

Original Article

Prenatal Influences on Sexual Orientation: Digit Ratio (2D:4D) and Number of Older Siblings

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Abstract: Prenatal androgen levels are suggested to influence sexual orientation in both sexes. The 2D:4D digit ratio has been found to associate with sexual orientation, but published findings have often been contradictory, which may partly be due to the large ethnic diversity between and within studied populations. In men, number of older brothers has been found to correlate positively with homosexuality. This phenomenon has been explained with a maternal immune reaction, which is provoked only by male fetuses and which gets stronger after each pregnancy. Here we assessed the relationship of sexual orientation to 2D:4D ratios and number of older siblings in Finland, where the population is found to be genetically relatively homogeneous. As in many previous studies, heterosexual men had lower 2D:4D than non-heterosexual men, which supports the notion that non-heterosexual men experience higher androgen levels in utero than population norms. Contrary to previous reports, non-heterosexual women had higher 2D:4D than heterosexual women. Non-heterosexual men had more older brothers and older sisters than heterosexual men. The greater number of older sisters in non-heterosexual men indicates that there are other factors that contribute to the higher birth order of homosexual men than the maternal immunization.

Keywords: homosexuality, interdigital ratio, hormones, fraternal birth order, maternal immune hypothesis

Introduction

The second to fourth finger digit ratio (2D:4D) is a sexually dimorphic trait in humans; males have a lower 2D:4D than women (see Hönekopp and Watson, 2010 for a meta-analysis). This difference is present already in two-year-old children (Manning, Scutt,

Wilson, and Lewis-Jones, 1998) and it is thought to be established prenatally by the 13th or 14th week of pregnancy (Garn, Burdi, Babler, and Stinson, 1975; Phelps, 1952). Because of its early emergence, sexual dimorphism in 2D:4D may reflect relative levels of first trimester prenatal androgens and estrogens. Low 2D:4D digit ratio has been associated with high levels of androgens, whereas higher ratio is associated with high estrogen levels (e.g., Manning, 2002; Manning et al., 1998; McIntyre, 2006). Evidence for this comes from studies on 2D:4D ratios of people affected by congenital adrenal hyperplasia (CAH), a condition which causes excessive androgen production during gestation. The 2D:4D ratios have been found to be smaller in men and women with CAH than in sex-matched controls (Hönekopp and Watson, 2010).

The masculinity and femininity of 2D:4D ratio may differ between right and left hands. It has been suggested that 2D:4D ratio, and many other sexually dimorphic traits, tends to be expressed more masculine on the right side of men's bodies (Hönekopp and Watson, 2010; Manning, 2002; Manning et al., 1998). There is some support for a reverse pattern in women; women may have a more feminine 2D:4D ratio in their right hand (Hönekopp and Watson, 2010; Manning, 2002; Manning et al., 1998). It is thought that like low 2D:4D, low right-left 2D:4D (i.e., the difference between right and left hand) correlates with high prenatal testosterone levels (Bennett, Manning, Cook, and Kilduff, 2010; Manning, Bundred, Newton, and Flanagan, 2003).

Several studies have investigated how the 2D:4D ratio varies with sexual orientation, as like 2D:4D ratio, sexual orientation is also thought to be determined prenatally and affected by prenatal androgen levels. Several lines of evidence support this observation. For example, male infants with apparently normal prenatal androgen exposure who have undergone gender reassignment to female shortly after birth appear to have sexual attraction to women (Mustanski, Chivers, and Bailey, 2002; Reiner and Gearhart, 2004). This suggests that the prenatal environment has effects on sexual orientation that persist despite discordance with the assigned gender role. Furthermore, women with congenital adrenal hyperplasia are more likely to be homosexual than control females (Hines, Brook, and Conway, 2004; Meyer-Bahlburg, Dolezal, Baker, and New, 2008; Money, Schwartz, and Lewis, 1984; Zucker et al., 1996). In light of these findings it is not surprising that numerous studies have found an association between 2D:4D ratios and sexual orientation (reviewed in Grimbos, Dawood, Burriss, Zucker, and Puts, 2010).

Although 2D:4D ratio has been found to associate with sexual orientation, the direction of the difference has not been consistent across all studies. For example, some studies have found that the 2D:4D ratio in homosexual males was higher (more feminine) than in heterosexual males (e.g., Lippa, 2003; Manning, Churchill, and Peters, 2007; McFadden and Shubel, 2002), but others have found the ratio to be lower (more masculine) in homosexual men than in heterosexual men (Rahman and Wilson, 2003; Robinson and Manning, 2000). Discrepancies across studies exist for homosexual women also, although not as substantial. For example, Lippa (2003) and van Anders and Hampson (2005) found that heterosexual and lesbian women showed no significant differences in 2D:4D ratios, whereas McFadden and Shubel (2002), Rahman and Wilson (2003), and Williams et al. (2000) reported smaller 2D:4D ratios for homosexual females than for heterosexual females. A recent meta-analysis on 18 independent samples of men and 16 independent

samples of women found that heterosexual women had higher left- and right-hand 2D:4D than did lesbians, but found no difference between heterosexual and gay men (Grimbos et al., 2010).

One reason for the dissonances between studies may be the large ethnic diversity between and within studied populations. Taking into consideration the ethnic background of participants is important because research shows that 2D:4D ratios vary substantially between different ethnicities and nationalities (Lippa, 2003; Manning, 2002; Manning et al., 2007). In fact, Lippa (2003) reported that ethnicity had a larger effect on 2D:4D ratios than sex. Manning (2002) reported finger length ratios of people from nine different nationalities. He found that the 2D:4D ratios ranged from mean ratios of about 0.99 to 1.00 for the groups with high 2D:4D ratios (Poland, Spain and England) to mean ratios of about 0.93 to 0.95 for the groups with low 2D:4D ratios (Zulus, Finns and Jamaicans). Intermediate mean 2D:4D ratios of about 0.96 to 0.97 were found in groups from South India, Germany and Hungary. Therefore, the differences in finger length ratios do not seem to follow a simple White-Black or North-South trend. Because of this, restricting the participants into, for example, Caucasians does not seem sufficient, because the ethnic differences extend to even subgroups within Caucasians. For example, the Caucasian group could contain people from populations of both high 2D:4D mean ratios (e.g., England) and low mean 2D:4D ratios (e.g., Finland). However, this is the way ethnicity has been categorized in most studies of 2D:4D ratios and sexual orientation (e.g., Hall and Love, 2003; Lippa, 2003; McFadden and Shubel, 2002; Miller, Hoffmann, and Mustanski, 2008; Rahman, 2005; Rahman and Koerting, 2008; Rahman and Wilson, 2003; Robinson and Manning, 2000; Smith, Hawkeswood, and Joiner, 2010). Still more studies have not controlled for ethnicity at all (e.g., Hall and Schaeff, 2008; Kraemer et al., 2006; Putz, Gaulin, Sporter, and McBurney, 2004; van Anders and Hampson, 2005; Wallien, Zucker, Steensma, and Cohen-Kettenis, 2008; Williams et al., 2000). The differences in ethnicity may obscure relationships between the 2D:4D ratios and variables other than ethnicity. Thus, it is possible that the differences in direction of effect, or the lack of effect, seen between studies may be at least partly due to different composition of ethnic groups in the heterosexual and homosexual samples in the individual studies.

There is another possible explanation to the contradictory findings in studies of sexual orientation and 2D:4D ratios. Manning and Robinson (2003) posed a hypothesis of universal mean 2D:4D in homosexual men, which suggests that mean 2D:4D ratios of homosexual men may vary only little between different ethnicities, whereas those of heterosexual men may show substantial ethnic variation. It follows that heterosexual men might have higher 2D:4D ratios than homosexual men in some populations, whereas in others they might have lower 2D:4D ratios than homosexuals. They investigated sexual orientation and 2D:4D ratios of men from many different nationalities, and found that 2D:4D of homosexual men varied between 0.96-0.97, whereas that of men recruited without regard to sexual orientation showed much higher variation. This may be due to local selection pressures (for example the intensity of men's competition for women) that affect heterosexual men but not homosexual men, leading to different 2D:4D ratios in heterosexual men in different ethnic groups. Data from some other studies support the universal mean of 0.96 to 0.97 for homosexual men, at least in Caucasians (e.g., McFadden

et al., 2005; Robinson and Manning, 2000).

Birth order is another factor that has been found to associate with sexual orientation. Research indicates that a later birth order is related to homosexuality in men; more specifically, homosexual men seem to have a greater number of older brothers than heterosexual men (for reviews, see Blanchard, 1997, 2001; Bogaert, 2002). This relation between high fraternal birth order and homosexuality is called *the fraternal birth order effect*. For example, Bogaert (2003) established that each additional older brother increased the odds of homosexuality by 38%. However, to our knowledge homosexuality has not been correlated with number of older sisters, younger brothers or younger sisters (e.g., Blanchard, 2001). The relationship between birth order and sexual orientation has yet to be demonstrated in women (e.g., Bogaert, 1997, 2002, 2003).

It has been hypothesized that the fraternal birth order effect reflects a maternal immune reaction, which is provoked only by male fetuses and which gets stronger after each pregnancy with a male fetus (Blanchard and Bogaert, 1996). The relevant fetal antigens in this immune reaction are thought to be Y-linked minor histocompatibility antigens (H-Y antigens) (e.g., Müller, 1996; Pierce et al., 2000; Wolf, 1998). These antigens are present on cell surfaces in males, but not in females, from an early stage of fetal development (Epstein, Smith, and Travis, 1980; Krco and Goldberg, 1976; Shelton and Goldberg, 1984; White, Anderson, and BonDurant, 1987; White, Lindner, Anderson, and BonDurant, 1983). It has been hypothesized that when the mother's immune system is alerted by these antigens, the mother produces certain antigens which cross the placental barrier and enter the fetal brain. They prevent the brain from developing in the male-typical pattern, so that the individual will later be attracted to men rather than women (Bogaert, 1996).

The aim of this study is to assess the relationship of two prenatal influences – birth order and 2D:4D – to sexual orientation. The current study improves on previous research by assessing large, ethnically homogeneous sample. The study was conducted in Finland, where the population has been found to be genetically relatively homogenous (Salmela et al., 2008). Furthermore, by only including people whose parents were both Finnish in our analysis, we aimed to further minimize the methodological problem caused by ethnic variation.

Materials and Methods

Participants

The original data consisted of 815 participants. However, as only the people whose parents were both Finnish were included in the analysis, the final analyses included 773 people. The participants were recruited from the lobby of University of Turku, from the Turku city library and from bars in Turku and Helsinki. Of the participants, 237 were heterosexual men, 63 were non-heterosexual men, 400 were heterosexual women, and 73 were non-heterosexual women. The mean age was 26.10 years ($SD = 7.69$) in heterosexual men, 24.57 years ($SD = 6.80$) in heterosexual women, 35.09 years ($SD = 10.10$) in non-heterosexual men and 25.16 years ($SD = 6.09$) in non-heterosexual women.

Procedure

The participants were asked to fill a questionnaire regarding sexual orientation and number of siblings. Sexual orientation was assessed by the Kinsey scales, which range from 0 for exclusive heterosexuality to 6 for exclusive homosexuality (Kinsey, Pomeroy, and Martin, 1948) (See Table 1). The participants were classified as heterosexual if they scored zero or one, or as non-heterosexual if they scored two or more (Hall and Love, 2003; Rahman and Wilson, 2003; van Anders and Hampson, 2005). To encourage honesty, participants were told that all of their responses would be anonymous. To further minimize the methodological problem posed by large ethnic variation in 2D:4D ratios, we asked the participants to report the ethnicity of their mother and father, and only included Finnish people in our analysis.

Table 1. The Kinsey scale, which was used in our experiment to assess sexual orientation

Rating	Description
0	Exclusively heterosexual
1	Predominantly heterosexual, only incidentally homosexual
2	Predominantly heterosexual, but more than incidentally homosexual
3	Bisexual
4	Predominantly homosexual, but more than incidentally heterosexual
5	Predominantly homosexual, only incidentally heterosexual
6	Exclusively homosexual
X	Asexual, Non-sexual

After filling the questionnaire, the participants' hands were photocopied two times using a CanoScan 4400F portable copy machine. The scans were saved in color, with a resolution of 96 dpi. Participants were asked to place their hands lightly palm down on the surface of the photocopier with their fingers held separately. After the first scan was taken, we asked the participants to remove their hands from the photocopier, and then place them on it again for the second scan. Photocopies of the participants' hands were paired with matching identification numbers to their completed questionnaires.

The lengths of index (2D) and ring (4D) fingers were measured in each hand by using the ImageJ program (ImageJ 1.42, National Institute of Mental Health, Bethesda, MD, USA). The lengths of the digits were measured from the ventral proximal crease of the digit to the tip. In the case there were multiple creases at the base of the digit, we took the measure from the most proximal of these creases (Manning et al.1998; Manning et al., 2000; Martin, Manning, and Dowrick, 1999). To assess the reliability of 2D:4D measures,

we measured the digit ratios of 34 participants from both two pictures of each hand. Repeatability of digit ratio was very high for both left ($R = 0.90$, $F_{33, 34} = 19.10$, $p < .0001$) and right hand ($R = 0.92$, $F_{33, 34} = 19.10$, $p < .0001$), so we analyzed the digit ratio from only one picture of the rest of the participants.

Analysis

The Kolmogorov-Smirnov test was used to test for normality. The finger length data were found to be normally distributed and variances were equal; therefore a two-way ANOVA was used to compare means in 2D:4D ratios between heterosexual and non-heterosexual men and women. The data for number of older siblings were not normally distributed and we were unable to transform it normal. Furthermore, the variances were not equal. Therefore, we used the Mann-Whitney U test to compare the number of siblings between heterosexual and non-heterosexual men and women. Equality of variances was tested with the Levene's test. Since age did not have significant effect on the results, we excluded this covariate from final analyses. All analyses were performed with PASW statistics 18 –program.

Results

Sex, sexual orientation and 2D:4D ratios

The two-way ANOVA revealed that women had significantly higher right hand 2D:4D ratio than men ($F_{1, 840} = 16.44$, $p < .0001$) (see Figure 1). Non-heterosexuals had higher right hand 2D:4D than heterosexuals in both sexes ($F_{1, 840} = 11.52$, $p = 0.001$) (see Figure 1). There was no interaction between sex and sexual orientation on right-hand 2D:4D ratio ($F_{1, 840} = 0.13$, $p = 0.72$). Heterosexual men showed an average 2D:4D ratio of 0.9549 ($SD = 0.03$) on the right hand, whereas the ratio of non-heterosexual men was 0.9678 ($SD = 0.03$). Right hand 2D:4D averaged 0.9687 ($SD = 0.03$) in heterosexual women and 0.9769 ($SD = 0.04$) in non-heterosexual women.

The two-way ANOVA revealed, that as for right hand, women had higher left hand 2D:4D ratio than men ($F_{1, 840} = 22.86$, $p < .0001$) (see Figure 2). There was also a tendency that non-heterosexuals had higher left hand 2D:4D than heterosexuals in both sexes ($F_{1, 840} = 3.69$, $p = .055$) (see Figure 2). There was no interaction between sex and sexual orientation on left hand 2D:4D ratio ($F_{1, 840} = 0.49$, $p = .483$). The mean left hand 2D:4D ratio of heterosexual men was 0.9556 ($SD = 0.04$), whereas that of non-heterosexual men was 0.9658 ($SD = 0.03$). Heterosexual women showed an average 2D:4D ratio of 0.9737 ($SD = 0.03$) on the left hand, whereas the mean left hand 2D:4D ratio of non-heterosexual men was 0.9768 ($SD = 0.03$).

Figure 1. The difference in right hand 2D:4D ratios between heterosexual and non-heterosexual men and women. Columns represent averages with standard error of means (SE)

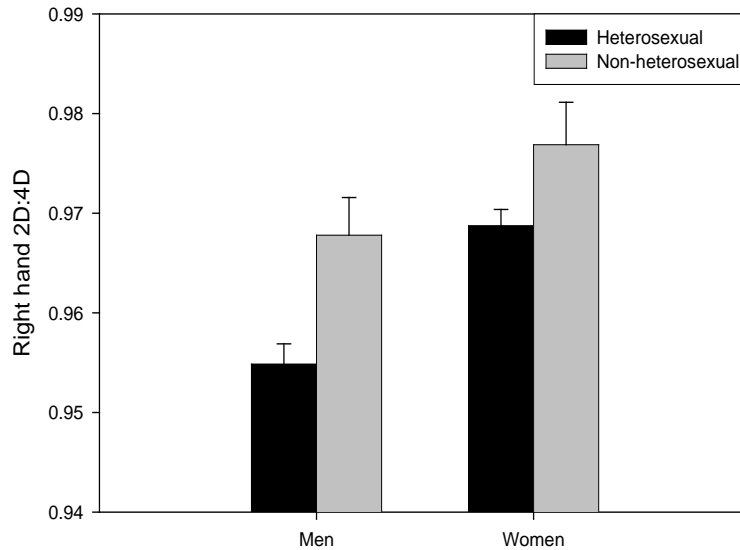
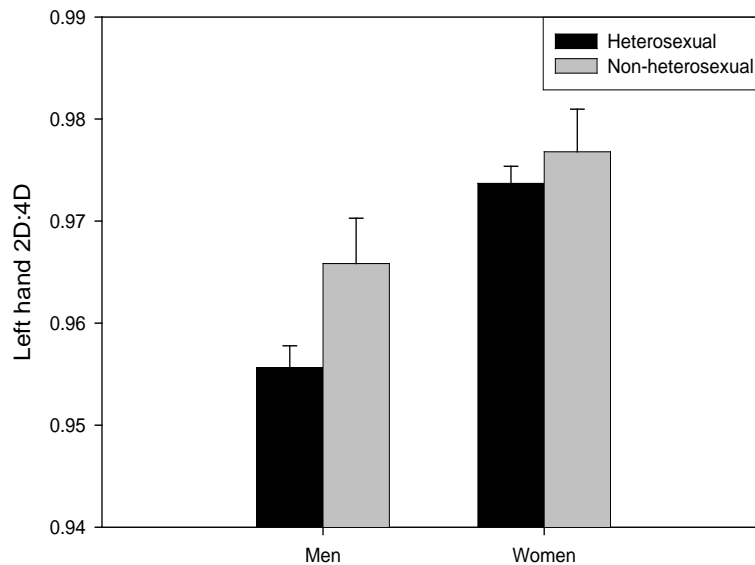


Figure 2. The difference in left hand 2D:4D ratios between heterosexual and non-heterosexual men and women. Columns represent averages with standard error of means (SE)



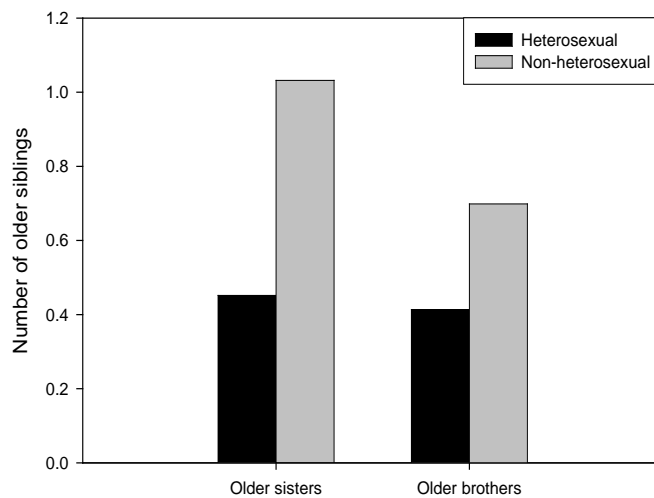
The two-way ANOVA did not find a difference in right-left 2D:4D (D_{r-l}) between men and women ($F_{1, 840} = 0.89, p = .347$). Likewise, the mean of the differences between

digit ratios of the right and left hands did not differ between heterosexuals and non-heterosexuals ($F_{1, 840} = 21.45, p = .172$). The interaction between sex and sexual orientation was not significant either ($F_{1, 840} = 0.14, p = 0.711$).

Sexual orientation and number of siblings

Non-heterosexual men had more older brothers ($Z = 2.40, p = .017$) and older sisters ($Z = 3.12, p = .002$) than heterosexual men (see Figure 3). Non-heterosexual men had less younger brothers than heterosexual men ($Z = -2.86, p = .004$) and there was a tendency that they had less younger sisters than heterosexual men ($Z = -1.69, p = .091$). However, there was no difference in total number of siblings between heterosexual and non-heterosexual men ($Z = 3.12, p = .221$).

Figure 3. The differences in number of older brothers and sisters between heterosexual and non-heterosexual men. Columns represent averages



There was no difference in number of older brothers between non-heterosexual and heterosexual women ($Z = 1.32, p = .186$). Likewise, no difference in number of older sisters between non-heterosexual and heterosexual women was found ($Z = 0.72, p = .474$). There was a tendency that non-heterosexual women had less younger sisters than heterosexual women ($Z = -1.79, p = .073$). There was no difference in number of younger brothers between non-heterosexual and heterosexual women ($Z = -0.81, p = .420$). Furthermore, no difference was found in the total number of siblings between heterosexual and non-heterosexual women ($Z = 0.72, p = .894$).

Discussion

Non-heterosexual men had higher right hand 2D:4D ratios than heterosexual men in our study on Finnish people. To generalize, previous studies have found that homosexual men had a higher 2D:4D in North America and a lower 2D:4D in Europe compared with

heterosexuals (reviewed in Grimbos et al., 2010), which makes our result surprising. However, this result would be expected in the light of the universal mean hypothesis (Manning and Robinson, 2003), which assumes that the universal mean 2D:4D of homosexual men varies between 0.96 and 0.97, since the mean 2D:4D of heterosexual men was clearly lower than this range in our data, whereas that of non-heterosexuals did fit the range. It seems that according to our data the mean 2D:4D ratios of heterosexual men are lower in Finland than in many other European countries (for mean 2D:4D ratios in several European countries, see Manning 2002; Manning, Churchill and Peters, 2007), which may explain the contradicting results in the relationship between sexual orientation and 2D:4D between our study and previous studies on Europeans (Grimbos et al., 2010).

Our study is the first one to find that non-heterosexual women have higher (more feminine) 2D:4D ratios than heterosexual women. As in men, this result was only significant for the right hand. A recent meta-analysis on 16 independent samples of women found that homosexual women had lower 2D:4D ratios than heterosexual women (Grimbos et al., 2010). The meta-analysis included samples from both North America and Europe. In light of our study it seems that this relationship does not apply to all populations, but that instead in some populations lower prenatal androgen exposure may be linked to female homosexuality. Further studies are needed to clarify if this positive relationship between 2D:4D ratio and female homosexuality is found in other populations or whether it is unique to Finnish women, and to investigate the causes of these population differences in the relationship between female 2D:4D ratio and sexual orientation.

It has been suggested that right-left 2D:4D correlates with prenatal testosterone levels; like a low 2D:4D, a low right-left 2D:4D is thought to associate with high prenatal testosterone (Bennett et al., 2010; Manning et al., 2003). However, we found no significant effect of sex or sexual orientation on right-left 2D:4D. Sexual orientation did associate more strongly with right hand 2D:4D though, as its effect was only marginally significant in the left hand. The stronger relationship between sexual orientation and 2D:4D ratio in the right hand compared to the left hand has been observed in previous studies (see Hönekopp and Watson, 2010 for a meta-analysis). The sex difference in 2D:4D ratio also seems to be greater for the right hand than for the left (Hönekopp and Watson, 2010). Similarly, Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, and Manning (2004) studied the relationship between prenatal hormone levels and 2D:4D ratios in 2-year-old children, and found a significant relationship for the right hand but not for the left hand. It has been suggested that prenatal androgens may have a stronger effect on the right hand than on the left hand, making right-hand 2D:4D a better indicator of prenatal androgen levels than left hand 2D:4D (Hönekopp and Watson, 2010).

As in many previous studies (for reviews, see Blanchard, 1997, 2001; Bogaert, 2002), in our study non-heterosexual men had more older brothers than heterosexual men. This fraternal birth order effect has been widely explained with the maternal immunization hypothesis (Blanchard and Bogaert, 1996). However, we also found that non-heterosexual men had more older sisters than heterosexual men. The greater number of older sisters in non-heterosexual men indicates that there are other factors that contribute to the higher birth order of homosexual men than the maternal immunization, as it assumes that only male fetuses cause the immunization. To our knowledge previous studies have failed to

find an association between homosexuality and number of older sisters in men (e.g., Blanchard and Bogaert, 1996; Blanchard, Zucker, Siegelman, Dickey, and Klassen, 1998). A factor that might contribute to the association between sexual orientation and number of older siblings could be poorer condition of the womb due to previous pregnancies, which might reflect to the prenatal androgens experienced by the fetus. In accordance with many previous studies we found no difference in number of older siblings between non-heterosexual and heterosexual women, which supports theories of gender-specific mechanisms in the development of sexual orientation.

To conclude, the primary finding of this study was that non-heterosexuals had higher right hand 2D:4D than heterosexuals in both sexes. Overall, the results we obtained support the hypothesis that prenatal androgens affect sexual orientation in both sexes. More specifically, it seems that lower prenatal androgen exposure is connected to homosexuality in both sexes in Finland. Contradictory finding with other European populations concerning the relationship between 2D:4D and male homosexuality may be explained by the universal mean hypothesis of homosexual men (Manning and Robinson, 2003), as our study does support the universal mean of 0.96-0.97 for gay men. In addition to having more older brothers, non-heterosexual men in our sample had more older sisters than heterosexual men, which indicates that there are other factors that contribute to the higher birth order of homosexual men than the maternal immunization (Blanchard and Bogaert, 1996), which is assumed to be induced only by male fetuses. Our data highlight the importance of considering the ethnicity of a sample when studying 2D:4D ratios. We encourage further studies especially on the relationship between 2D:4D and female sexual orientation in different populations, and on the mechanisms by which larger number of older siblings increases the probability of male homosexuality.

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