033	<0.01
		Right 4D	0.474**	22	CA = 0.1434 (4D) - 4.1896	<0.01
	Left CA	Left 2D	0.450**	20	CA = 0.1115 (2D) - 1.1573	<0.01
		Left 4D	0.366**	13	CA = 0.0934 (4D) - 0.0802	0.005
Female	Right CA	Right 2D	0.469**	22	CA = 0.1423 (2D) + 0.2864	<0.01
		Right 4D	0.357**	13	CA = 0.1192 (4D) + 1.5073	0.003
		Right 2 & 4D ratio	0.285*	8	CA = 11.906 (2D:4D) - 0.5829	0.014
	Left CA	Left 2D	0.449**	20	CA = 0.1841 (2D) - 2.7981	<0.01
		Left 4D	0.322**	10	CA = 0.1192 (4D) + 1.479	0.006

r = Pearson correlation, R^2 = Coefficient of determination, ** correlation is significant at P<0.01, * correlation is significant at P<0.05

DISCUSSION

The study was carried out to determine the relationship between carrying angle and the 2nd and 4th digit ratio in a sample of University of Port Harcourt students. Carrying angles were determined as well as lengths of 2nd and 4th digit (the ratio of 2D and 4D). Carrying angle was found to be higher in females, compared to the males. The 2nd and 4th digit lengths were higher in males compared to the females. While the digit ratios (2D and 4th ratio) were slightly higher in females due to the larger difference between the length of their 2nd digit length (2D) and 4th digit length (4D).

In males, the 2nd digit length is a better predictor of carrying angle. While in female, similar results was obtained. There was negative correlation between the right carrying angle and the right (2D to 4D) ratio. No significant difference between carrying angle and the digit parameters measured on both sex and side of the limb.

Potter *et al* [4] had similar results and opinion, concerning the carrying angles of male and female individuals. Similarly, (Sönmez *et al* [5] and Manning *et al* [6]) have all shown the mean female carrying angle to be significantly greater than that of the males as observed in the current study, also in agreement with the findings of the current study. To the best of our knowledge, no human study has ever reported the carrying angle of males to be greater than those of females. This is because carrying angle permits the arm to be swung without contacting the hips, and females on the average have smaller shoulders and wider hips compared to males, which may necessitate increase in carrying angle. [7] Some authors have reported to the contrary, authors (Steel and Chein-Wei *et al* [8]; Cohen-Bendahan *et al* [9]) have reported no significant difference in carrying angle of males and female, but acknowledged that female values were greater. These varying opinions or differences in reported values, could be ascribed to the differences in the population studied, and or study techniques. A sample of young subjects were involved in this study.

Previous studies (Khare *et al* [10]; John, *et al* [11]) have argued that the 2D:4D necessarily decreases with increasing finger length, and as observed in the current study, male subjects have longer 2nd and 4th digits compared to the females, which may be the basis for the sex difference in digit ratios as observed in this study. These differences in 2D:4D as observed in male and female subjects in the current study, as well as the previous studies could be due to androgen exposure in intrauterine life as reported by several studies. Kempel *et al* [12]; Sanders *et al* [13] and Voracek *et al* [14] reported that the 2D:4D ratio in mice is controlled by the balance of androgen to estrogen signaling during a narrow window of digit development. On the other hand, the formation of the digits in humans, in utero, is thought to occur by 13 weeks, and the bone-to-bone ratio is consistent from this point into an individual's adulthood. During this period if the fetus is exposed to androgens, the exact level of which is thought to be sexually dimorphic, the growth rate of the 4th digit is increased, as can be seen by analyzing the 2D:4D ratio of opposite sex dizygotic twins, where the female twin is exposed to excess androgens from her brother in utero, and thus has a significantly lower 2D:4D ratio. In the current study males were observed to have higher digit lengths compared to the females. This could be ascribed to the fact that the female subjects involved in the study were not exposed to androgens inutero. Hence their digit length were not on the average equal to that of their male counterparts, although differences were generally not significant at $p<0.05$.

CONCLUSION

The study established carrying angle to be higher in female subjects compared to their male counterparts. Digit lengths and ratio were higher in male subjects compared to the females. In males, the 4th digit length was a better predictor of carrying angle on the right, while the 2nd digit length was a better predictor of carrying angle on the left.

For females, the 2nd digit length was a better predictor of carrying on the right as well as on the left limb. The 2nd and 4th digit ratio can only estimate carrying angle with a very low accuracy (precision) on the right in female subjects. The findings of this study will be relevant in anthropometry in estimating carrying angles from 2nd and 4th digit lengths and ratio and also in surgical repair (management) of fracture, dislocation or subluxation of the elbow.

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