Are 2D:4D Finger-Length Ratios Related to Sexual Orientation? Yes for Men, No for Women

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The ratio of index and ring finger lengths (2D:4D) is thought to be a marker of prenatal androgen exposure. In a sample of over 2,000 participants, men had significantly lower 2D:4D ratios than women ($d = .36$ and $.23$ for right and left hands, respectively), and these results were consistent across ethnic groups. Heterosexual men had significantly lower (more male typical) 2D:4D ratios than gay men ($d = .32$ and $.31$ for right and left hands, respectively), and these results tended to be consistent across ethnic groups. Heterosexual and lesbian women showed no significant differences in 2D:4D ratios, after ethnicity was taken into account. The current findings add to evidence that prenatal hormonal factors may be linked to men's sexual orientation.

Neurohormonal theories of human sexual orientation have focused on possible prenatal effects of sex steroids, particularly androgens, on the developing brain (Byne & Parsons, 1993; Ellis & Ames, 1987; Meyer-Bahlburg, 1984). These theories draw support from animal experimentation showing that prenatal and perinatal sex hormones influence male- and female-typical sexual behaviors in a number of mammalian species, including nonhuman primates (Adkins-Regan, 1988; Breedlove, 1994; Cooke, Hegstrom, Villeneuve, & Breedlove, 1998; Gorski, 1985; Vasey, 1995; Wallen, 1996). Typically, animal experiments have demonstrated that early exposure to androgens tends to "masculinize" and "defeminize" sexual behaviors and, presumably, also the brain structures that underlie these behaviors. Drawing on animal models, neurohormonal theories of human sexual orientation propose that high prenatal androgen exposure during critical periods of development may be associated with heterosexuality in men and homosexuality in women, whereas low androgen exposure may be associated with homosexuality in men and heterosexuality in women (Bailey, 1995; Ellis & Ames, 1987).

The period when androgens surge during male fetal development and presumably trigger male-typical brain development occurs from the 7th to 24th weeks of fetal development, with androgens peaking at approximately the 18th week (i.e., the middle of the second trimester; Wilson, 1999). Although there may be different neural critical periods for various kinds of sex-typed behaviors (e.g., sex-typed play, aggression, sexual behaviors), neurohormonal theories of sexual orientation generally focus on effects from the 2nd to 5th months of gestation (Ellis & Ames, 1987), and

they propose that androgens likely have organizational effects on sexually dimorphic structures in subcortical regions of the developing brain that are responsible for sexual behaviors (e.g., regions of the hypothalamus; see Byne et al., 2001; LeVay, 1991).

Because experimental studies on the behavioral effects of prenatal hormones cannot be conducted on humans for obvious ethical reasons, researchers have tended instead to rely on correlational evidence from individuals who have experienced atypical levels of hormones or who have been exposed to drugs or to environments that influence hormones (Collaer & Hines, 1995; Lippa, 2002a). The most complete and methodologically sophisticated data come from studies of females with congenital adrenal hyperplasia (CAH; see Berenbaum, 2002). Because of an enzymatic defect, CAH females' adrenal glands produce atypically high levels of androgens prenatally, resulting in varying degrees of physical and behavioral masculinization. Consistent with the neurohormonal theory of sexual orientation, CAH women report elevated levels of homosexual fantasy and behavior compared with non-CAH controls (Berenbaum, 2002; Dittmann, Kappes, & Kappes, 1992; Zucker et al., 1996).

Other conditions that produce atypical prenatal hormone levels or atypical hormone action include androgen insensitivity syndrome (which occurs when individuals lack androgen receptors to utilize testosterone), 5α-reductase deficiency (a genetic enzyme deficiency that prevents testosterone from being converted to dihydrotestosterone and that leads genetic males to appear female or genitally ambiguous at birth), and Turner syndrome (which occurs when affected individuals have just a single X chromosome instead of a pair of sex chromosomes; for a review, see Collaer & Hines, 1995). Because studies of individuals exposed to atypical prenatal hormone levels are correlational in nature, their findings are necessarily ambiguous, with biological and social effects confounded. For example, CAH girls are sometimes physically masculinized at birth and subject to "corrective" surgery. As a result, they may be treated differently from nonaffected girls by their caretakers. Androgen-insensitive XY individuals appear female physically, and thus it is not clear whether their female-typical behaviors are due to rearing or to lack of early androgen effects. Because reductase-deficient XY individuals who are reared as girls

sometimes look genitally ambiguous, their ability to adopt masculine roles after puberty may reflect socialization differences as well as the organization effects of prenatal testosterone resulting from their XY genotype. In addition, Turner syndrome females experience direct effects of their atypical genotype as well as a lack of sex hormones because of absent or nonfunctioning ovaries.

For both practical and methodological reasons, researchers have not been able to assess prenatal androgen levels directly in humans and then trace their relation to later sex-typed social and sexual behaviors. However, recent studies have pursued a promising alternate strategy to investigate possible associations between prenatal hormones and adult sex-typed behaviors. By assessing participants on physiological and behavioral markers that are thought to be linked to prenatal androgen exposure, these studies investigate whether markers are associated with sex-typed behaviors and traits in adults. If physical markers that are thought to covary with prenatal androgen exposure also covary with adult sex-typed behaviors, then this is seen as evidence that prenatal androgen levels are linked to adult sex-typed behaviors. Among recently studied putative markers of early androgen exposure are *dermatoglyphics* (finger print ridge patterns), handedness, *autoacoustic emissions* (click-induced or spontaneous faint sounds generated by the inner ear), waist-to-hip ratios, and index-to-ring-finger (2D:4D) finger-length ratios. Recent research has found associations between all of these markers and human sexual orientation (Hall, 2000; Lalumière, Blanchard, & Zucker, 2000; Manning, 2002; McFadden, 2002; McFadden & Pasanen, 1998; Mustanski, Bailey, & Kaspar, 2002; Singh, Vidaurri, Zambarano, & Dabbs, 1999; Williams et al., 2000). However, the results have been complex, fragmentary, and at times inconsistent.

The study reported here focused on possible associations between 2D:4D finger-length ratios and sexual orientation in men and women. The 2D:4D ratio is an easily measured physical characteristic that is sexually dimorphic and thought to be linked to prenatal androgen levels. Physical anthropologists have long noted that men are more likely than women to have ring fingers relatively longer than their index fingers (i.e., low 2D:4D ratios), whereas women are more likely than men to have index fingers relatively longer than their ring fingers (i.e., high 2D:4D ratios; Baker, 1888; for a review, see Peters, Mackenzie, & Bryden, 2002). Manning (2002) reported that sex differences in 2D:4D ratios tend to be small to moderate in magnitude ($d = .2–.5$), depending on the population studied.

Although adult ranges of 2D:4D ratios are present early in fetal development (Garn, Burdi, Babler, & Stinson, 1975; Phelps, 1952), it is not clear when sex differences in 2D:4D ratios first appear. Robinson and Manning (2000) speculated that 2D:4D ratios are likely fixed by the 14th week of gestation, which is within the critical period when testosterone has organizational effects on developing fetuses. After birth, 2D:4D ratios and sex differences in 2D:4D ratios appear to be stable over time, and they seem not to be affected by postnatal variations in hormone levels, including the large variations that occur at puberty (Manning, 2002). This again suggests that 2D:4D ratios are fixed at an early age, probably prenatally.

Most physical sex differences that occur early in life (such as genital differences) are thought to result from the action of sex hormones, and researchers have therefore inferred that sex differences in 2D:4D ratios also likely result from the early effects of

sex hormones, particularly androgens (Manning, 2002; Williams et al., 2000). Brown, Hines, Fane, and Breedlove (2001) have collected preliminary data showing that both CAH males and females tend to have smaller (more male-typical) 2D:4D ratios than non-CAH controls, and this provides new evidence that 2D:4D ratios are associated with prenatal androgen levels. Manning (2002) reviewed research showing that 2D:4D ratios are correlated with a variety of physiological, behavioral, and psychological traits that are plausibly influenced by prenatal sex hormones.

Several recent studies have investigated possible links between 2D:4D ratios and sexual orientation. In a widely reported study, Williams et al. (2000) assessed 2D:4D ratios and sexual orientation in 720 adults attending a street fair in the San Francisco Bay area. These researchers found a significant difference between lesbians' and heterosexual women's right-hand 2D:4D ratios, with lesbians showing lower (more male-typical) ratios. Although gay men and heterosexual men did not show a significant difference in 2D:4D ratios, there was a nonsignificant tendency for gay men to have higher (more female-typical) ratios in the left hand. Brown, Finn, Cooke, and Breedlove (2002) conducted a follow-up study on the relationship between 2D:4D ratios and women's sexual orientation, again assessing participants at a Bay area street fair. They found lesbian–heterosexual differences in 2D:4D ratios for "butch" but not for "femme" lesbians (with butch lesbians showing lower 2D:4D ratios), and this finding hints that prenatal androgens may be linked to sexual orientation only for certain subgroups of women.

In a British study of 88 gay men and 88 age-matched heterosexual men, Robinson and Manning (2000) reported that gay men had lower (more male-typical) left-hand 2D:4D ratios than heterosexual men, and they inferred from this that gay men may be exposed to higher prenatal testosterone levels than heterosexual men. This finding contradicts perhaps the most straightforward version of the neurohormonal theory of sexual orientation—that high prenatal androgen levels masculinize sexual behavior and low levels feminize sexual behavior. Complicating Robinson and Manning's results, however, was the additional finding that exclusively homosexual men had higher (more female-typical) 2D:4D ratios than nonexclusively homosexual and bisexual men.

Manning (2002) noted that some theories argue that unusually high prenatal androgen exposure in males can lead to homosexuality (Geschwind & Galaburda, 1985a, 1985b), whereas others have argued just the opposite (Ellis & Ames, 1987). Complicating matters further, some theories argue that stress-induced testosterone surges in one period of fetal development may be followed by abnormal declines in later periods (e.g., James, 1989), and this may produce seemingly paradoxical effects—that is, characteristics associated with high testosterone levels in one period (e.g., low 2D:4D ratios) could then sometimes become associated with characteristics that are associated with low testosterone levels in another critical period (e.g., male homosexuality). Finally, some theorists have proposed that the effects of prenatal testosterone levels may be nonmonotonic (McFadden, 2002). In the case of male sexual orientation, this would imply that up to a certain point, increased levels of testosterone are masculinizing, but after that point increased levels are feminizing.

Robinson and Manning's (2000) study of heterosexual and homosexual men assessed a relatively ethnically homogeneous population (mostly White British and Scottish men), whereas the

Williams et al. (2000) and Brown et al. (2002) studies likely did not (because they used convenience samples in ethnically diverse California). The ethnic background of participants is important because recent research shows that 2D:4D ratios vary substantially across ethnic and nationality groups (Manning, 2002). Ethnic differences in 2D:4D ratios can be much larger than sex or sexual orientation differences, and therefore ethnic variations have the potential to generate spurious findings in studies of sexual orientation and 2D:4D ratios if the ethnic composition of heterosexual samples differs from that of homosexual samples.

Two strategies exist for dealing with the methodological problem posed by large ethnic variations in 2D:4D ratios: (a) Researchers can assess ethnically homogeneous populations of heterosexual and homosexual participants, or (b) researchers can assess sufficiently large samples to ensure that ethnic variations tend to balance out and are therefore less likely to generate spurious homosexual–heterosexual differences. The current study used both of these strategies. Because participants were assessed on ethnicity, the current analyses could examine the consistency of heterosexual–homosexual differences across ethnic groups, and because large numbers of heterosexual and homosexual participants were assessed, participants' ethnicity and national origins were likely to be quite varied. By investigating the relationship between sexual orientation and 2D:4D ratios in large, ethnically diverse groups of heterosexual and homosexual men and women, the current study hoped to provide new and methodologically cleaner evidence on possible relationships between 2D:4D ratios and sexual orientation in both men and women.

Method

Participants

Participants were 849 men and 1,235 women. Most heterosexual participants were college students and staff at California State University, Fullerton. Most gay and lesbian participants were volunteers solicited at gay pride festivals in Long Beach, California and Orange County, California.[1]

Assessing sexual orientation. Participants completed an anonymous questionnaire that included a demographic cover sheet, a section that asked about sexual orientation, and a number of personality scales. Sexual orientation was assessed by asking participants to respond "true" or "false" to whether they currently used each of the following labels to describe themselves: *heterosexual* (*"straight"*), *gay*, *lesbian*, and *bisexual*.

Men and women were classified as gay or lesbian, respectively, if they checked "true" to using these labels to describe themselves. Participants were classified as heterosexual if they checked "true" to using the label *heterosexual* to describe themselves and if they also checked "false" to using the label *gay* (for men) or *lesbian* (for women) or if they did not respond to these items. Because not all participants responded to sexual orientation questions and because some participants (e.g., those who labeled themselves only as *bisexual*) were not categorized as heterosexual, gay, or lesbian, the number of participants in analyses that contrast sexual orientation groups is somewhat smaller than the total sample of 2,084 participants.

Final analyses included 351 heterosexual men (mean age = 23.8 years, median age = 20.0 years, SD = 10.69), 461 gay men (mean age = 40.0 years, median age = 36.0 years, SD = 11.18), 707 heterosexual women (mean age = 22.9 years, median age = 19.0 years, SD = 8.89), and 472 lesbian women (mean age = 35.7 years, median age = 35.0 years, SD = 9.98). Although gay and lesbian participants were on average older than heterosexual participants, none of the key findings that follow proved

to be age dependent. Analyses that contrasted younger gay and lesbian participants (those 30 years old or younger) with heterosexual participants yielded similar results to analyses that contrasted all gay and lesbian participants with heterosexual participants. Thus, participants of all ages were included in most analyses to maximize statistical power.

Ethnic characteristics of participants. Participants were asked to report their ethnicity (White, Hispanic, Asian, African American, Middle Eastern American, Native American, Multiracial, or other). Table 1 presents the ethnic breakdown of heterosexual men, heterosexual women, homosexual men, and homosexual women. As Table 1 shows, homosexual samples included a relatively higher percentage of White participants than heterosexual samples, whereas heterosexual samples included a relatively higher percentage of Hispanic and Asian participants than homosexual samples.

Photocopying Hands and Measuring Finger Lengths

Participants' hands were photocopied with a Canon PC400 portable copy machine. Participants were asked to place their hands palm down on the glass surface of the photocopier with their fingers held together and the tips of their right and left index fingers and right and left thumbs touching. There were a small number of participants who could have only one hand photocopied because of injury or disability. Also, a small number of participants whose hands were photocopied had unusable questionnaire data because of missing questionnaire responses. Photocopies of participants' hands were stapled to their completed questionnaires. Subsequently, each questionnaire and hand photocopy pair were labeled with matched identification numbers and then separated. Researchers who measured finger lengths from photocopies were blind to the gender and sexual orientation of participants.

The lengths of index (2D) and ring (4D) fingers were measured in each hand by at least two independent raters (I served as one rater and student research assistants served as second raters). Using a clear plastic rule, raters measured finger lengths to the nearest half millimeter from the basal (lowest) finger crease to the fingertip along the medial line bisecting the finger. Some fingers were measured by two student research assistants, and in these cases measured lengths were averaged to form one "research assistant" measurement.

The Reliability of Finger Lengths and 2D:4D

To assess the reliability of finger-length measures, the two measures of finger lengths were correlated. These correlations were .94 for right 2D, .96 for right 4D, .93 for left 2D, and .96 for left 4D (n = 2,073–2,077, all ps <

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[1] One reviewer of this article noted that college students (who made up the huge majority of heterosexual participants in the current study) and gay pride festival attendees (who made up the majority of gay and lesbian participants) do not constitute representative heterosexual and homosexual samples. The reviewer specifically proposed that "it seems plausible that reasons for choosing to openly celebrate one's sexual orientation are related to personality factors that, in turn, stem from hormones." All participants in the current study were assessed on several measures of masculinity and femininity, and college student participants were also assessed on Big Five personality traits. In general, relations between 2D:4D finger-length ratios and personality traits were weak and nonsignificant. Thus, there was little evidence that 2D:4D ratios and, by implication, prenatal androgen levels were linked to broad personality dimensions. These findings do not rule out the possibility that gay men and lesbians who participate in gay pride festivals differ in personality from those who do not. However, if attendees and nonattendees differ on the broad personality traits we assessed, these personality traits seem not to be much associated with 2D:4D ratios.

Table 1

Ethnic Composition of Heterosexual Male, Heterosexual Female, Homosexual Male, and Homosexual Female Samples (Percentages of Whole Sample That Reported Ethnicity)

Ethnicity	Heterosexual		Homosexual	
	Male	Female	Male	Female
White	45	42	69	69
Hispanic	22	22	15	15
Asian	17	20	4	2
African American	3	3	3	2
Middle Eastern	2	1	1	1
Native American	0	0	1	2
Multiracial	5	5	4	5
Other	6	6	3	4

.001). Interrater correlations for computed 2D:4D ratios were .73 ($p <$ .001) for the left hand (α for mean rating = .84) and .73 for the right hand ($p < .001$; α for mean rating = .84).

Because over 8,000 fingers were measured two times, there were likely a small number of measurement, data transcription, and data entry errors. To identify possible errors, the difference between the two measures of each finger was computed, and when this difference was greater than or equal to 3 mm, I remeasured that finger. The new measurement then replaced the old measurements. This process identified a small number (a small fraction of 1%) of gross measurement and data entry errors. Because of this data correction process, the reliability statistics given in the previous paragraph are lower bound estimates. In all subsequent analyses of finger lengths, the mean of the measures from the two independent raters (or the replacement measures for double-checked fingers) serve as the final measure of finger lengths, and right-hand and left-hand 2D:4D ratios were computed from these final finger-length measures.

Distributions of 2D:4D ratios were visually inspected, and several outlier values (greater than 3.5 standard deviations from the mean) were eliminated. The presence of these values did not substantially alter any of the results that follow. However, their elimination slightly reduced the variance and increased the normality of distributions. Visual inspection showed that 2D:4D distributions closely approximated superimposed normal distributions. Over all participants, skewness and kurtosis statistics were .13 and .04 for left-hand 2D:4D ratios and .05 and .05 for right-hand 2D:4D ratios. For men, skewness and kurtosis statistics were .11 and .09 for the left hand and −.01 and .03 for the right hand, and for women these statistics were .12 and .00 for the left hand and .10 and .02 for the right hand.

Finger Lengths, 2D:4D, and Height

Self-reported height (recorded in inches) was collected from 299 men (129 heterosexual men and 170 gay men) and from 414 women (253 heterosexual women and 161 lesbians). Not surprisingly, height was moderately correlated with finger lengths. For men, height correlated .56 with right 2D, .55 with right 4D, .55 with left 2D, and .53 with left 4D (all ps < .001). For women, the corresponding correlations were .50, .46, .50, and .47 (all ps < .001). For men, height correlated .03 with right 2D:4D and .01 with left 2D:4D (both *ns*). For women, height correlated .11 both with right and with left 2D:4D (ps < .05).

Results

The central analyses that follow contrast men with women and heterosexual with homosexual participants on 2D:4D ratios and on finger lengths. To convey results as simply as possible, the fol-

lowing sections typically begin with two-tailed t tests and present group contrasts in terms of effect sizes (Cohen's d statistic). Because multiple measures were obtained from each participant (four finger lengths and right-hand and left-hand 2D:4D ratios), repeated-measures analyses of variance (ANOVAs) are often presented as secondary analyses to provide more complete analyses of patterns in the data. Finally, because 2D:4D ratios and finger lengths covaried with ethnicity, ethnic groups are treated as between-subjects factors in some analyses. Analyses of ethnicity generally contrasted the three largest broad ethnic groups in the study: Whites, Hispanics, and Asians.

Sex Differences in 2D:4D Ratios and Finger Lengths

Table 2 presents sex differences in 2D:4D ratios for all participants, White participants, Hispanic participants, and Asian participants.[2] In all cases, men had significantly lower 2D:4D ratios than women.

For all groups, sex differences in 2D:4D were larger for the right hand than for the left hand. To determine whether this right-hand-versus-left-hand difference was significant, a 2 × 2 (sex × hand) repeated-measures ANOVA was conducted on 2D:4D ratios, with sex of participant serving as a between-subjects factor and right-hand versus left-hand a within-subjects factor. Supporting the observation that 2D:4D sex differences were larger in the right hand than in the left hand, the ANOVA yielded a significant Sex × Hand interaction, $F(1, 2067) = 10.00$, $p = .002$, $\eta^2 = .005$. The ANOVA also yielded a significant main effect for sex, $F(1, 2067) = 50.99$, $p = .000$, $\eta^2 = .024$, and for hand, with right-hand 2D:4D ratios lower than left-hand 2D:4D ratios (respective Ms = .951 and .963); $F(1, 2067) = 344.31$, $p = .000$, $\eta^2 = .143$.

To examine ethnic differences in 2D:4D ratios, a repeated-measures 2 × 3 × 2 (sex × ethnicity × hand) ANOVA was conducted on 2D:4D ratios. The three ethnic groups examined were Whites, Hispanics, and Asians. Because there were other ethnic groups represented in the total sample, the current analysis was conducted on a subset of the total sample. Consistent with previous analyses, this ANOVA showed a sex difference in 2D:4D ratios, $F(1, 1768) = 47.38$, $p = .000$, $\eta^2 = .026$. There was also a significant main effect for ethnicity, $F(2, 1768) = 71.67$, $p = .000$, $\eta^2 = .075$, but no significant interaction between sex and ethnicity, $F(2, 1768) = 1.05$, *ns*. Mean 2D:4D ratios for Whites, Hispanics, and Asians were .957, .940, and .943 for the right hand and .970, .950, and .953 for the left hand (respective ns were 1,137 for Whites, 395 for Hispanics, and 242 for Asians).

It is noteworthy that the effect size (η^2) for ethnicity was considerably larger than the effect size for sex. This has implications for subsequent analyses that contrast heterosexual and homosexual participants, for if sexual orientation groups differ in their ethnic composition (as they did in the current study), then ethnic differences in 2D:4D ratios could lead to spurious results

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[2] The current sample included only small numbers of African American participants: 11 heterosexual men, 12 gay men, 21 heterosexual women, and 9 lesbian women. Neither sex differences nor heterosexual–homosexual differences in 2D:4D ratios were significant for African American participants. However, because of the small sample sizes, these results should be viewed as unreliable.

Table 2

Sex Differences in Right-Hand (RH) and Left-Hand (LH) Index-to-Ring-Finger (2D:4D) Ratios for Participant Groups

Participant group	Sex difference effect size	Men		Women	
		M	SD	M	SD
All[a]					
RH	−.36***	.944	.034	.956	.033
LH	−.23***	.958	.034	.966	.036
White[b]					
RH	−.40***	.949	.035	.963	.033
LH	−.27***	.965	.033	.974	.034
Hispanic[c]					
RH	−.34**	.934	.033	.944	.031
LH	−.21*	.945	.035	.952	.035
Asian[d]					
RH	−.57***	.932	.028	.949	.031
LH	−.46**	.943	.030	.959	.036

Note. Negative effect sizes (Cohen's *d*) indicate that men have lower 2D:4D ratios than women. Significance levels are based on two-tailed *t* tests comparing men's and women's mean 2D:4D ratios.
[a] 845–846 men, 1,227–1,229 women. [b] 496–498 men, 643 women.
[c] 153 men, 243–244 women. [d] 84 men, 158 women.
* $p < .05$. ** $p < .01$. *** $p < .001$.

when comparing 2D:4D ratios of heterosexual and homosexual participants.

Sex Differences in Absolute Finger Lengths

Table 3 presents sex differences in right-hand and left-hand finger lengths. Once again, differences are presented in terms of effect sizes. The data in Table 3 show that there were large sex differences in the lengths of all four measured fingers. However, sex differences in 4D were larger than sex differences in 2D. To statistically test this apparent Sex × Digit interaction, a 2 × 2 × 2 (sex × digit × hand) repeated-measures ANOVA was conducted on finger lengths, with participant sex constituting a between-subjects factor and digit (2D vs. 4D) and hand (right vs. left) within-subjects factors. Not surprisingly, the ANOVA showed a huge main effect for sex, $F(1, 2069) = 1,105.97$, $p = .000$, $\eta^2 = .348$. It also showed a significant Sex × Digit interaction, $F(1,$

Table 3

Sex Differences in Absolute Finger Lengths

Finger	Effect size	Mean finger length (in millimeters)	
		Men	Women
Right 4D	1.51***	77.46 (4.71)	70.69 (4.29)
Left 4D	1.51***	77.59 (4.72)	70.88 (4.27)
Right 2D	1.26***	73.04 (4.63)	67.54 (4.20)
Left 2D	1.34***	74.24 (4.53)	68.39 (4.24)

Note. Positive effect sizes (Cohen's *d*) indicate that men have longer fingers than women. Significance levels are based on two-tailed *t* tests comparing men's and women's mean finger lengths. Data in parentheses are standard deviations. Men: $n = 846$–848; women: $n = 1,229$. 4D = ring finger; 2D = index finger.
*** $p < .001$.

$2069) = 98.29$, $p = .000$, $\eta^2 = .045$, supporting the observation that sex differences in 4D were in fact larger than sex differences in 2D.

In addition, the ANOVA showed a significant main effect for digits, with 4D longer than 2D (*M*s = 73.5 mm and 70.3 mm, respectively), $F(1, 2069) = 3,945.51$, $p = .000$, $\eta^2 = .656$, and a significant main effect for hand, with left-hand fingers longer on average than right-hand fingers (*M*s = 72.2 and 71.6 mm, respectively), $F(1, 2069) = 462.49$, $p = .000$, $\eta^2 = .183$. Finally, there was a significant Digit × Hand interaction, $F(1, 2069) = 330.92$, $p = .000$, $\eta^2 = .138$, and a significant Sex × Hand interaction, $F(1, 2069) = 7.46$, $p = .006$, $\eta^2 = .004$. The first of these interactions is of more substantive interest than the second, because it indicates that 2D and 4D lengths differed more in the right hand (mean difference = 3.67 mm) than in the left hand (mean difference = 2.83 mm). The second interaction shows a weak tendency for the difference in left- and right-hand finger lengths to be greater in men (0.65 mm) than in women (0.52 mm); however, this effect may be due simply to the fact that men on average have longer fingers than women.

Heterosexual–Homosexual Differences in 2D:4D Ratios and Finger Lengths

2D:4D ratios in heterosexual and gay men. Table 4 presents heterosexual–gay differences in men's 2D:4D ratios for the right hand and for the left hand, and these differences are presented for the following groups: all men, White men, Hispanic men, Asian men, and men 30 years of age or younger. The pattern of results

Table 4

Heterosexual–Gay Male Differences in Right-Hand (RH) and Left-Hand (LH) Index-to-Ring-Finger (2D:4D) Ratios for Various Groups of Men

Participant group	Effect size	Heterosexual		Gay	
		M	SD	M	SD
All[a]					
RH	−.32***	.937	.031	.948	.035
LH	−.31***	.952	.033	.962	.034
White[b]					
RH	−.37***	.941	.030	.953	.036
LH	−.44***	.955	.032	.969	.032
Hispanic[c]					
RH	−.24††	.929	.035	.937	.030
LH	−.21†	.941	.036	.948	.034
Asian[d]					
RH	−.22	.931	.028	.937	.030
LH	.17	.945	.028	.940	.033
Age ≤ 30 years[e]					
RH	−.29**	.937	.031	.946	.030
LH	−.30**	.951	.033	.961	.033

Note. Negative effect sizes (Cohen's *d*) indicate that heterosexual men have lower 2D:4D ratios than gay men, and positive effect sizes indicate the reverse. Significance levels are based on two-tailed *t* tests comparing heterosexual and gay men's 2D:4D ratios.
[a] 349 heterosexual, 459–460 gay. [b] 155–156 heterosexual, 317–318 gay. [c] 78 heterosexual, 71 gay. [d] 59 heterosexual, 19 gay. [e] 306 heterosexual, 135–136 gay.
† $p = .20$. †† $p = .15$. ** $p < .01$. *** $p < .001$.

tends to be consistent across groups: Heterosexual men had significantly lower (more male-typical) 2D:4D ratios than gay men did. The only group for which this pattern did not hold was Asian men. However, because of the small number of gay Asian men ($n = 19$), the difference between heterosexual Asian and gay Asian men's 2D:4D ratios should be regarded as statistically unreliable.

To compare sexual orientation and ethnicity effects, a $2 \times 3 \times 2$ (sexual orientation $\times$ ethnicity $\times$ hand) repeated-measures ANOVA was conducted on men's 2D:4D ratios. Sexual orientation and ethnicity were between-subjects factors, and hand (right vs. left) was a repeated-measures factor. The three main ethnic groups examined were Whites, Hispanics, and Asians. This ANOVA showed significant main effects for sexual orientation, $F(1, 693) = 4.79$, $p = .029$, $\eta^2 = .007$, and for ethnicity, $F(2, 693) = 19.08$, $p = .000$, $\eta^2 = .052$. It is noteworthy that the magnitude of the ethnicity effect was much greater than the magnitude of the sexual orientation effect.

Absolute finger lengths of heterosexual and gay men. The previous analyses showed the heterosexual men had lower 2D:4D ratios than gay men, but they do not indicate whether these differences were due to heterosexual–gay differences in the length of 2D, the length of 4D, or the length of both fingers. To answer this question, analyses were conducted that compared the absolute finger lengths of heterosexual men and gay men. Table 5 presents mean 2D and 4D lengths for heterosexual men and gay men, and it also presents effect sizes for heterosexual–gay differences. The data in Table 5 show significant heterosexual–gay differences for 4D but not for 2D. The pattern of results suggests that the significant heterosexual–gay difference in 4D length was not due simply to an overall height or stature difference between heterosexual and gay men, which presumably would affect all digit lengths.

To test whether there was in fact a stronger link between sexual orientation and 4D than between sexual orientation and 2D, a $2 \times 2 \times 2$ (sexual orientation $\times$ digit $\times$ hand) repeated-measures ANOVA was conducted on men's finger lengths. Sexual orientation was a between-subjects factor, and digit (2D vs. 4D) and hand (right vs. left) were within-subjects factors. This analysis did not show an overall difference in finger length between gay men and heterosexual men, $F(1, 806) = 1.93$, $p = .17$. However, it did

show a significant interaction between sexual orientation and digit, $F(1, 806) = 20.73$, $p = .000$, $\eta^2 = .025$, consistent with the pattern shown in Table 5.

As noted earlier, self-reported height was obtained from 128 heterosexual men and 169 gay men. The previous ANOVA was conducted on just these participants, with height treated as a covariate. Despite the reduced sample size and the statistical control for height, this ANOVA once again showed a significant interaction between sexual orientation and digit, $F(1, 294) = 5.58$, $p = .019$, $\eta^2 = .019$.

2D:4D ratios in heterosexual and lesbian women. Table 6 presents heterosexual–lesbian differences in women's 2D:4D ratios for the right and left hands. Although there was one significant difference and one marginally significant difference for all women combined, these differences were not consistent across groups. Furthermore, these differences were opposite in direction to those found in previous studies—that is, in the current data lesbian women had higher (more female-typical) ratios than heterosexual women. It is possible that the differing ethnic composition of the heterosexual and lesbian samples may have contributed to these significant differences in 2D:4D ratios. If so, then these differences may represent spurious findings.

To take ethnicity effects into account, a $2 \times 3 \times 2$ (sexual orientation $\times$ ethnicity $\times$ hand) repeated-measures ANOVA was conducted on women's 2D:4D ratios. Sexual orientation and ethnicity were between-subjects factors, and hand (right vs. left) was a repeated-measures factor. The three main ethnic groups examined were Whites, Hispanics, and Asians. There proved to be no main effect for sexual orientation, $F(1, 987) = 0.04$, $p = .84$, but there was a significant main effect for ethnicity, $F(2, 987) = 31.60$, $p = .000$, $\eta^2 = .06$.

There were very few Asian lesbians in this analysis ($n = 11$), and it is possible that this small cell size distorted the results of the ANOVA. To test this possibility, the ANOVA was conducted again, this time with ethnicity defined in terms of just two groups (White, Hispanic) rather than three groups (White, Hispanic, Asian). Despite the change, the results were much the same. There was no main effect for sexual orientation, $F(1, 836) = 0.37$, $p = .54$, but there was a significant main effect for ethnicity, $F(1, 837) = 60.01$, $p = .000$, $\eta^2 = .067$.

Absolute finger lengths of heterosexual and lesbian women. Table 7 presents absolute 2D and 4D lengths for lesbians and heterosexual women and effect sizes for lesbian–heterosexual differences. Unlike the corresponding table for men, there were no significant differences for women.

Sex Differences in 2D:4D Ratios Revisited

Table 1 presents findings on sex differences in 2D:4D ratios. However, the current study sampled large numbers of gay men, who proved to have higher 2D:4D ratios than heterosexual men. Because of the large number of gay men in the current sample, Table 1 may overestimate population means for men's 2D:4D ratios, and as a result, the effect sizes for sex differences presented in Table 1 may underestimate population sex differences in 2D:4D. To explore this possibility, effect sizes for sex differences in 2D:4D ratios were computed for just heterosexual participants. These effect sizes were in fact larger than those presented in Table 1 ($d = -.49$ for the right hand and $d = -.37$ for the left

Table 5
Differences in Absolute Finger Lengths of Heterosexual and Gay Men

Finger	Effect size	Mean finger length (in millimeters)	
		Heterosexual	Gay
Right 4D	0.16*	77.91 (4.61)	77.15 (4.71)
Left 4D	0.20**	78.13 (4.56)	77.21 (4.77)
Right 2D	−0.02	72.99 (4.40)	73.07 (4.75)
Left 2D	0.02	74.28 (4.30)	74.19 (4.70)

Note. Positive effect sizes (Cohen's *d*) indicate that heterosexual men have longer fingers than gay men, and negative effect sizes indicate the reverse. Significance levels are based on two-tailed *t* tests comparing heterosexual and gay men's mean finger lengths. Data in parentheses are standard deviations. Heterosexual men: $n = 349$–350; gay men: $n = 460$–461. 4D = ring finger; 2D = index finger.
* $p < .05$. ** $p < .01$.

hand, both ps = .000). The corresponding effect sizes for sex differences in homosexual participants' 2D:4D ratios were smaller: −.35 (p = .000) for the right hand and −.19 for the left hand (p = .004). Representative population samples would, of course, include many more heterosexual than homosexual individuals, and therefore sex differences in 2D:4D ratios in representative samples would likely be closer to the computed sex differences for heterosexual participants.[3]

Discussion

The current study found that heterosexual men had lower (more male typical) 2D:4D ratios than gay men, and these differences appeared to result from differences in 4D lengths rather than differences in 2D lengths. After controlling for ethnicity, there was no evidence that heterosexual women differed from lesbian women in 2D:4D ratios, nor did heterosexual and lesbian women differ in their absolute finger lengths. The current study improved on previous research by assessing large, ethnically diverse samples and by comparing the consistency of findings across ethnic groups. The fact that heterosexual–homosexual differences in men's 2D:4D ratios tended to be consistent across hands, across ethnic groups, and in age-matched groups increases the likelihood that these findings are reliable. Conversely, the fact that the one significant heterosexual–lesbian difference observed in women's 2D:4D ratios was not consistent across ethnic groups suggests that it was a spurious result.

The current study used a relatively coarse system for classifying participants' ethnicity, and future studies could improve on this by assessing participants' ethnicity and national origins in more fine-grained ways. Another promising method to control for ethnicity effects would be to assess 2D:4D ratios in same-sex siblings who

Table 6

Heterosexual–Lesbian Differences in Right-Hand (RH) and Left-Hand (LH) Index-to-Ring-Finger (2D:4D) Ratios for Various Groups of Women

Participant group	Effect size	Heterosexual		Lesbian	
		M	*SD*	*M*	*SD*
All[a]					
RH	−0.22***	.953	.032	.960	.034
LH	−0.11†	.964	.035	.968	.037
White[b]					
RH	−0.07	.961	.031	.964	.034
LH	−0.01	.973	.033	.974	.035
Hispanic[c]					
RH	−0.21	.943	.031	.949	.028
LH	0.18	.955	.031	.948	.041
Asian[d]					
RH	0.08	.950	.032	.947	.026
LH	−0.02	.959	.035	.960	.049

Note. Negative effect sizes (Cohen's *d*) indicate that heterosexual women have lower 2D:4D ratios than lesbians, and positive effect sizes indicate the reverse. Significance levels are based on two-tailed *t* tests comparing heterosexual women's and lesbians' mean 2D:4D ratios.
[a] 704–705 heterosexual, 467–468 lesbian. [b] 292 heterosexual, 325 lesbian. [c] 155–156 heterosexual, 71 lesbian. [d] 142 heterosexual, 11 lesbian.
† p = .068. *** p < .001.

Table 7

Differences in Absolute Finger Lengths of Heterosexual and Lesbian Women

Finger	Effect size	Mean finger length (in millimeters)	
		Heterosexual	Lesbian
Right 4D	0.06	70.81 (4.12)	70.55 (4.57)
Left 4D	0.00	70.90 (4.09)	70.88 (4.54)
Right 2D	−0.06	67.47 (4.17)	67.70 (4.27)
Left 2D	−0.06	68.31 (4.16)	68.58 (4.41)

Note. Positive effect sizes (Cohen's *d*) indicate that heterosexual women have longer fingers than lesbians, and negative effect sizes indicate the reverse. All differences are nonsignificant on the basis of two-tailed *t* tests comparing heterosexual women's and lesbians' mean finger lengths. Data in parentheses are standard deviations. Heterosexual women: *n* = 705; lesbians: *n* = 468. 4D = ring finger; 2D = index finger.

are concordant and discordant on sexual orientation. Such siblings would necessarily be matched on ethnicity (and on other sources of genetic variation as well).

In the current study, heterosexual–homosexual differences for men tended to be smaller in magnitude than sex differences in 2D:4D ratios, and both heterosexual–homosexual differences and sex differences were considerably smaller in magnitude than ethnic differences. If both heterosexual–homosexual differences and sex differences in 2D:4D ratios result from androgen effects, then it makes sense that heterosexual–homosexual differences should be smaller than sex differences. In a sense, male–female differences serve as the gold standard of hypothesized androgen effects on 2D:4D, for it is certain that most males and females experience very large mean differences in prenatal exposure to androgens. If, as suggested by neurohormonal theories of sexual orientation, adult sexual orientation is sometimes influenced by variations in prenatal androgen levels at critical stages of development, then these variations would be superimposed on large mean sex differences in prenatal androgen levels.

Whenever possible, future studies on 2D:4D ratios and sexual orientation should compare effect sizes for heterosexual–homosexual differences with effect sizes for sex differences. If the first is larger than the second, then this increases the likelihood that heterosexual–homosexual differences may be influenced by methodological artifacts such as ethnic differences in heterosexual and homosexual samples. It seems likely that 2D:4D ratios are influenced by many factors in addition to androgen levels, because sex differences in 2D:4D ratios are relatively small in comparison to other common physical sex differences (e.g., male–female height differences or sex differences in absolute finger length).

The current study is the first to show consistent heterosexual–homosexual differences in 2D:4D ratios in both hands. The consistency of the sexual orientation effect for men, both across hands and across ethnic groups, may be due to the large samples obtained in the current research. Given the likelihood that 2D:4D ratios

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[3] By implication, one explanation for why Asians were the group with the largest sex differences in 2D:4D (see Table 2) is that there were relatively few gay Asian men in the current sample.

constitute a very "noisy" indicator of prenatal androgen exposure and that only a fraction of the variance in 2D:4D ratios is linked to androgen effects, it is probably necessary to sample very large numbers of participants for reliable sexual orientation differences in 2D:4D ratios to emerge. By the same token, the null results for women in the current study are also likely to be reliable, given the large numbers of heterosexual and lesbian women studied.

The current study found that sex differences in 2D:4D were stronger for the right hand than for the left hand, and this finding has been reported by others as well (Brown et al., 2002; Manning, Scott, Wilson, & Lewis-Jones, 1998; Williams et al., 2000). Brown et al. (2002) observed that such findings "suggest that the right hand finger ratios are more sensitive to prenatal androgen than are those on the left" (p. 126). Some theories of brain lateralization have speculated that the two halves of the brain grow at different rates and that prenatal androgens can retard brain development and therefore differentially affect the two halves of the brain, depending on the timing of androgen exposure (Geschwind & Galaburda, 1985a). It is conceivable that androgen effects could also differ for the right and left sides of other bilateral bodily structures. However, such theories remain speculative and unproven. Another possibility is that the density of androgen receptors varies in different parts of the body. If androgens affect the development of the right hand more than the left and if variations in prenatal androgen levels also influence sexual orientation, it then seems reasonable to expect that heterosexual–homosexual differences in 2D:4D might be greater in the right hand than in the left hand. This pattern was not observed in the current data, however.

Manning (2002) has argued that androgens affect 4D more than 2D length, and this was supported in the current study. Sex differences proved to be larger for 4D than for 2D, and there were heterosexual–homosexual differences in men's 4D but not 2D lengths. Although not reported here, ethnic groups sometimes showed differences in 2D lengths as well as 4D lengths, and this provides evidence that the processes underlying ethnic differences in 2D:4D may not be the same as those underlying sex differences and heterosexual–homosexual differences in 2D:4D. More broadly, this suggests that there are multiple physiological processes that affect 2D:4D ratios.

The current study found that heterosexual men have lower (more male-typical) 2D:4D ratios than gay men, whereas Robinson and Manning (2000) reported just the opposite. Additional studies will be needed to resolve these conflicting results. Nonetheless, it is worth noting again that the very large sample sizes in the current study and the stability of the current findings for men across hands and across ethnic groups increase the likelihood that the current findings are reliable. Furthermore, the current findings are consistent with a number of other studies showing that gay men are intermediate between heterosexual men and heterosexual women on a number of sex-linked behaviors, traits, and physical characteristics (e.g., Bailey, Gaulin, Agyei, & Gladue, 1994; Gladue & Bailey, 1995; Kimura, 1999; LeVay, 1991; Lippa, 2000, 2002b).

The current data add to evidence that for men at least, prenatal androgen levels may be linked to adult sexual orientation. However, even if neurohormonal theories of sexual orientation have some validity, they may prove to provide only a partial explanation for the development of human sexual orientation. Illustrating this point is recent research showing that male but not female sexual orientation is associated with the number of older brothers an individual has (Blanchard, 1997). Mathematical analyses of relevant data have suggested that with each additional older brother, a male's odds of being homosexual increase by approximately 33%, and about one gay man in seven is estimated to be homosexual because of the older brothers effect (Cantor, Blanchard, Paterson, & Bogaert, 2002). The most promising theoretical explanation for the older brothers effect is that, with each succeeding male fetus, a mother is increasingly likely to develop an immunological reaction against Y-linked antigens in male fetal cells, and this immunological reaction affects the sexual differentiation of the fetal male brain (Blanchard, 2001). This example provides a concrete demonstration that (a) a given theory may account for only some cases of homosexuality (or heterosexuality), and (b) a given physiological process may affect sexual orientation in one sex but not in the other.

Why did the current study find heterosexual–homosexual differences in 2D:4D ratios for men but not for women? One possibility is that male sexual orientation is more influenced by prenatal androgens than female sexual orientation is, or that there is more variation, on average, in males' than in females' prenatal androgen levels. However, given other sorts of evidence that prenatal androgens play a role in female sexual orientation (e.g., evidence from CAH females), this hypothesis seems unlikely to be true in its strongest form—that is, that prenatal androgens influence male sexual orientation but do not at all influence female sexual orientation. A second possibility is that the critical period when androgens influence sexual orientation differs for males and females. If the prenatal period during which 2D:4D ratios are established coincides with the male but not with the female critical period for androgen influences on sexual orientation, then this could generate the current pattern of results. One way to investigate this possibility is to study other physical markers, which may be influenced by prenatal androgen levels during other periods of fetal development, and see if they are associated with adult sexual orientation. Yet a third possible explanation is that only some subgroups of homosexual men and women owe their sexual orientation to the effects of prenatal androgens. This hypothesis is supported by recent research showing different correlates of sexual orientation among butch versus femme lesbians (Brown et al., 2002; Singh et al., 1999). However, even if only some subgroups of lesbians owe their sexual orientation to the prenatal effects of androgens, this would seemingly weaken but not eliminate heterosexual–lesbian 2D:4D differences in very large samples of women.

The finding that male but not female sexual orientation was associated with 2D:4D ratios is consistent with recent theoretical speculations that various aspects of male sexuality are relatively more driven by biological factors (e.g., genes, prenatal hormones, adult hormone levels), whereas aspects of female sexuality are relatively more molded by cultural, social, and situational factors (Baumeister, 2000; Baumeister & Tice, 2001; Peplau, 2001). This is not to say that male sexual orientation is impervious to social influences or that female sexual orientation is free of biological influences but rather that the relative balance of biological and social influences may differ, on average, for males and females. In regard to this hypothesis, future research can investigate whether other putative markers of prenatal androgens show sex differences in their relation to sexual orientation (e.g., see Bogaert, Friesen, & Klentrou, 2002, for evidence that there are heterosexual–homosexual differences in the age of puberty for males but not for

females, and Lalumière et al., 2000, for evidence that the relation between handedness and sexual orientation may differ for men and women).

The current data provide at least partial support for the hypothesis that prenatal androgen levels are associated with adult sexual orientation. Even if neurohormonal theories of sexual orientation are true in general outline, though, the linkage between prenatal hormones and adult sexual orientation is likely to be a complex one, moderated by many factors (Berenbaum, 2002; McFadden, 2002). For example, the effects of prenatal androgens may depend critically on the timing of androgen surges and declines. Androgen effects may depend not only on absolute androgen levels but also on variations in individuals' ability to utilize androgens (e.g., variations in the nature, location, or quantity of androgen receptors in various tissues). As noted earlier, some androgen effects may be nonlinear, with increasing androgen levels masculinizing structures up to a point, but then feminizing structures after some "optimal" level is reached. Finally, androgen effects are likely to be moderated by the presence of other hormones and chemical factors.

The existence of all these potentially complicating factors makes the current findings all the more remarkable—that for men, at least, there was in fact a consistent and significant relationship between a possible marker of prenatal androgen levels and adult sexual orientation. Additional large-scale studies will be necessary to establish whether the current findings replicate in other populations. If they do, then the question of whether 2D:4D ratios are related to sexual orientation may prove to have a two-part answer: yes for men but no for women.

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