Males Do Not Reduce the Fitness of Their Female Co-Twins in Contemporary Samples

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Lummaa et al. (2007) presented historical data collected from twins born in Finland between 1734 and 1888 which suggested that females (N = 31) born as part of an opposite sex (OS) twin pair were 25% less likely to reproduce than female twins (N = 35) born as part of a same sex (SS) pair. They hypothesized that this reduction in fitness was due to masculinization of the female fetus via prenatal effects of the hormones of a male fetus. Because such masculinization would presumably take place in modern populations as well, it would seem important to establish to what degree it does so, and if so, whether reproduction is affected. We therefore address the question of reproduction differences in individual female twins from same-sex (N = 1979) and opposite-sex (N = 913) dizygotic pairs in studies carried out in Australia, the Netherlands, and the United States. In all three samples, there were no differences in the number of children or age of first pregnancies in women from same sex pairs compared to those from opposite sex pairs. Similarly, there were no differences in psychological femininity between women from pairs of the same or opposite sex.

Keywords: fertility, hormone transfer, twinning

Lummaa et al. (2007) recently presented historical data from Finnish church registers suggesting that females born of opposite sex (OS) twin pairs were 25% less likely to reproduce than female twins born of same sex (SS) pairs. The authors suggested that the reduced fitness of females with male co-twins might be due to the hormones of the male fetus affecting the female fetus, as has been found to occur in litter-bearing mammals (Ryan & Vandenbergh, 2002). In animal studies, females that as fetuses had been located between two male fetuses were affected by the male hormones of the adjacent fetuses, which resulted in delayed maturation, longer estrus cycles, reduced sexual attractiveness to males, and shorter reproductive life spans. This suggests that human females with opposite-sex co-twins might be masculinized in their behavior or appearance, rendering them less attractive to males, and hence reducing mating opportunities and number of offspring.

Lummaa et al. gathered data from church records on twins born in five regions in Finland between 1734 and 1888. Due to a combination of famine, war, and lack of modern medical care only 35% of the 754 twin individuals identified in Lummaa et al's pre-industrial Finnish sample survived to adulthood (age 15) and only 15% survived to age 30. As a consequence of the high mortality, the number of twin individuals for each twin type was small (17 to 35 for each twin type), and the generalizability of these findings, both to other historic populations and to contemporary populations, is unclear. In fact, Lummaa et al. cited a study in modern Finland (Rose et al., 2002) that failed to find an effect of a male co-twin on age at first reproduction.

In the current article, we present evidence from three large contemporary twin studies that show no difference between females born as members of opposite-sex or same-sex twin pairs in psychological femininity, or in the number of children, number of pregnancies, or age of first child. Our evidence is based on 1979 females born in same sex (SS) and 913 born in opposite sex (OS) dizygotic twin pairs, and is derived from large twin studies in Australia, the Netherlands, and the US. Modern populations differ from pre-industrial ones in many ways. However, it is unlikely that the access to such things as modern medicine and modern means of contraception is influenced by the sex of one's co-twin. Thus, a natural control for these influences exists within the three samples. We also examine and correct for the effects of birth control, education and religion, on the data.

Received 18 June, 2008; accepted 30 June, 2008.

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For analyses of reproductive effects, samples were restricted to females above age 50 who have presumably completed their reproduction. Analyses of effects on femininity are presented both for females above age 50 and for all females.

Methods

The data in this article were collected from female participants from large twin registries in Australia, the Netherlands and the United States. All data were collected as part of broadly focused Health and Lifestyle questionnaires. All samples have previously been shown to be representative of the populations from which they were gathered (Baker et al., 1996; Distel et al., 2007; Heath et al., 1997; Kendler et al., 1995; Truett et al., 1994; Vink et al., 2004). In addition, as none of these studies focused primarily on fertility or procreation there is no reason to suspect a reporting bias in the available data.

Reproductive Information

Australian data. The twins were originally recruited for participation in one or more health and lifestyle studies from the Australian National Health and Medical Research Council Twin Registry (ATR), a volunteer register begun in 1978, which has more than 30,000 twin pairs enrolled and in various stages of active contact. The first health and lifestyle questionnaire study, conducted in 1980–1982, was sent to all available twin pairs aged over 18 at that time (that is, born prior to 1965). A second study was conducted in 1988–1990 and focused on those twins who responded to the original survey. In each questionnaire, the study participants were asked to provide information on the number, sex, and dates of birth and death of their children, and the number of full-term pregnancies, miscarriages and terminations. Participants also provided demographic data on religion, education, use of birth control, and relationship history. We used the most recent reports for each participant. Detailed information on the samples, questionnaires, and response rates can be found in (Heath & Martin, 1994; Heath et al., 2001; Jardine & Martin, 1984; Truett et al., 1994).

In the present analyses we examine the effect of twin type (same vs. opposite sex) on number of children. We also examine the total number of pregnancies (including full-term pregnancies, stillbirths, miscarriages and terminations) and age of first pregnancy. In addition, we examine the potential confounding effects of religion (Catholic vs. other), education (7–11 years vs. 12 or more years), use of birth control (ever used vs. never), number of years spent in marriage-like relationships (defined as married or cohabiting, and summed over all relationships) and presence of stepchildren (defined as whether or not the household includes stepchildren regardless of cohabitation status). Participants in these studies also completed two personality scales, a 56-item version of Eysenck's Personality Questionnaire (Eysenck et al., 1985) and a 54-item version of Cloninger's Tridimensional Personality Questionnaire (Cloninger et al., 1991). Items from these scales were used to construct a psychological femininity scale described below.

Dutch data. These were collected as part of a longitudinal survey of health, lifestyle and personality in adolescent and adult twin families registered with the Netherlands Twin Register. Since 1991, a survey has been sent out every 2 to 3 years to twins and their family members. For a detailed description see Boomsma et al. (2002, 2006). In the surveys of 1993, 1995, 1997, 2000, 2002 and 2004, the twins were asked to report the number of children they had.

For the present study, we used the data from the most recent completed questionnaire. In addition, participants were asked to provide information on the age they had their first child, marital status and family situation, years of marriage, educational attainment, religion, and the use of a birth control pill. In these analyses we examine the effect of twin type (same vs. opposite sex) on the number of children and age of first pregnancy. In addition, we examine the potential confounding effects of being religious (yes/no), being a church member (yes/no) and of the kind of religion (Catholic vs. other), as well as education (lower vs. higher education), use of birth control (ever used vs. never), number of years spent in marriage like relationships (defined as married or cohabiting as reported for the last relationship) and the presence of step children (yes/no). Participants in these studies also completed the Amsterdams Biografische Vragenlijst (ABV), which is similar in content to the Eysenck Personality Questionnaire (de Wilde, 1970). The ABV was included in the surveys of 1991, 1993, 1997, 2000 and 2002. Items from the ABV were used to compute psychological femininity and masculinity scales, as described below.

United States data. The data used in this study were collected as part of the Virginia 30,000 Health and Life-Style Questionnaire for Twins. This study is based on the kinships (N = 30,000) of 14,763 twin men and women aged 18 to 88 years. The data were collected in the late 1980s, and included assessments of political and social attitudes, socio-demographics, personality traits, and life-events. Detailed information on the sample, response rates, and sampling technique can be found in Baker et al. (1996), Eaves et al. (1999) and Truett et al. (1994). Within the questionnaire, participants were asked to provide information on the number of children. Participants also provided demographic data on religion, education and relationship history. In these analyses we examine the effect of twin type (same vs. opposite sex) on number of children. In addition, we examine the potential confounding effects of religion (Catholic vs. other), education (7–11 years vs. 12 or more years) and number of years spent in marriage-like relationships (defined as married or cohabiting and summed over all relationships). Participants in these studies also completed the Eysenck's Personality Questionnaire (Eysenck et al., 1985) which was used to construct a psychological femininity scale, as described below.

Psychological Femininity Scales

Australia. The construction of the femininity scale was based on all Australian twins (2034 male and 3876 female) in the first health and lifestyle study who responded to the two personality scales, a 56-item version of Eysenck's Personality Questionnaire (Eysenck et al., 1985) and a 54-item version of Cloninger's Tridimensional Personality Questionnaire (Cloninger et al., 1991). The 21 items on which men and women differed most in their responses were selected to form a femininity scale. Each individual who responded to at least 18 of the 21 scale items was assigned a score corresponding to the number of items he or she answered in the feminine direction. Men obtained a mean score of 10.32, SD = 3.43, N = 2015; women obtained a mean score of 13.88, SD = 3.16, N = 3819. The effect size of 1.09 for the difference was substantial, but left ample room for variation within each sex. The split-half reliability of the Femininity scale among the women, the group of principal interest for the present study, was .67, based on the responses to odd- and even-numbered items.

The Netherlands. Using the scoring algorithms outlined by Wilde (1970), femininity and masculinity scores were constructed for the surveys that included the ABV. These scales were validated previously by Wilde and are based on answer tendencies that are more likely to be expressed by males (for masculinity) and more likely to be expressed by females (for femininity). The masculinity scale consists of 29 items and the femininity scale consists of 18 items. As suggested by Wilde, these two scales were combined into one masculinity–femininity score (MF-score) by applying the formula 20 + masculinity score – femininity score. Pearson correlations for this score were high across occasions (> .68), so for the analyses in this paper, a mean score across the time points was calculated for all participants 21 years and older. Males scored significantly higher on this MF-score than females (mean 31.6, SD 4.2 for males vs. mean 27.4, SD 4.3 in females), an effect size of .99.

United States. The construction of the femininity scale was based on all twins in the study (5321 male and 9432 female) who responded to Eysenck's Personality Questionnaire (Eysenck et al., 1985). The 20 items on which men and women differed most in their responses were selected to form a femininity scale. Each individual who responded to at least 18 of the 20 items was assigned a score corresponding to the number of items he or she answered in the feminine direction. Men obtained a mean score of 9.29, SD = 3.22, N = 5150; women obtained a mean score of 11.49, SD = 3.17, N = 9031, an effect size of .68. However, only those twins for whom the co-twins sex were known were using in the femininity scale analysis reducing the sample size to 7531.

Statistical Analyses

Reproductive fitness analyses. For these analyses we considered only data collected from female dizygotic twins who were over 50 at the time of data collection. The characteristics of the three twins are summarized in Table 1. The data were analyzed using a simple

Table 1

Description of Australian, Dutch and US Samples

	Australian	Dutch	US
N individuals by twin type			
Females from SS pairs	323	137	1519
Females from OS pairs	153	57	703
Total	476	194	2222
Year of birth (range)	1897–1939	1917–1954	1894–1937
Religion (%)			
Catholic	16.8	36.6	16.5
Protestant	70.1	40.7	71.4
Jewish	0	0	4.3
Other	1.7	2.6	3.1
None	5.9	8.8	2.6
Not answered	5.5	11.3	2.2
Education (%)			
High school diploma or less	63.2	60.5	16.6
Education post high school	36.8	39.5	83.4*
Reproductive variables			
Mean number of years married (*SD*)	29.1 (12.5)	32.4 (10.1)	34.9 (10.5)
Ever used birth control (%)	35.9	70.2	NA
Stepchildren in the household (%)	2.8	1.6	NA

Note: NA = not available; *A subset of participants in the Virginia 30,000 study were recruited through an advertisement in an American Association of Retired Persons newsletter. The majority of data used in this study comes from this subset which is known to have a higher education level than the general American population (Davies & Love, 2002; Truett et al., 1994).

Table 2

Significant Covariate Effects in the Australian, Dutch and American Samples

Variable	Birth control (ever/never)	Years married	Catholic	Stepchildren	Education
Number of children					
Australian females	ns	ns	χ_1^2 = 17.63 β = .09	ns	ns
Dutch females	ns	χ_1^2 = 14.44 β = .06	*	ns	ns
American females	ns	χ_1^2 = 9.44 β = .01	χ_1^2 = 34.31 β = .61	ns	ns
Number of pregnancies					
Australian females	ns	ns	χ_1^2 = 21.18 β = 1.01	ns	ns
Age 1st pregnancy					
Australian females	ns	ns	ns	ns	χ_1^2 = 9.03 β = 1.3
Dutch females	ns	χ_1^2 = 8.12 β = –.16	ns	ns	χ_1^2 = 38.62 β = 4.38

Note: ns = nonsignificant, * being Roman Catholic was not related to the number of children, but being religious was associated with an increase in the average number of children (χ_1^2 = 4.87, 1.53 children in those not religious and 2.50 in those religious). Being a member of a church showed an even stronger association with on average 3.11 children in church members versus 1.92 children in those who were not church members (χ_1^2 = 24.52).

structural equation model to correct for the relatedness of the co-twins (who share on average half their genes and a common home environment during childhood). These analyses consider the data from both co-twins simultaneously, yielding unbiased estimates of the means and variances of same and opposite sex twin pairs through explicitly modeling the covariance between the co-twins. Mx 1.63 (Neale et al., 2006), a matrix algebra program widely used within genetic studies, was used for all analyses. We tested the significance of potential confounding variables by sequentially entering the predictors into the model as regression coefficients (fixed effects) on the mean. Significant covariates were retained for the analyses of mean differences. We then tested for differences between the twins from same and opposite pairs by comparing the fit (–2 log likelihood) of the model in which the means of these groups were allowed to differ to the fit of a model in which the means were constrained to be equal using a 1 degree of freedom likelihood ratio chi-square test.

Psychological femininity analyses. These analyses were firstly conducted using the participants from the reproductive fitness analyses, and then for all adult female twins regardless of zygosity. The means of females with female co-twins were compared those with male co-twins using Mx. The relationship between psychological femininity, age at first child and number of children was assessed by Pearson correlations.

Results

The effects of covariates on reproductive variables are shown in Table 2. For both Australian and US participants Catholicism was associated with a small increase in both the number of pregnancies and the number of children. However, within the Netherlands, religiosity rather than religious affiliation was associated with an increased number of children. For Dutch and American women, the number of children also increased slightly with each year spent in a marriage or marriage-like relationship. Education was associated with a later age at first pregnancy, but not with the other reproductive variables. The presence of stepchildren in the family or whether birth control had ever been used had no significant effect on reproduction in any sample.

Reproductive Fitness

Means and standard deviations for the number of children born, number of pregnancies and age of first pregnancy are given in Table 3.

There were no significant differences in the number of children born to women from SS and OS pairs (Australian χ_1^2 = 0.68; Dutch χ_1^2 = 0.37; US χ_1^2 = 0.06). Similarly, there were no differences in the total number of pregnancies (Australian χ_1^2 = 0.25); nor were there any differences in the age of first pregnancy (Australian χ_1^2 =1.40; Dutch χ_1^2 =0.12). Table 4 addresses the probability of reproducing at all. This did not differ between twins born in same-sex and opposite-sex pairs in any of the three samples.

Psychological Femininity

As shown in Table 5, in the full sample of females femininity did not differ between females born in same- versus opposite-sex pairs in the Australian, Dutch or US samples. Among the subsample used for the reproductive fitness analyses (the over-50s) a significant difference was seen in the Australian sample but not in the Dutch or US samples. However, this mean difference was in the opposite direction to that predicted in that femininity was higher for females with a male co-twin than for those with a female co-twin.

Table 3

Number of Children Born, Number of Pregnancies and Age of First Pregnancy, By Twin Type and Sample

	Australian			Dutch			US		
	Mean	(*SD*)	*N*	Mean	(*SD*)	*N*	Mean	(*SD*)	*N*
Number of children born									
Females from SS pairs	2.89	(1.83)	323	2.29	(1.43)	137	2.48	(1.77)	1519
Females from OS pairs	3.01	(1.64)	153	2.63	(1.83)	57	2.51	(1.73)	703
Total number of pregnancies									
Females from SS pairs	3.27	(1.97)	315						
Females from OS pairs	3.34	(1.86)	151						
Age at first pregnancy									
Females from SS pairs	24.43	(4.45)	282	25.76	(4.27)	119			
Females from OS pairs	25.01	(4.11)	139	25.16	(4.69)	48			

Note: The *N*s refer to the number of women for whom data were available for each measure. Differences between *N*s arise because some women chose not to answer some questions. For the Australian sample the number of pregnancies was corrected for multiple births, still births, miscarriages and terminations.

Table 4

Twin Individuals Reproducing, by Twin Type and Sample

Twin type	Same Sex		Opposite Sex		χ_1^{2}*
Number of Children	0	1 or more	0	1 or more	
Females					
Australian	48	275	15	138	2.3
Dutch	14	123	7	50	0.18
American	228	1291	103	600	0.5

Note: *None of these chi-squares are statistically significant: a χ^2 value of 3.84 would be required for statistical significance at $p < .05$.

As shown in Table 6, small positive correlations were observed between psychological femininity and the number of children born in the Australian and US full samples. However, this effect explains a minimal amount of variation in the number of children (r^2 = .02) and this effect was not observed in the Australian or US over-50 samples. Conversely, no effect was seen in the full Dutch sample; however, in the Dutch over-50 sample, a small but significant negative correlation was observed with more feminine women having slightly fewer children. In the Dutch data from the full sample, a significant correlation was observed suggesting that women with more feminine personalities had their first pregnancies later. This difference was not observed in Dutch over-50 sample or the Australian data. Taken as a group these results do not indicate a systematic relationship between reproductive fitness and psychological femininity.

Discussion

We found no differences in the number of children, number of pregnancies, or age of having a first child between females born of same- or opposite-sex twin pairs in three large contemporary samples in Australia, the Netherlands, and the US. Based on the data presented here, we conclude that there are currently no notable differences in reproduction between females from same-sex and opposite-sex twin pairs in modern Western populations. Nor are there differences in psychological femininity, a variable hypothesized by Lummaa et al. to explain reproductive differences.

We did find effects on reproduction for a number of the variables included as covariates in the analyses. As might be expected, religion was associated with the number of children: in the Australian and US samples, Catholics tended on average to have

Table 5

Mean and Standard Deviations of Psychological Femininity in Female Twins From Same- Versus Opposite-Sex Pairs, for Entire Sample and the Reproductive Fitness (Over 50) Subsample

	Same-sex pair			Opposite sex pair				
	Mean	*SD*	*N individuals*	*Mean*	*SD*	*N individuals*	χ_1^2	*p*
Australian								
Entire sample	13.62	3.14	3131	13.88	3.26	688	.01	.98
over 50	13.25	3.06	299	13.93	3.06	143	4.51	.03
Dutch								
Entire sample	27.76	4.37	860	27.41	4.40	557	2.00	.16
over 50	27.54	4.38	129	26.57	4.16	55	1.81	.18
US								
Entire sample	11.46	3.17	6190	11.53	3.11	1341	.50	.48
over 50	11.75	3.12	1455	11.81	3.08	668	.17	.68

Note: *p* = probability based on *t* test of the difference between means; *d* = effect size, the effect on femininity of having a female twin, in *SD* units.

Table 6

Correlation of Two Fitness-related Variables With Psychological Femininity in Female Twins, for Entire Sample and the Reproductive Fitness (Over 50) Subsample

	Number of children born			Age at first pregnancy		
	r	*N*	*p*	*r*	*N*	*p*
Australian						
Entire sample	.05	3789	.003	.01	2985	.63
Over 50	.04	442	.34	.01	388	.83
Dutch						
Entire sample	–.01	1404	.82	.18	718	.00
Over 50	–.15	177	.04	.13	156	.10
US						
Entire sample	.04	7483	<.001			
Over 50	–.03	2109	.16			

Note*:* *p* = probability (two-tailed)

about one more child than non-Catholics; in the Netherlands, it was church membership that was related to an increased number of children. This most likely reflects cultural differences in religious participation. Also in line with previous studies, more educated individuals tended to have their first child later than less educated individuals. The use of birth control did not significantly influence the number of children that a woman produced in her lifespan. Interesting from a sociobiological perspective was the lack of effect of stepchildren on any of the variables analyzed. However, clear predictions of the direction of such an effect are difficult: a sociobiologist might hypothesize fewer children born to those whose partners already had children (limiting the total family size), or alternatively, a greater number of children (ensuring the competitiveness of biological offspring).

The data used in the present study differ from that collected by Lummaa et al. in a number of important ways. First, the data presented here were collected via self-report rather than church registers (or the modern equivalents of birth certificates or medical records). However, we believe that self-report is an accurate method for assessing variables relating to the number of children an individual has. Second, the data of Lummaa et al. were population based (assuming that virtually all members in the Finnish population were registered with the Lutheran church), whereas our data come from volunteer samples. On the other hand, in the present analyses the zygosity of all twins was known, while zygosity information for same-sex twins was not available to Lummaa et al. Also, it is conceivable that having children might change the willingness of individuals to complete and return surveys. However, given that many of the Australian and US participants were ascertained prior to starting families, and that the mean number of children reported was comparable to census data, this seems unlikely.

What, then, may have caused the discrepancies between Lummaa's findings in pre-industrial samples and our own contemporary samples? There are many possibilities.

One is that the hormone-transfer phenomenon that is central to their theory on reduced reproducibility in females from opposite sex pairs does not occur in humans, or at any rate did not account for the Lummaa et al. results. The evidence of fetal hormone transfer in humans remains somewhat equivocal, with frequent failures to replicate findings. One review concludes: 'Taken as a whole, the research conducted to date on humans suggests that twins may be subject to some minor hormonal influences in utero. These hormonal influences do not appear to cause the same level of modifications in humans as they do in the other mammals with larger litters' (Ryan & Vandenbergh, 2002, pp. 673).

Another possibility is that the conditions have changed so much between pre-industrial societies and modern populations that the reproductive advantage has somehow disappeared. This is one interpretation suggested by Lummaa et al. (2007). Presumably, these authors do not believe that the diffusion of androgens through fetal membranes or its prenatal effects have changed radically during this period, as they cite a number of recent studies on finger-length ratios, auditory phenomena, craniofacial growth, as evidence that a hormone-transfer phenomenon of this kind occurs in humans. Moreover, they propose masculinized attitudes/behaviors in females with prenatal androgen exposure as a reason for decreased marriage probability (Lummaa et al., 2007).

Is it the case that that masculinization of females by prenatal androgens indeed does occur, but is no longer affecting reproductive success in modern societies, although it did in pre-industrial Finland? Arguing against the first premise is the fact that women in our study with male co-twins were not substantially more masculine or less feminine than those with female co-twins, a result also obtained in the contemporary Finnish study (Rose et al., 2002). As to the second premise, we would need to suppose that the influence of psychological femininity on reproduction has decreased markedly, and may have reversed, in order to explain the inconsistent patterns of correlations we observe between number of children and femininity.

In summary, although a replication of Lummaa et al. results is desirable in order to confirm that in the past females with male co-twins had reduced reproductive success, our findings indicate that females from opposite-sex twins in modern-day societies do not experience diminished reproductive success in comparison with females from same-sex pairs.

Acknowledgments

The authors would like to thank the twins and their families for participation. In addition we would like to acknowledge the following funding sources:

- *Australian data*: NIH grants AA10249, AA07728, AA11998 from the U.S. National Institute on Alcohol Abuse and Alcoholism and DA12854 from the U.S. National Institute on Drug Abuse.
- *Dutch data*: This study was supported by The Netherlands Organization for Scientific Research (NWO-MW 904-61-193, NWO 575-25-006, NWO 904-61-090, NWO 985-10-002, NWO 480-04-004), the Borderline Personality Disorder Research Foundation.
- *US data:* USDHHS grants AA06781, MH40828, MH068521 and a gift from RJR Nabisco.

SEM was supported by an Australian NHMRC Sidney Sax Fellowship (443036). PKH was supported in part by US NIH Grant MH20030-09.

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