Second to fourth digit ratio: a predictor of adult penile length

In Ho Choi¹, Khae Hawn Kim¹, Han Jung¹, Sang Jin Yoon¹, Soo Woong Kim² and Tae Beom Kim¹

The second to fourth digit ratio (2D:4D) has been proposed as a putative biomarker for prenatal testosterone and covaries with the sensitivity of the androgen receptor (AR). Both prenatal testosterone and the AR play a central role in penile growth. In this study, we investigated the relationship between digit ratio and penile length. Korean men who were hospitalized for urological surgery at a single tertiary academic centre were examined in this study, and 144 men aged 20 years or older who gave informed consent were prospectively enrolled. Right-hand second- and fourth-digit lengths were measured by a single investigator prior to measurement of penile length. Under anaesthesia, flaccid and stretched penile lengths were measured by another investigator who did not measure nor have any the information regarding the digit lengths. Univariate and multivariate analysis using linear regression models showed that only height was a significant predictive factor for flaccid penile length (univariate analysis: \( r = 0.185, P = 0.026 \); multivariate analysis: \( r = 0.172, P = 0.038 \)) and that only digit ratio was a significant predictive factor for stretched penile length (univariate analysis: \( r = -0.216, P = 0.009 \); multivariate analysis: \( r = -0.201, P = 0.024 \); stretched penile length \( = -9.201 \times \) digit ratio + 20.577). Based on this evidence, we suggest that the digit ratio can predict adult penile size and that the effects of prenatal testosterone may in part explain the differences in adult penile length.

Asian Journal of Andrology (2011) 13, 710–714; doi:10.1038/aja.2011.75; published online 4 July 2011

Keywords: digit ratio; flaccid penile length; stretched penile length

INTRODUCTION

The ratio of second to fourth digit length (digit ratio, 2D:4D) is sexually dimorphic in humans (the mean digit ratio is lower in males than females)¹⁰ and is thought to be fixed early in development.⁶–¹⁰ Across vertebrate species including humans, the Homeobox (Hox) a and d genes regulate limb development, including fingers and toes, as well as development of the urogenital system, including testes, ovaries and penis.⁶,⁷,¹¹,¹² Manning et al.¹³ observed that the mean testis volume was significantly negatively correlated with the right digit ratio in azoospermic men.¹³ These observations have led to the suggestion that patterns of digit formation may be related to gonad function.¹,¹¹,¹⁴

A previous study reported that the digit ratio of the right hand was negatively correlated with the foetal testosterone/foetal estradiol ratio.¹⁵ As a result, a high level of foetal testosterone relative to foetal estradiol is associated with a low digit ratio. More convincing evidence regarding a link between prenatal testosterone and digit ratio comes from observations of digit ratios in girls with congenital adrenal hyperplasia⁴ and in genetic males with complete androgen insensitivity.¹⁶

A lack of association between digit ratio and circulating testosterone levels¹⁷ and the longitudinal stability of digit ratio¹⁸ has also been reported. These findings add to the evidence demonstrating that digit ratio is a suitable tool to study the effects of prenatal androgen. Furthermore, it has recently been suggested that the digit ratio of the right hand is related to the activity of the androgen receptor (AR).¹⁹

Like digit development, penile growth is influenced by prenatal testosterone.²⁰–²⁶ Androgens and a functioning androgen receptor are known to be necessary for normal development of the human penis.²⁰–²⁶ However, to date, there have been few studies that reveal why men who undergo normal puberty have different penile lengths.

Based on these evidences, we hypothesized that prenatal testosterone levels play a possible role in different penile lengths and considered the possibility that digit ratio might be related to penile length; therefore, we investigated the relationship between digit ratio and penile length.

MATERIALS AND METHODS

Korean men hospitalized for urological surgery at a single tertiary academic centre were examined in this study, and 144 men aged 20 years or older were prospectively enrolled. Institutional Review Board approvals were obtained and all patients gave informed consent. Men with hypospadias, urethral stricture, Peyronie’s disease, penile cancer, or a history of endocrine disease, urethroplasty or other penile surgery (except for circumcision) that has a major influence on penile length were excluded.

All the patients’ height, weight, and finger and penile lengths were measured. The second and fourth digit lengths of the right hand were measured by a single investigator prior to measurement of penile length. Using a digital Vernier calliper accurate to 0.01 mm, digit lengths were measured directly on the ventral surfaces of the fingers, from the crease proximal to the palm at the base of each digit to the digit tip.¹ To minimize measurement errors, mean values of two digit ratios that were calculated from duplicate measurements were used in
RESULTS

Patients’ characteristics are summarized in Table 1. Table 2 describes the detailed types of urology patients who were included in the study. None of the patients who were included in the study have a disease that has a strong influence on penile length (Table 2).

Table 3 summarizes the relationships between penile length and other study variables. Flaccid penile length was correlated with stretched penile length ($r=0.727$, $P=0.000$) (Table 3). In the univariate analysis using a linear regression model, height, body mass index (BMI) and digit ratio were associated with flaccid penile length. Among these three variables (height, BMI and digit ratio), only height was a significant predictive factor for flaccid penile length ($r=0.172$, $P=0.038$) in the multivariate analysis using a linear regression model. Similarly, in the univariate analysis using a linear regression model, height, the fourth-digit length and digit ratio were associated with stretched penile length. Among these three variables (height, fourth-digit length and digit ratio), only digit ratio was a significant predictive factor for stretched penile length ($r=-0.201$, $P=0.024$) in the multivariate analysis using a linear regression model (Table 3).

As shown in Figure 1, stretched penile length was found to be negatively associated with digit ratio. Penile ratio (stretched penile length/flaccid penile length) was negatively correlated with flaccid penile length ($r=-0.698$, $P=0.000$); however, it was not correlated with stretched penile length ($r=-0.046$, $P=0.585$) (Table 3).

DISCUSSION

Androgens and a functioning AR are known to be necessary for normal development of the human penis. Although several studies have demonstrated that postnatal androgen exposure is important for penis growth, penis formation and its capacity to grow are determined foetally by foetal androgen action. Foetal androgen levels in males are elevated between weeks 8 and 24 of gestation, with peak levels occurring between weeks 14 and 16. Activation of AR by prenatal testosterone also appears to contribute to the development of male internal genital structures and the differentiation of male external genitalia.

Table 1 Characteristics of the study population (n=144)

| Site          | Diagnosis                  | Operation name          | No. |
|---------------|----------------------------|-------------------------|-----|
| Kidney        | Renal cell carcinoma       | Radical nephrectomy     | 21  |
|               | Renal cell carcinoma       | Partial nephrectomy     | 15  |
|               | Non-function kidney        | LESS nephrectomy (retroperitoneum) | 1   |
|               | Renal stone                | Percutaneous nephrolithotomy | 1   |
| Ureter        | Transitional cell carcinoma| Nephroureterectomy       | 5   |
|               | UPJ stricture              | Acucise                 | 2   |
|               | Upper ureter stone         | Lapa ureterolithotomy    | 4   |
|               | Mid to lower ureter stone  | Ureteroscopic stone removal | 4   |
| Bladder       | Bladder tumour             | TURB                    | 39  |
|               | Bladder tumour             | Radical cystectomy      | 15  |
|               | Bladder stone              | Cystolitholapaxy        | 15  |
|               | Bladder neck stricture     | Transurethral incision  | 1   |
|               | Hernatmria                 | Transurethral coagulation | 1   |
| Prostate      | Prostate cancer            | Radical retropubic prostatectomy | 12 |
|               | Benign prostate hyperplasia| TURP                    | 11  |
|               | Benign prostate hyperplasia| Open prostatectomy      | 1   |
|               | R/O prostate cancer        | Prostate biopsy (transperineal) | 1   |
| Scrotum       | Varicocele                 | Varicoelectomty         | 13  |
|               | S/P vasectomy              | Vaso-vasostomy          | 4   |
|               | Male infertility           | Epi-vasostomy           | 1   |
|               | Hydrocele                  | Hydroelectomy           | 6   |
|               | Testicular tumour          | Radical orchietomy      | 4   |
|               | Undescended testis         | Orchiopexy              | 2   |
|               | Epididymal cyst            | Epididymal cyst excision | 3   |
|               | Epididymitis               | Epididymecty            | 2   |
|               | Inguinal hernia            | Hernomphrapy            | 1   |
|               | Laceration                 | Wound repair            | 1   |
|               | Condyloma                  | Condyloma excision      | 1   |

Abbreviations: LESS, laparoendoscopic single-site; TURB, transurethral resection of bladder tumour; TURP, transurethral resection of prostate; UPJ, ureteropelvic junction.
Several studies observed that Homeobox genes (Hox a and d) control the development of digits as well as the differentiation of testes and ovaries.\textsuperscript{6,7,11,12} This observation has led to the suggestion that patterns of digit formation may be related to the development of the penis and to gonad function.\textsuperscript{1,11,14}

Recently, Lutchmaya et al.\textsuperscript{15} showed that the digit ratio of the right hand was negatively correlated with foetal testosterone/foetal estradiol ratio.\textsuperscript{15} This may mean that digit ratio is sensitive to the effects of relative foetal testosterone and foetal oestrogen concentrations and that a high concentration of testosterone leads to a low digit ratio and suggests high prenatal testicular activity.\textsuperscript{40}

Furthermore, Manning et al.\textsuperscript{19} demonstrated that the digit ratio of the right hand is positively correlated with the number of CAG repeats in the AR gene and suggested that the digit ratio of the right hand is related to the activity of AR. It has been well established that the length of the CAG repeats is negatively related to sensitivity to testosterone.\textsuperscript{41,42}

However, replication of this relationship between this AR gene polymorphism and digit ratio was largely unsuccessful.\textsuperscript{43} Furthermore, although it seems that digit ratio is related to Hox a and d genes\textsuperscript{6,7,11,12} and AR gene\textsuperscript{19} polymorphism, a recent study\textsuperscript{44} showed that digit ratio was not related to single-nucleotide polymorphisms in the AR gene or in the Hox cluster of genes but was instead related to variation in the LIN28B gene,\textsuperscript{44} which has previously been associated with height\textsuperscript{45} and age at menarche in females.\textsuperscript{46–48} In contrast, another study observed simultaneous heterozygosities at three single-nucleotide polymorphisms in the HOX genes in a group of autistic individuals with low digit ratios,\textsuperscript{49} which indicates that the digit ratio may be related to the HOX genes. Like these, the use of digit ratio as a non-invasive retrospective biomarker for prenatal androgen exposure is controversial;\textsuperscript{50} however, many researchers have adopted digit ratio as such.\textsuperscript{1,4,13,15–18,40,51–55}

To date, it is well known that there are significant ethnic differences in digit ratio. In one study, the Oriental Han had the highest mean digit ratio, followed by the Caucasian Berbers and Uygurs, with the lowest mean ratios found in the Afro-Caribbean Jamaicans.\textsuperscript{56}

Unlike digit ratio, studies have not found a relationship between penis size and race.\textsuperscript{57} However, there is considerable evidence that normal stretched penile length varied between ethnic groups.\textsuperscript{35,58–60}

Among various ethnic groups, East Asians have slightly shorter stretched penile length when compared with other ethnic groups (Caucasian and African-American).\textsuperscript{35,58–60}

Furthermore, to date, there have been few studies that reveal why men who undergo a normal puberty have different penile lengths. Interestingly, one study in Bulgaria observed that the average penis is bigger at birth and also at the end of sexual maturation in rural populations compared with urban populations.\textsuperscript{61} These data indicate that penile size at birth may be associated with penile size after puberty, and that prenatal androgen may have some influence on adult penile size.

Therefore, we hypothesized that the penile length differences between East Asians and other ethnicities may be the result of genetic differences and that the penile length differences between individuals in the same ethnic group may come from the differences of the milieu in utero, and we further considered the possibility that digit ratio might be related to penile length.

Among the many studies involving measurement of penile size, several reports have shown correlations between penile length and other somatometric parameters. To date, two studies have shown a correlation between height and penile length.\textsuperscript{52,53} Like those studies, the present study showed that flaccid penile length was positively

### Table 3 Relationships between penile length and other study variables

| Variables                   | Flaccid penile length | Stretched penile length |
|-----------------------------|-----------------------|-------------------------|
|                             | Univariate            | Multivariate            | Univariate            | Multivariate            |
|                             | r                     | P value                 | r                     | P value                 | r                     | P value                 |
| Age                         | 0.066                 | 0.430                   | 0.051                 | 0.542                   | 0.117                 | 0.192                   |
| Height                      | 0.185                 | 0.026                   | 0.172                 | 0.038                   | 0.142                 | 0.088                   |
| Weight                      | −0.035                | 0.677                   | −0.046                | 0.585                   |                       |                         |
| BMI                         | −0.147                | 0.079                   | −0.138                | 0.095                   | −0.064                | 0.449                   |
| Second digit length         | −0.036                | 0.664                   | 0.001                 | 0.989                   |                       |                         |
| Fourth digit length         | 0.054                 | 0.523                   | 0.123                 | 0.141                   | 0.003                 | 0.977                   |
| Digit ratio                 | −0.155                | 0.064                   | −0.122                | 0.141                   | −0.216                | 0.009                   |
| Stretched penile length     | 0.727                 | 0.000                   | −0.046                | 0.585                   | 0.024                 |                         |
| Penile ratio                | −0.698                | 0.000                   |                       |                         |                       |                         |

Abbreviations: BMI, body mass index; digit ratio, second digit length/fourth digit length; penile ratio, stretched penile length/flaccid penile length.

---

**Figure 1** The relationship between digit ratio and stretched penile length. Stretched penile length was found to be negatively associated with digit ratio. $y = -9.201x + 20.577$ (r = −0.216, P = 0.009) (y: stretched penile length; x: digit ratio).
correlated with height. Furthermore, the univariate and multivariate analyses showed that only height was a significant predictive factor for flaccid penis length (Table 3). However, in the present study, stretched penile length was not correlated with height but was negatively correlated with digit ratio (Table 3).

Two previous studies found correlations between the length of the second digit (index finger) and penile length. The present study does not support these findings; neither the length of the second digit nor the length of the fourth digit correlated with flaccid or stretched penile length (Table 3). However, the results of our univariate and multivariate analyses did show that stretched penile length correlated with digit ratio (Table 3), as men with a lower digit ratio tended to have a longer penile length (Figure 1). This means that it is not finger length but digit ratio that can predict adult penile length.

In the present study, penile ratio was negatively correlated with flaccid penile length (Table 3). These results indicate that elasticity of a small flaccid penis is higher than that of a large flaccid penis. This supports assertions by Masters and Johnson that a longer flaccid penis is not necessarily longer in erection than a shorter flaccid penis. In the present study, we measured only the fingers of the right hand because there are numerous reports that differences between the sexes in digit ratio are greater on the right hand than on the left, and there are suggestions that the right hand may be more sensitive to the influence of testosterone. Several studies have suggested that males with a low digit ratio may be more likely to suppress signs of pain or discomfort, which could lead to the tendency to measure a longer stretched penis length in this group (low digit ratio) compared to the high-digit-ratio group. However, in the present study, penile length was measured under anaesthesia, avoiding pain or discomfort when the penis was fully stretched. Therefore, penile length measurement in our study was not influenced by pain perception.

It is also possible that the elasticity of soft tissues is influenced by prenatal testosterone and that age differences may explain some variation in penile length because penile extensibility decreases with age owing to the loss of elasticity of the tunica albuginea. However, in our data, there was no relationship between age and penile length (flaccid penis length: r = 0.066, P = 0.430; stretched penile length: r = 0.051, P = 0.342) (Table 3). Therefore, penile length may not be influenced by penile extensibility that decreases with age as a result of loss of elasticity of the tunica albuginea. These findings are similar to the results of Wessells et al.

One limitation of our study is that it is not based on a normal population; rather, participants were recruited from among patients who were hospitalized for urological surgery at a single tertiary academic centre. Nevertheless, we assert that our results present sufficient evidence that a relationship exists between digit ratio and adult penile length, as we excluded patients with conditions known to have a strong influence on penile length.

Another limitation of this study is that we measured stretched penile length, not erect penile length. However, many studies have reported a strong correlation between stretched penile length and erectile penile length and shown that stretched penile length provides a reliable estimate of the potential maximal elongation during erection. Therefore, the technique applied here for stretched penile length measurement is highly recommended for accurate prediction of erect penile length.

During the foetal period, high concentrations of testosterone lead to high testicular activity, resulting in a lower digit ratio. In the present study, patients with a lower digit ratio tended to have a longer stretched penile length. Stretched penile length was negatively associated with digit ratio. Based on this evidence, we suggest that digit ratio can predict adult penile size and that the effects of prenatal testosterone may in part explain the differences in adult penile length.

AUTHOR CONTRIBUTIONS
IHC designed the study and acquired the data; KHK performed statistical analysis and helped to draft the manuscript; SWK acquired the data; SJY interpreted the data; SWK critically revised the manuscript for important intellectual content; TBK critically revised the manuscript for important intellectual content and helped to draft the manuscript.

COMPETING FINANCIAL INTERESTS
The authors have no financial or any other conflict of interest to declare regarding the contents of this article.
Digit ratio and penile length
IH Choi et al

26 Vogt K. Microphallus. Emedicine from WebMD. http://www.emedicine.com/PED/topic1448.htm (accessed 12 November 2007).

27 Conte F, Grumbach M. Pathogenesis, classification, diagnosis and treatment of anomalies of sex. In: DeGroot LJ, editors. Endocrinology. 3rd ed. Philadelphia, PA: W. B. Saunders Co; 1995. pp168–70.

28 Quigley CA, de Bellis A, Marschke KB, El-Awady MK, Wilson EM et al. Androgen receptor defects: historical, clinical, and molecular perspectives. Endocr Rev 1995; 16: 271–321.

29 Hinman FJ. Penis and male urethra. In: UroSurgical Anatomy. Philadelphia, PA: W. B. Saunders Co; 1993. p418.

30 George F, Wilson J. Sex determination and differentiation. In: Knobil E, Neill J, Hinman FJ. Penis and male urethra. In: UroSurgical Anatomy. Philadelphia, PA: W. B. Saunders Co; 1993. p418.

31 Byne W. Developmental endocrine influences on gender identity: implications for management of disorders of sex development. Mt Sinai J Med 2006; 73: 950–9.

32 Allaway HC, Bloski TG, Pierson RA, Lujan ME. Digit ratios (2D:4D) determined by computer-assisted analysis are more reliable than those using physical measurements, photocopies, and printed scans. Am J Hum Biol 2009; 21: 365–70.

33 Scutt D, Manning JT. Symmetry and ovulation in women.

34 Manning JT. Fluctuating asymmetry and bodyweight in men and women: implications for the (CAG)n-expanded neuropathies.

35 Son H, Lee H, Huh JS, Kim SW, Paick JS. Studies on self-esteem of penile size in men.

36 Wessells H, Lue TF, McAninch JW. Penile length in the flaccid and erect states; normal measurements, photocopies, and printed scans.

37 Williams TJ, Pepitone ME, Christensen SE, Cooke BM, Huberman AD et al. The length and location of CAG trinucleotide loci associated with 2D:4D finger-length ratio, a putative retrospective biomarker of receptor defects: historical, clinical, and molecular perspectives.

38 Macleod DJ, Sharpe RM, Welsh M, Fisken M, Scott HM. Prenatal testosterone exposure.

39 Macleod DJ, Sharpe RM, Welsh M, Fisken M, Scott HM. Prenatal testosterone exposure.

40 Williams TJ, Pepitone ME, Christensen SE, Cooke BM, Huberman AD et al. The length and location of CAG trinucleotide loci associated with 2D:4D finger-length ratio, a putative retrospective biomarker of receptor defects: historical, clinical, and molecular perspectives.

41 Chamberlain NL, Driver ED, Miesfeld RL. The length and location of CAG trinucleotide loci associated with age at menarche and age at natural menopause.

42 Sulem P, Gudbjartsson DF, Rafnar T, Holm H, Olafsdottir EJ et al. Genome-wide association study identifies sequence variants on 6q21 associated with age at menarche. Nat Genet 2009; 41: 734–8.

43 He C, Kraft P, Chen C, Buring JE, Pare P et al. Genome-wide association studies identify loci associated with age at menarche and age at natural menopause. Nat Genet 2009; 41: 724–8.

44 Sugie T, Sugie H, Fukuda T, Osawa J. Study of HOXD genes in autism particularly regarding the ratio of second to fourth digit length. Brain Dev 2010; 32: 356–61.

45 McIntyre MH. The use of digit ratios as markers for perinatal androgen action. Reprod Biol Endocrinol 2006; 4: 10.

46 Schwardtgeger A, Heer J. Second to fourth digit ratio (2D:4D) of the right hand is associated with socioecpess and augmenting-reducing. Pers Indiv Diff 2008; 45: 493–7.

47 Keogh E, Mounce B, Brosnan M. Can a sexually dimorphic index of prenatal hormonal exposure be used to examine cold pressor pain perception in men and women? Eur J Pain 2007; 11: 231–6.

48 Yamamoto A, Mencova B, Pechova K, Rokyla R. Can second to fourth digit ratio (2D:4D) predict sensitivity to pain? Acta Neuro Sup Rediviva 2009; 51: 159–62.

49 Coates JM, Gurnell M, Ruscichini A. Second-to-fourth digit ratio predicts success among high-frequency financial traders. Proc Natl Acad Sci USA 2009; 106: 623–8.

50 Manning JT, Churchill AJ, Peters M. The effects of sex, ethnic, and sexual orientation on self-measured digit ratio (2D:4D). Arch Sex Behav 2007; 36: 223–33.

51 Schwerdtfeger A, Heer J. Second to fourth digit ratio predicts success among high-frequency financial traders. Proc Natl Acad Sci USA 2009; 106: 623–8.

52 Manning JT, Stewart A, Bundred PE, Trivers RL. Sex and ethnic differences in 2nd to 4th digit ratio of children. Early Hum Dev 2004; 80: 161–8.

53 Adams MV. The Multicultural Imagination: Race, Color, and the Unconscious.

54 Wylie KR, Eardley I. Penile size and the ‘small penis syndrome’. BJU Int 2007; 99: 1449–55.

55 Wang CH, Lin WD, Bau DT, Tsai CH, Liu DC et al. Penile length of normal boys in Taiwan. Acta Paediatr Taiwan 2006; 47: 293–6.

56 Wylie KR, Eardley I. Penile size and the ‘small penis syndrome’. BJU Int 2007; 99: 1449–55.

57 Adams MV. The Multicultural Imagination: Race, Color, and the Unconscious.

58 Wylie KR, Eardley I. Penile size and the ‘small penis syndrome’. BJU Int 2007; 99: 1449–55.

59 Wang CH, Lin WD, Bau DT, Tsai CH, Liu DC et al. Penile length of normal boys in Taiwan. Acta Paediatr Taiwan 2006; 47: 293–6.

60 Edward R. Definitive Penis Size Survey. 6th ed. 2002. http://www.sizesurvey.com

61 Edward R. Definitive Penis Size Survey. 6th ed. 2002. http://www.sizesurvey.com

62 Edward R. Definitive Penis Size Survey. 6th ed. 2002. http://www.sizesurvey.com

63 Multiples E, Borouzas D, Mavrikos S, Dellis A, Bourounis M. Image analysis of the penis and other soft tissue structures of the male genitalia.

64 Multiples E, Borouzas D, Mavrikos S, Dellis A, Bourounis M. Image analysis of the penis and other soft tissue structures of the male genitalia.

65 Wessells H, Lue TF, McAninch JW. Penile length in the flaccid and erect states; normal measurements, photocopies, and printed scans.

66 Wessells H, Lue TF, McAninch JW. Penile length in the flaccid and erect states; normal measurements, photocopies, and printed scans.

67 Wessells H, Lue TF, McAninch JW. Penile length in the flaccid and erect states; normal measurements, photocopies, and printed scans.

68 Wessells H, Lue TF, McAninch JW. Penile length in the flaccid and erect states; normal measurements, photocopies, and printed scans.

69 Wessells H, Lue TF, McAninch JW. Penile length in the flaccid and erect states; normal measurements, photocopies, and printed scans.

70 Wessells H, Lue TF, McAninch JW. Penile length in the flaccid and erect states; normal measurements, photocopies, and printed scans.

71 Wessells H, Lue TF, McAninch JW. Penile length in the flaccid and erect states; normal measurements, photocopies, and printed scans.