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Photocopies Yield Lower Digit Ratios (2D:4D) Than Direct Finger Measurements

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The ratio between 2nd and 4th digit length (2D:4D) may be a negative correlate of prenatal testosterone. This possibility has led to a number of studies of 2D:4D and its relationship with sexual orientation and other sex-dependent traits. At first, 2D:4D ratio was calculated from measurements made directly on the fingers but recently a number of studies have used measurements from photocopies of the hands. Here, we compared finger lengths (2D, 3D, 4D, and 5D) and ratios obtained from these two measurement techniques. Our sample consisted of 30 homosexual men and 50 men and 70 women who were not selected for their sexual orientation. We found evidence that (1) 2D:4D from photocopies tended to be lower than that from direct measurements, (2) there were differences in finger lengths such that 2D from photocopies tended to be shorter or equal in length to direct measurements, while 4D from photocopies tended to be longer or equal in length to direct measurements, (3) the sex differences in 2D:4D tended to be stronger for photocopy measurements, and (4) the pattern for length differences across 2D to 5D appeared to be different for homosexual men compared to men and women recruited without regard to sexual orientation. We conclude that there are differences in digit ratios obtained from photocopies and direct measurements, and these differences arise from length differences recorded from the different protocols. Therefore, 2D:4D ratios obtained from photocopies and direct measurements should not be combined within one study nor should they be used together in comparative studies. We suggest that finger length differences between the two techniques could result from the shapes of fat-pads at the tips of the fingers and these may be dependent on sex and sexual orientation.

KEY WORDS: digit ratio; finger fat-pads; 2D:4D; sexual orientation.

INTRODUCTION

The relative length of the 2nd and 4th digit (2D:4D) is sexually dimorphic such that males tend to have lower mean 2D:4D than do females. It has been suggested that the dimorphism is established in utero, shows little change at puberty, and that 2D:4D is negatively associated with prenatal testosterone and positively with prenatal estrogen (Manning, Scutt, Wilson, & Lewis-Jones, 1998).

This report measured finger lengths directly on the hand; however, a number of studies have since calculated 2D:4D from measurements of photocopies of the hand (e.g., Lippa, 2003; Rahman & Wilson, 2003; Robinson & Manning, 2000; Williams et al., 2000). Taking finger measurements from photocopies reduces sampling times, provides a permanent facsimile of the hand, and comparisons of measurements of 2D:4D from photocopies and directly from the fingers show high intraclass correlation coefficients (e.g., Robinson & Manning, 2000). Therefore, the use of photocopiers to record images of the hands is now popular. However, we have recently noticed that, in comparison with data from direct measurements, there

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seems to be a tendency for studies using photocopiers to obtain lower mean values of 2D:4D.

In this study, we compared digit lengths and digit ratios measured from photocopies of the hands with those measured directly from the fingers themselves. Studies that have calculated 2D:4D ratios from measurements made on hands and those from photocopies have reported intraclass correlation coefficients (r_1). The r_1 is calculated using a Model II single factor analysis of variance (ANOVA) test:

$$r_1 = (\text{Groups MS} - \text{Error MS})/(\text{Groups MS} + \text{Error MS})$$

where MS is mean squares. However, r_1 values are not sensitive to directional differences between samples. We therefore decided to check for directional distortion in finger measurements (including digits 2, 3, 4, and 5) from photocopies.

METHOD

Participants and Measure

Thirty Caucasian men with Kinsey scores of 5–6 were recruited from the Merseyside region in England. The protocol for measurement is given by Manning (2002). Briefly, the participants were asked to put their fingers together and place their palms lightly on the center of the glass photocopier plate. One photocopy per hand was made. Care was taken to ensure the creases at the base of the finger and the tips of the finger could be clearly seen on the photocopy. When quality was poor, a second photocopy was taken. Measurements of right and left 2D, 3D, 4D, and 5D were made with callipers that recorded to 0.01 mm. The scorer was unaware of the hypothesis of directional effects, and measurements directly from the fingers were made without knowledge of those from the photocopies. We were concerned with directional effects and not random measurement error, but in this sample all measurements were made twice by the same scorer. With the direct measurements, the scorer measured the left hand first and then the right hand. After a pause, while the photocopies were taken, the direct measurements on the fingers were repeated. Finger lengths were calculated from the means of first and second measurements.

A total of 50 Caucasian men and 70 Caucasian women were recruited from Austria and England (for details, see Fink, Neave, & Manning, 2003). The lengths of right and left 2D, 3D, 4D, and 5D were measured from photocopies and directly from the fingers. The protocol for photocopying the hands was the same as with the homosexual sample. All measurements were made with callipers recording to 0.01 mm, the scorer was unaware of the hypothesis of directional distortion, and direct measurements were made without knowledge of the photocopy measurements.

RESULTS

With regard to the homosexual sample, we found high and significant r_1 values for first and second measurements for both methods of measurement (direct from fingers: r_1 values varied from 0.991 for right 3D down to 0.979 for left 4D; and from photocopies r_1 values varied 0.999 for right 2D down to 0.965 for left 5D). We compared 2D:4D from direct finger and photocopy measurements by calculating r_1 values. The 2D:4D's were significantly related to one another (2D:4D right hand: $r_1 = 0.73$, $F(1, 29) = 6.40$, $p = .0001$; left hand: $r_1 = 0.65$, $F(1, 29) = 4.72$, $p = .0001$). However, subtracting 2D:4D of direct finger measurement (y) from 2D:4D from photocopies (x) showed the latter was significantly lower than the former for both hands (2D:4D right hand: $x - y = -0.006$, $t(29) = -3.51$, $p = .002$; left hand: $x - y = -0.011$, $t(29) = -4.94$, $p = .0001$).

In order to understand why 2D:4D calculated from photocopies was lower than that from direct finger measurements, we considered differences in absolute finger length from the two methodologies (Table I, Fig. 1). It turned out that in comparison to finger length measured directly there was a significant tendency for 2D and 3D to be shorter when measured from photocopies. For 4D and 5D, photocopy measurements tended to be longer but the differences were not significant. It was this pattern of directional distortion which lowered 2D:4D from photocopies.

With regard to the male sample recruited without determining sexual orientation, the 2D:4D ratios from photocopies and direct measurements showed significant r_1 values (right hand: $r = 0.75$, $F(1, 49) = 7.00$, $p = .0001$; left hand $r_1 = 0.64$, $F(1, 49) = 4.56$, $p = .0001$). However, 2D:4D calculated from the photocopies was significantly lower than that calculated from direct measurements for both right and left hand (2D:4D right hand: $x - y = -0.012$, $t(49) = -4.57$, $p = .0001$; left hand $x - y = -0.018$, $t(49) = -5.72$, $p = .0001$). With regard to discrepancies in absolute finger length, fingers 3D (right hand only), 4D, and 5D were significantly longer when measured from photocopies compared to direct finger measurements (Table I, Fig. 1). This is what gave rise to lower 2D:4D ratios from photocopies.

With regard to the female sample, comparisons of 2D:4D from direct and photocopy measurements showed

Table I. Mean Differences in Finger Length ($x - y$) Between Fingers Measured From Photocopies (x) and Fingers Measured Directly on the Hand (y)

	Homosexual men ($n = 30$)		Nonselected men ($n = 50$)		Nonselected women ($n = 70$)	
Digit	$x - y$ (*SD*)	*p*	$x - y$ (*SD*)	*p*	$x - y$ (*SD*)	*p*
2D Right hand	−0.71 (1.10)	.002	−0.08(1.15)	*ns*	0.24 (1.22)	*ns*
3D Right hand	−0.32 (0.49)	.001	0.38 (1.34)	.049	0.46 (1.35)	.006
4D Right hand	0.26 (1.17)	*ns*	0.92 (1.06)	.0001	0.38 (1.75)	.07
5D Right hand	0.37 (1.04)	.06	1.13 (1.25)	.0001	0.95 (1.15)	.0001
2D Left hand	−0.53 (1.00)	.007	−0.25 (1.54)	*ns*	0.08 (1.33)	*ns*
3D Left hand	−0.68 (1.22)	.005	0.03 (1.06)	*ns*	0.11 (1.24)	*ns*
4D Left hand	0.03 (0.97)	*ns*	1.22 (1.13)	.0001	0.48 (1.53)	.01
5D Left hand	0.29 (1.29)	*ns*	1.38 (1.44)	.0001	1.27 (1.13)	.0001

Note. Negative values of $x - y$ indicate measurements from photocopies were, on average, shorter than those from direct measurements. Positive values of $x - y$ show that finger lengths from photocopies were, on average, longer than those from direct measurements. The *p* values reflect deviations from the expected value of 0 (one-sample *t* test).

significant r_1 values (right hand: $r_1 = 0.67$, $F(1, 69) = 5.09$, $p = .0001$; left hand $r_1 = 0.65$, $F(1, 69) = 4.66$, $p = .0001$). In this sample, there was evidence that left hand 2D:4D from photocopies was lower than that from direct measurements of the fingers, but there was no such effect for the right hand (2D:4D right hand: $x - y = -0.002$, $t(69) = -0.82$, *ns*; left $x - y = -0.006$, $t(69) = -2.02$, $p = .048$). Regarding discrepancies in absolute digit length, we found right 3D and left 4D were significantly greater when measured from photocopies, and this also applied to right and left 5D (Table I, Fig. 1).

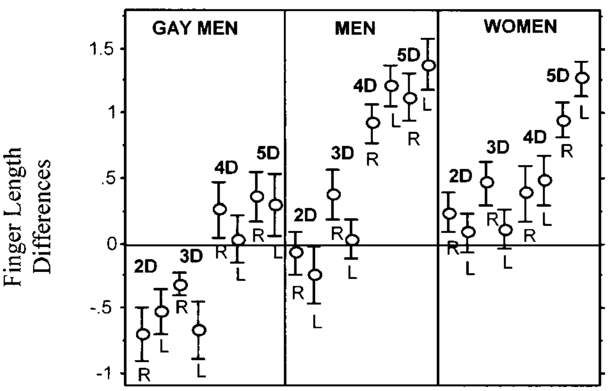

Fig. 1. Means ± *SE* (mm) of differences in length ($x - y$) between finger length (2nd digit = 2D, 3D, 4D, 5D) measured from photocopies (x) and fingers measured directly on the hand (y). Right and left hands are indicated by R and L. Means below zero show measurements from photocopies are, on average, shorter than those from direct measurements. Positive values of $x - y$ show that finger lengths from photocopies are, on average, longer than those from direct measurements. The *p* values for the deviations from 0 are given in Table I.

With mean 2D:4D ratios available for males and females recruited without regard to sexual orientation, we can compare the strength of sex differences in 2D:4D when calculated from photocopies and direct measurement (Table II). As expected, both types of finger measurement showed sex differences in 2D:4D such that males had lower values of 2D:4D than females. The 2D:4D's from photocopies were significantly sexually dimorphic for both right and left hands (right hand, $p = .0001$, $d = .75$; left hand, $p = .003$, $d = .56$). However, sex differences in 2D:4D from direct finger measurements were significant only for the right hand (right hand, $p = .02$, $d = .43$; left hand, $p < .10$, $d = .19$).

It appears that difference scores for finger lengths measured by photocopies and direct measurement often departed significantly from zero with the result that mean 2D:4D from the former was often lower than for the latter; in addition sex differences in 2D:4D may be stronger in 2D:4D's measured from photocopies. However, an inspection of Fig. 1 indicated that the difference scores may also vary by sexual orientation (with some significant negative difference scores in homosexuals but significant positive difference scores in unselected men and women) and across fingers.

We tested for these effects with a 3 (Group) × 2 (Hand) × 4 (Fingers) repeated measures analysis of variance. A repeated measures ANOVA test assumes that the correlations between all variables are more or less equal. This assumption was violated for these data. We therefore examined the results using the Greenhouse-Geisser (GG) statistic. There were significant main effects for Group [GG: $F(2, 147) = 9.22$, $p = .0001$] and Fingers [GG: $F(2.704, 397.417) = 57.17$, $p = .0001$], a significant Group × Fingers interaction [GG: $F(5.407, 397.417) = 4.392$, $p = .0001$], and a significant Hand × Fingers

Table II. Sex Differences in 2D:4D Measured From Photocopies and From Direct Measurements on the Fingers

	Male mean 2D:4D (*SD*)	Female mean 2D:4D (*SD*)	*t*	*p*	*d*
Photocopies right hand	.956 (0.029)	.979 (0.028)	4.45	.0001	.75
Photocopies left hand	.963 (0.033)	.981 (0.030)	3.06	.003	.56
Direct measures right hand	.968 (0.033)	.982 (0.031)	2.30	.02	.43
Direct measures left hand	.981 (0.034)	.987 (0.031)	<1	*ns*	.19

interaction [GG: $F(2.801, 411.771) = 3.489$, $p = .018$]. With regard to the Group × Fingers interaction, paired *t* tests with a Bonferroni correction (0.05/4, $p = .013$) were carried out. For 2D, the mean difference scores were negative for homosexual men and positive for women recruited without regard to sexual orientation, and the discrepancy between these scores was significant (mean difference between the scores $= -1.55$, $p = .002$). There were no significant differences for the comparisons of difference scores between homosexual men and nonselected men and for nonselected women and nonselected men ($p > .0125$). For 3D, homosexual men had negative mean difference scores and men and women recruited without regard to sexual orientation had positive mean difference scores. These discrepancies were significant (homosexual men and nonselected men, mean difference $= -1.41$, $p = .006$; homosexual men and nonselected women, mean difference $= -1.56$, $p = .001$). There was no significant difference between difference scores in nonselected men and women ($p > .0125$). For 4D, all three groups had positive difference scores, and these were smallest for homosexual men. There were significant differences for homosexual men and nonselected men (mean difference $= -1.85$, $p = .003$), and nonselected men and women (mean difference $= -.57$, $p = .01$). There was no significant difference between homosexual men and nonselected women ($p > .0125$). For 5D, all difference scores were positive with the smallest scores shown by homosexual men. Comparisons showed significant discrepancies between the difference scores of homosexual men and nonselected men (mean difference $= -1.85$, $p = .001$) and homosexual men and nonselected women (mean difference $= -1.57$, $p = .001$). There was no significant difference between nonselected men and women ($p = .0125$). With regard to the Hand × Fingers interaction, paired comparisons indicated a significant discrepancy for left and right hand occurring at 3D, such that left 3D had negative difference scores and right 3D had positive scores (mean difference $= -3.07$, $p = .003$). There were no other significant pairings ($p > .0125$).

DISCUSSION

We have the following results: (1) 2D:4D ratios tended to be lower when measured from photocopies compared to 2D:4D from direct finger measurements, (2) difference scores (photocopies - direct measurements) for 2D, 3D, 4D, and 5D lengths showed significant effects. These differed across fingers such that 2D from photocopies was shorter or equal to 2D from direct measurements, and 4D from photocopies was equal to or longer than 4D from direct measurements, (3) 2D:4D from photocopies and direct measurements showed significant sex differences, but there was some evidence that the effect was stronger in the former, (4) the pattern of finger differences appeared to differ between male homosexuals and males unselected for sexual orientation. Compared to finger lengths from direct measurements, the homosexuals showed photocopy measurements with shorter 2D and the unselected males had longer 4D.

We have shown that there are differences in digit ratios obtained from photocopies and direct measurements. These differences derive from difference scores for finger length obtained from the two measurement techniques. We do not know why these significant difference scores arise but we offer the following hypothesis, which concerns variation in the shape of finger tips. It is likely that the directional differences in finger lengths arise at the tips of the fingers where they lift-off from the glass plate of the photocopier. Sexually dimorphic fat-pads, established in utero, are found in the finger tips. There appears to be a negative association between the number and type of sex chromosome and size of finger tip fat-pad. Individuals with Turner syndrome (XO) have larger fat-pads than those in XY individuals, who have larger fat-pads than XX individuals and so on (Alter, 1965; Ponnudurai, 1999). Therefore fat-pad size is sexually dimorphic but it is not known whether there is variation in pad size across fingers. We suggest that across-finger three-dimensional variation in fat-pad size and shape results in small distortions of the two-dimensional photocopy image that differs between fingers. This may arise because light that strikes the surface of the finger tip may be reflected back into the photocopier at various angles which are determined by the curvature of the finger as it lifts-off from the glass plate. An increase in fat-pad size may result in an increase in curvature and an increase in apparent finger length on the photocopy. Therefore such effects are the result of transforming a three-dimensional structure (the finger tip) into a two-dimensional image (the photocopy). In order to investigate this hypothesis it would be necessary to measure fat-pad size and finger tip curvature. At present we know of no measurement protocol for this.

We also note the pattern of length distortion in the hands of gay men appears different from that of general population samples of men and women. The homosexual sample showed that photocopies reduce the length of 2D and 3D but the normative sample shows increases in 4D and 5D (Fig. 1). Sex differences in fat-pads may have potential in the investigation of prenatal sex steroid effects on sexual orientation.

We conclude that 2D:4D ratios calculated from measurements of photocopies and fingers show significant repeatabilities. However, there was also a significant tendency for the 2D:4D's from photocopies to be lower than 2D:4D's calculated from direct finger measurements in five out of six of our comparisons. We do not think our finding invalidates 2D:4D data collected from photocopies, but at present we should bear in mind that 2D:4D from photocopies may conflate sex differences in finger length and finger fat-pads. If this is correct, 2D:4D from photocopies may correlate with sex-dependent variation in finger length and in fat-pad size and shape. However, before we decide that 2D:4D measured from photocopies contains more sex-dependent information than 2D:4D from direct finger measurements, we need to further investigate the fat-pad and finger length hypothesis. For now, data sets should not mix finger measurements or digit ratios from the two protocols. If studies include samples measured by the two different methodologies (e.g., comparisons of mean 2D:4D across ethnic groups; Manning et al., 2002), their findings should be verified from similar studies using direct finger measurements (Manning, Henzi, Venkatramana, Martin, & Singh, 2003) and photocopy measurements (Lippa, 2003) only.

REFERENCES

Alter, M. (1965). Is hyperploidy of sex chromosomes associated with reduced total finger ridge count? *American Journal of Human Genetics*, *17,* 473.

Fink, B., Neave, N., & Manning, J. T. (2003). Second to fourth digit ratio, body mass index, waist-to-hip ratio, and waist-to-chest ratio: Their relationships in heterosexual men and women. *Annals of Human Biology*, *30,* 728–738.

Lippa, R. A. (2003). Are finger-length ratios related to sexual orientation? Yes for men, no for women. *Journal of Personality and Social Psychology*, *85,* 179–188.

Manning, J. T. (2002). *Digit ratio: A pointer to fertility, behavior and health*. New Brunswick, NJ: Rutgers University Press.

Manning, J. T., Barley, L., Lewis-Jones, I., Walton, J., Trivers, R. L., Thornhill, R., et al. (2002). The 2nd to 4th digit ratio, sexual dimorphism, population differences and reproductive success: Evidence for sexually antagonistic genes. *Evolution and Human Behavior*, *21,* 163–183.

Manning, J. T., Henzi, P., Venkatramana, P., Martin, S., & Singh, D. (2003). Second to fourth digit ratio: Ethnic differences and family size in English, Indian and South African populations. *Annals of Human Biology*, *30,* 579–588.

Manning, J. T., Scutt, D., Wilson, J., & Lewis-Jones, D. I. (1998). The ratio of 2nd to 4th digit length: A predictor of sperm numbers and concentrations of testosterone, luteinizing hormone and oestrogen. *Human Reproduction*, *13,* 3000–3003.

Ponnudurai, R. (1999). Relevance of sequential development of dermatoglyphics to schizophrenia. *Psychiatry Research*, *89,* 59–67.

Rahman, Q., & Wilson, G. D. (2003). Sexual orientation and the 2nd to 4th finger length ratio: Evidence for organizing effects of sex hormones or developmental instability? *Psychoneuroendocrinology*, *28,* 288–303.

Robinson, S. J., & Manning, J. T. (2000). The ratio of 2nd to 4th digit length and male homosexuality. *Evolution and Human Behavior*, *21,* 333–345.

Williams, T. J., Pepitone, M. E., Christensen, S. E., Cooke, B. M., Huberman, A. D., Breedlove, N. J., et al. (2000). Finger-length ratios and sexual orientation. *Nature*, *404,* 455–456.