Journal of Anatomy

J. Anat. (2011) **218**, pp202–208 doi: 10.1111/j.1469-7580.2010.01318.x

Index to ring digit ratio in Saudi Arabia at Almadinah Almonawarah province: a direct and indirect measurement study

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Abstract

The digit ratio, or the relative lengths, of the 2nd and 4th digits (2D : 4D) shows a sex difference, with males tending to have lower values in comparison with females. This sex differences arises early in the fetus and may result from the effects of prenatal testosterone and estrogen on the relative growth rate of the 2nd and 4th digits. This study aimed to estimate finger lengths and the 2D : 4D ratios for the first time in Saudi Arabian subjects using direct and indirect measurements, and to evaluate the correlations between both indirect and direct 2D : 4D with adult testosterone and various sexually dimorphic physical traits. The results revealed the following: (i) mean 2D : 4D in Saudi Arabian samples varied from 0.96 to 0.99; (ii) mean 2D : 4D was lower for indirect compared to direct 2D : 4D; (iii) sex differences in indirect 2D : 4D were higher than in direct 2D : 4D measurements; (iv) there were no significant correlations between indirect or direct 2D : 4D and testosterone level; (v) there were four significant correlations between direct 2D : 4D and body size traits but no significant correlations between indirect 2D : 4D and body size.

Key words image analysis; Saudi Arabia; second digit and fourth digit ratio; sex-linked traits; testosterone.

Introduction

The digit ratio, or the relative lengths, of the 2nd and 4th digits (2D : 4D) shows a sex difference such that males tend to have lower values in comparison with females (Manning et al. 1998; Manning, 2002; Breedlove, 2010; Galis et al. 2010). This sex difference arises early in the fetus and may result from the effects of prenatal testosterone and estrogen on the relative growth rate of the 2nd and 4th digits (Malas et al. 2006; Berenbaum et al. 2009). Manning et al. (1998) have suggested that 2D : 4D is negatively correlated with prenatal testosterone and positively correlated with prenatal estrogen. In addition to showing sex differences, 2D : 4D also differs markedly across ethnic and national groups, with Caucasian populations showing higher 2D : 4D than Black and East-Asian populations (Manning, 2002). However, the picture regarding sex and ethnic differences is obscured by differences in mean 2D : 4D that may arise as a result of different measurement protocols. Important in this respect is the effect of direct and indirect (from photocopies or scans) measurement of fingers on values of 2D : 4D. Indirect finger measurements have been found to yield lower mean 2D : 4D than direct finger measurements in five reports (Allaway et al. 2009; Burriss et al. 2007; Caswell & Manning, 2009; Fink et al. 2006a,b; Manning et al. 2005). However, this is controversial as Voracek & Dressler (2006) found 2D : 4D from indirect measurements was higher than from direct measurements, and Voracek & Offenmüller (2007) reported no difference in 2D : 4D from indirect and direct measurements. Furthermore, sex differences in 2D : 4D may differ with regard to measurement protocol such that the sex difference in indirect 2D : 4D may be greater than the sex difference in direct 2D : 4D (Manning et al. 2005; Hönekopp & Watson, 2010). The effects of indirect and direct finger measurements on 2D : 4D have been reviewed in Manning et al. (2010). In this report we present for the first time mean values of male and female 2D : 4D in Saudi Arabia. We compare the values of Saudi 2D : 4D and the sex differences in 2D : 4D from indirect and direct measurements. Finally, we consider correlations between indirect and direct 2D : 4D and testosterone and various sexually dimorphic physical traits.

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Accepted for publication *3 October 2010*
Article published online *2 November 2010*

Subjects and methods

Participants

A total of 560 Saudi individuals (276 males and 284 females) between 15 and 34 years of age with a mean age of 20.82 (±2.28) were included in this study. All were chosen from the students and employees of Taibah University at Almadinah Almonawarah province. They were invited to participate in a study of 'individual differences in biological traits'. Each individual filled in a questionnaire on ethnicity.

Subjects with finger anomalies, deformities, scars or inflammation were not included in the study. Participation in this work was optional and all participants signed informed consent statements. The study plan was accepted by the Saudi Arabia University ethics committee.

From all the participants, 57 male and 54 female subjects provided blood samples for testosterone level determination. To ensure that the sex hormone level remained relatively stable, the samples from female participants were taken 10 days after the onset of menstruation.

Anthropometrics

Measurement of the digit lengths and determination of 2D : 4D

The lengths of the 2nd and 4th digits were determined using a direct and an indirect method of measurement.

Direct measurement of the digit lengths. Following Manning et al. (2001) and Csatho et al. (2003), the participants were asked to remove rings and the lengths of the 2nd and 4th digits were measured directly (using vernier calipers accurate to 0.01 mm) on the ventral surfaces of both right and left hands from the basal crease of the digit to its tip. Every digit was measured twice and the average was taken. When there was a band of creases at the base of the digit, the most proximal crease was considered.

Indirect measurement of the digit lengths. The participants were instructed to place the palms of their hands in a relaxed position with fingers lightly placed on the glass of the scanner (HP Deskjet G4050-color flatbed scanner) without applying pressure, providing slight abduction of fingers (Bocci et al. 2001). After saving the scanned images onto the computer, the true color image analysis software package using an image analysis system (Leica Imaging System, Switzerland) was run for manipulation of the images and data collection. Finger lengths were measured from the middle of the most proximal crease to the tip on the ventral surface of both right and left hands (Fig. 1).

Digit lengths measured by both the direct (in cm) and the indirect methods (in μm) were computed for determination of the 2D : 4D by dividing the 2nd digit length by the 4th digit length. For comparing the digit lengths of the direct and the indirect methods, all measurements were done in cm.

To assess the reliability of the measure, we calculated the intra-class correlation coefficient (ICC) of 2D : 4D for the two measurement methods. For the direct measurements, ICC was 0.84 and 0.81 for the right and left hands, respectively. For the indirect measurements, ICC was 0.93 and 0.93 for the right and left hands, respectively. Both assessments were therefore considered reliable, with the indirect method being more accurate.

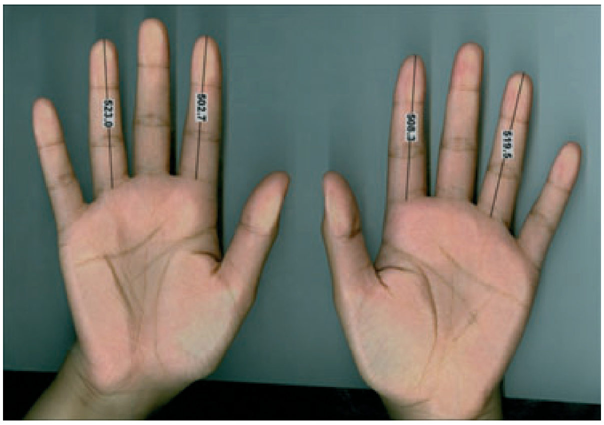

Fig. 1 A photomicrograph showing the indirect measurement of the digit lengths by image analysis system.

Measurement of a number of sexually dimorphic physical traits

Measurement of waist breadth and hip breadth in females and determination of waist-hip ratio (WHR). The waist breadth and the hip or bi-iliac breadth were taken (in cm) to calculate the WHR by dividing the waist measure by the hip measure (Hughes & Gallup, 2003).

Measurement of the shoulder breadth and hip breadth in males for determination of the shoulder-hip ratio (SHR). The shoulder or bi-acromial breadth and hip breadth were taken to calculate SHR by dividing the shoulder breadth by the hip breadth (Hughes & Gallup, 2003).

Measurement of the neck circumference (NC) and neck length (NL) for determination of the neck-length circumference ratio (NLCR). NL and NC were measured (in cm) to calculate NLCR by dividing NL by NC (Roebuck, 1995).

Measurement of the standing height and weight of body for determination of the body mass index (BMI). Standing height was measured (in cm) and standing weight was recorded (in kg). BMI was calculated as weight (in kg) divided by the square of the height (in meters) (Roebuck, 1995).

Detection of testosterone in serum

A 5-μL sample of blood was placed into tubes each containing ethylenediaminetetraacetic acid (EDTA). The blood samples were allowed to clot for 30 min and then centrifuged at 4 °C for 20 min. Using reagents from Euskirchen, Germany, the serum testosterone levels were measured by enzyme linked immuno-sorbent assay (ELISA) (Antony et al. 2002).

Statistical analysis

The obtained results were statistically analyzed using SPSS statistical package V 13.0. Possible significant differences in 2DL, 4DL, 2D : 4D and testosterone were detected using independent *t*-test for sex and method differences and the effect of size was calculated (Cohen, 1988).

The average of the mean 2D : 4D of both sexes was taken for probable sex differentiation of the sample and termed the 'sectioning point' (Kanchan et al. 2010). A dividing line (cut-off point) for 2D : 4D between the two sexes was arrived at, based on sectioning point analysis. Sectioning point = (mean male value ± mean female value)/2.

Pearson's correlation was used to assess the relationship of 2D : 4D, serum testosterone, SHR, WHR, NLCR and BMI.

Results

The mean finger lengths measured by the indirect method for the right and left hands in both males and females were significantly lower than those measured by the direct method ($P = 0.000$). Mean 4DL was significantly higher than mean 2DL in both hands ($P = 0.000$) and this difference in finger lengths was higher in males than in females (Table 1).

There were significant differences in the mean 2D : 4D values obtained by the two methods of measurements, with the indirect method values being lower ($P = 0.000$, df = 566) (except for right 2D : 4D in females, $P = 0.3$, df = 566). As calculated by the indirect method, the means of the derived ratios were significantly lower in males than in females for both hands ($P = 0.000$, df = 558) with a greater sex difference in the right hand (mean difference = 0.02 and 0.01 for the right and left hands, respectively). However, by the direct method, the mean 2D : 4D was significantly lower in males for the left hand ($P = 0.000$, mean difference = 0.02, df = 558), but not for the right hand ($P = 0.44$, mean difference = 0.003, df = 558) (Table 2).

Based on the mean directly measured 2D : 4D for both sexes, the sectioning point was found to be 0.98 for both the right and the left hand. Using this value as a cut-off point, for the right hand, 2D : 4D ≤ 0.98 could identify 49% as males, whereas 2D : 4D > 0.98 could identify 57% as females. For the left hand, 2D : 4D ≤ 0.98 could identify 51% as males, whereas 2D : 4D > 0.98 could identify 63% as females.

On the other hand, the sectioning point of the indirectly measured 2D : 4D was found to be 0.97 for the right and for the left hand. Using this value as a cut-off point, for the right hand, 2D : 4D ≤ 0.97 could identify 71% as males, whereas 2D : 4D > 0.97 could identify 54% as females. For the left hand, 2D : 4D ≤ 0.97 could identify 66% as males, whereas 2D : 4D > 0.97 could identify 46% as females.

In Saudi individuals, the mean testosterone level and all anthropometric body measures (NL, NC, NLCR, height, weight, BMI, SHR and WHR) showed a significant sex difference ($P = 0.000$) (Table 3).

Using the direct method of measurement, the right 2D : 4D was significantly correlated with three measures: male BMI ($P = 0.043$), male NL ($P = 0.013$) and female NLCR ($P = 0.022$). The left 2D : 4D was significantly correlated with only male BMI ($P = 0.009$) (Table 4). In contrast, using the indirect method, no significant correlation was detected between either the right or the left 2D : 4D and any of the selected anthropometric variables for either males or females (Table 5).

No significant correlation was detected between testosterone level and the direct or indirect measured ratios (Tables 4 and 5).

Discussion

In Saudi samples, we have found that the mean 2D : 4D varied from 0.96 to 0.99. Mean 2D : 4D was lower for indirect 2D : 4D compared to direct 2D : 4D measurements. Sex

Table 1 Mean values of finger lengths measured by the direct and indirect methods in males and females.

Variable	Males (n = 276) (mean ± SD)	Females (n = 284) (mean ± SD)	Effect of size	Sex difference (P-value)	df
Right 2DL					
Direct (cm)	6.92 ± 0.46	6.26 ± 0.41	1.52	0.665 (0.000)*	558
Indirect (μm)	5.65 ± 0.34	5.18 ± 0.32	1.42	0.467 0.000*	558
Method difference (P-value)	1.274 (0.000)*	1.075 (0.000)*	–		
Right 4DL					
Direct (cm)	7.05 ± 0.48	6.39 ± 0.44	1.43	0.661 (0.000)*	558
Indirect (cm)	5.92 ± 0.38	5.30 ± 0.33	1.73	0.608 (0.000)*	558
Method difference (P-value)	1.133 (0.000)*	1.080 (0.000)*	–		
Left 2DL					
Direct (cm)	6.88 ± 0.46	6.30 ± 0.42	1.32	0.586 (0.000)*	558
Indirect (cm)	5.64 ± 0.35	5.13 ± 0.33	1.49	0.509 (0.000)*	558
Method difference (P-value)	1.248 (0.000)*	1.171 (0.000)*	–		
Left 4DL					
Direct (cm)	7.07 ± 0.48	6.36 ± 0.45	1.51	0.712 (0.000)*	558
Indirect (cm)	5.88 ± 0.37	5.28 ± 0.33	1.68	0.591 (0.000)*	558
Method difference (P-value)	1.202 (0.000)*	1.081 (0.000)*	–		

2DL, 2nd finger length; 4DL, 4th ring length; df, degrees of freedom.
*P-value ≤ 0.05.

Table 2 Mean values of 2D : 4D measured by the direct and indirect methods in males and females.

Variable	Males (n = 276) (mean ± SD)	Female (n = 284) (mean ± SD)	Effect of size	Sex difference (P-value)	df
Right 2D : 4D					
Direct	0.98 ± 0.04	0.98 ± 0.04	0.00	0.003 (0.443)	558
Indirect	0.96 ± 0.03	0.976 ± 0.037	−0.67	0.021 (0.000)*	558
Method difference (P-value)	0.028 (0.000)*	0.003 (0.256)	–		
Left 2D : 4D					
Direct	0.97 ± 0.04	0.99 ± 0.04	−0.5	0.017 (0.000)*	558
Indirect	0.96 ± 0.04	0.97 ± 0.04	−0.25	0.011 (0.000)*	558
Method difference (P-value)	0.013 (0.000)*	0.020 (0.000)*	–		

2D : 4D, 2nd to 4th finger ratio; df, degrees of freedom.
*P-value ≤ 0.05.

Table 3 Mean values of serum testosterone and the selected anthropometrics in males and females.

Variable	Males (n = 276) (mean ± SD)	Females (n = 284) (mean ± SD)	Effect of size	P-value
Testosterone level (ng mL^{-1})	7.47 ± 2.31	0.78 ± 0.43	3.61	0.000*
Neck measures				
Neck length (cm)	16.89 ± 2.57	12.42 ± 1.61	2.09	0.000*
Neck circumference (cm)	37.29 ± 3.18	30.42 ± 3.69	2.00	0.000*
NLCR	0.46 ± 0.08	0.42 ± 0.14	0.36	0.000*
Height	1.65 ± 0.22	1.56 ± 0.067	0.55	0.000*
Weight	79.10 ± 28.83	56.03 ± 12.32	1.04	0.000*
Body mass index (kg m^{-2})	25.82 ± 6.89	23.14 ± 4.60	0.46	0.000*
Shoulder hip ratio (in males) Waist hip ratio (in females)	1.27 ± 0.15	0.82 ± 0.1	3.53	0.000*

NLCR, neck-length-circumference ratio.
*P-value ≤ 0.05.

differences in indirect 2D : 4D were higher than in direct 2D : 4D. No significant correlations were found between direct or indirect 2D : 4D and testosterone level. Moreover, indirect 2D : 4D showed no significant correlation with any of the selected sexually dimorphic physical traits, whereas - direct 2D : 4D was significantly correlated with four of these traits.

The present study in a Saudi Arabian sample revealed that 2DL and 4DL values measured by the indirect method were significantly lower than the values obtained by the direct method in both sexes for the right and left hands. These results are in contrast with those of Manning et al. (2005), who found that 2DL from photocopies was shorter or equal to 2DL from direct measures, and that 4DL from photocopies was equal to or longer than 4DL from direct measures. This difference in measurements might be due to racial differences or the more precise values obtained by the image analysis system used in this study.

In the present research, the mean 2DL and 4DL values were significantly higher in males than in females. This might be due to the effect of androgen on men's 2D and 4D, as was reported by Lippa (2003) and Grimbos et al. (2010).

The mean 2D : 4D in Saudi Arabian samples varied from 0.96 to 0.99. In comparison with other national and ethnic values of 2D : 4D, these means are quite high and are consistent with the pattern found for Caucasian populations (Manning, 2002).

Mean 2D : 4D was lower for indirect 2D : 4D compared to direct 2D : 4D. This replicates the findings of Allaway et al. (2009), Burriss et al. (2007), Caswell & Manning (2009), Fink et al. (2006a,b) and Manning et al. (2005). However, it does not replicate the report of Voracek & Dressler (2006), who found higher values in indirect 2D : 4D, or that of Voracek & Offenmüller (2007), who reported no difference in mean 2D : 4D using indirect and direct 2D : 4D measurements.

Table 4 Correlation of the directly measured 2D : 4D with the mean values of serum testosterone and the selected anthropometrics.

Variable	Right 2D : 4D Correlation coefficient	Right 2D : 4D *P*-value	Left 2D : 4D Correlation coefficient	Left 2D : 4D *P*-value
Testosterone				
Males (*n* = 276)	0.043	0.752	−0.017	0.897
Females (*n* = 284)	−0.108	0.437	0.084	0.548
Neck length				
Males (*n* = 276)	0.122*	0.043	0.052	0.391
Females (*n* = 284)	0.078	0.189	0.015	0.804
Neck circumference				
Males (*n* = 276)	0.095	0.114	0.077	0.204
Females (*n* = 284)	−0.019	0.744	0.007	0.900
NLCR				
Males (*n* = 276)	0.063	0.296	0.011	0.862
Females (*n* = 284)	0.147*	0.013	0.022	0.712
Weight				
Males (*n* = 276)	0.081	0.179	0.078	0.196
Females (*n* = 284)	−0.102	0.088	−0.063	0.288
Height				
Males (*n* = 276)	0.035	0.559	0.006	0.927
Females (*n* = 284)	−0.035	0.553	0.011	0.854
Body mass index (kg m^{-2})				
Males (*n* = 276)	0.138*	0.022	0.158**	0.009
Females (*n* = 284)	−0.099	0.097	−0.081	0.175
Shoulder hip ratio				
Males (*n* = 276)	−0.033	0.588	−0.083	0.167
Waist hip ratio				
Females (*n* = 284)	0.091	0.126	−0.038	0.524

*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).
2D : 4D, 2nd to 4th finger ratio; NLCR, neck-length-circumference ratio.

Table 5 Correlation of the indirectly measured 2D : 4D with the mean values of serum testosterone and the selected anthropometrics.

Variable	Right 2D : 4D Correlation coefficient	Right 2D : 4D *P*-value	Left 2D : 4D Correlation coefficient	Left 2D : 4D *P*-value
Testosterone				
Males (*n* = 276)	0.103	0.447	0.134	0.319
Females (*n* = 284)	−0.039	0.781	−0.071	0.609
Neck length				
Males (*n* = 276)	0.115	0.057	0.031	0.605
Females (*n* = 284)	−0.038	0.522	−0.032	0.587
Neck circumference				
Males (*n* = 276)	−0.029	0.635	0.016	0.789
Females (*n* = 284)	0.037	0.537	0.011	0.854
NLCR				
Males (*n* = 276)	0.118	0.050	0.022	0.718
Females (*n* = 284)	0.013	0.825	0.035	0.557
Weight				
Males (*n* = 276)	0.011	0.852	0.041	0.496
Females (*n* = 284)	−0.105	0.077	−0.008	0.891
Height				
Males (*n* = 276)	−0.040	0.506	0.060	0.322
Females (*n* = 284)	−0.087	0.144	−0.037	0.539
Body mass index (kg m^{-2})				
Males (*n* = 276)	0.005	0.934	0.079	0.188
Females (*n* = 284)	−0.068	0.254	−0.001	0.991
Shoulder hip ratio				
Males (*n* = 276)	0.078	0.195	−0.028	0.638
Waist hip ratio				
Females (*n* = 284)	0.063	0.291	−0.028	0.641

2D : 4D, 2nd to 4th finger ratio; NLCR, neck-length-circumference ratio.
Correlation is significant at the 0.05 level (two-tailed).

In the Saudi samples, sex differences in indirect 2D : 4D were higher than in direct 2D : 4D. This replicates the findings of Manning et al. (2005) and Hönekopp & Watson (2010). In addition, using the indirect method, the right hand showed a greater sex difference than the left hand; this could be due to the greater sensitivity of the right hand to prenatal androgen compared with the left hand, as reported by Brown et al. (2002) and Rammsayer & Troche (2007). Nevertheless, the direct 2D : 4D values in Saudi subjects demonstrated significant sex difference in the left hand but not in the right, in line with Fink et al. (2006a).

In Saudi individuals, the direct 2D : 4D of the right hand was significantly correlated with male BMI, male NL and female NLCR, whereas the left 2D : 4D was significantly correlated with male BMI only. There were no significant correlations between the indirect 2D : 4D and various sexually dimorphic physical traits. This replicates the finding of Fink et al. (2003) that BMI and 2D : 4D are positively correlated in men, and the reports of Burriss et al. (2007) and Manning et al. (2010) that direct 2D : 4D is more strongly correlated with target traits compared with indirect 2D : 4D. Putz et al. (2004) suggested that the usefulness of 2D : 4D as a predictor of other sex hormone-mediated traits is limited and explained this by the involvement of the developmental timing. Sex hormone levels fluctuate substantially during human growth and development, and various sexually dimorphic traits differentiate at different times. Thus, traits that differentiate under the same hormonal influences may be uncorrelated in their expression if they differ in developmental timing. Puts et al. (2008) added that 2D : 4D should predict sexually dimorphic traits that differentiate under the influence of the same hormones during the same critical period. The correlations between BMI, NL, NLCR and 2D : 4D might be spurious. This is because all of these variables are probably correlated with height. Ratios such as BMI and 2D : 4D are often correlated with their constituent variables (in this case, mass, stature, 2nd digit length and

4th digit length, respectively) and of course finger lengths are correlated with height.

In this study, no significant correlation was detected between direct or indirect 2D : 4D and testosterone level. This is in agreement with Bang et al. (2005), who found no reliable association between 2D : 4D and testicular function in Danish men. In contrast, Manning et al. (1998) found that adult testicular activity was correlated with 2D : 4D in a population from the Merseyside area in the UK.

In the present work, the indirect/measured right 2D : 4D values were more sensitive, specific and accurate than the left values in relation to adult serum testosterone level in both males and females. This may confirm the suggestion of Manning et al. (1998) and Hönekopp & Watson (2010), that the relationship between 2D : 4D ratio and testosterone is particularly strong in the right hand.

Conclusion

This is the first time finger lengths and 2D : 4D have been estimated in a Saudi Arabian sample. 2D : 4D values obtained indirectly from the scanned images (analyzed by an image analysis system) were significantly lower than those obtained by the direct method. The sex difference of indirect 2D : 4D was higher than that of the direct method. This sex difference was significantly greater in the right hand. No significant correlation was detected between direct or indirect 2D : 4D and testosterone level.

Recommendations

Further studies using direct measurements and image analyzing technique are warranted to address the accuracy of these simple methods in assessing 2D : 4D and the degree of sexual dimorphism in different localities. More longitudinal studies relating prenatal androgenization effect on 2D : 4D values later in life would be of great value.

Acknowledgements

This work was supported by grant No. 424/430 from Taiba University, Almadinah Almonawarah, Kingdom of Saudi Arabia.The authors gratefully acknowledge Dr. Fawzya Habib, Vice Dean, College of Medicine, Taibah University, for her help in encouraging the students to participate in this study. Great thanks go to Dr. Khaled S. Heissam, Department of Family Medicine, Taibah University, for his assistance in statistical analysis of data. Research assistants are thanked for their help in taking various measurements and blood samples.

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