

Original Article

Sex-of-offspring Differences Between Mothers

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Abstract: Evolutionary biologists and psychologists have long been aware of maternal effects on the secondary sex ratio in mammals. Up till now these have appeared inconsistent but re-analysis of the evidence, focusing on normally distributed maternal testosterone and its physiological and behavioral *sequelae*, reveals some support for the existence of sex-of-offspring differences between mothers. In addition to the animal studies showing a relationship between maternal, testosterone-based dominance and the secondary sex ratio, research on human mothers shows sex-of-offspring differences in a range of testosterone-related attributes (physiological, behavioral and cognitive) measured at varying times from before the child was conceived to the mother's maturity. Further exploration of these differences might help elucidate the problems surrounding sex determination in mammals.

Keywords: Maternal dominance, maternal testosterone, sex allocation

Introduction

Reproductive physiologists commonly regard the determination of the sex of the mammalian offspring as a matter of chance, depending on whether an X- or a Y-chromosome-bearing spermatozoon from the father is the first to penetrate the outer layer of the ovum. However, over a period of 25 years, evolutionary biologists have shown that in a number of mammalian species the sex ratio of the offspring can vary significantly, depending on within-sex variance in maternal dominance. Scores of studies have documented statistically significant atypical offspring sex ratios as they relate to this maternal characteristic in eutherian mammals (Brown, 2001; Sheldon and West, 2004). The findings in general indicate that in the wild, dominant mothers, usually also in good condition, have more male offspring.

For a long time, results appeared inconsistent, forcing many theorists to conclude that the findings must be a consequence of sampling error (Brown and Silk, 2002). However, by referring to the maternal dominance hypothesis the seemingly conflicting data

may be reconciled. Briefly, the hypothesis may be described as follows. A dominant female will command priority access to resources (and hence will often be in good condition). Dominance, in turn is a behavioral characteristic which is underpinned by testosterone. Individual differences in the level of maternal testosterone are hypothesized to influence the determination of the sex of the offspring (Grant, 2007), and there is already some evidence to show that the mother's follicular testosterone could be related to the subsequent sex of the offspring, with higher levels being related to the conception of males (Grant and Irwin, 2005). A possible proximate mechanism has recently been demonstrated. Bovine ova that matured *in vivo* in follicular fluid with high levels of maternal testosterone were subsequently significantly more likely to be fertilized *in vitro* by Y-chromosome-bearing spermatozoa (Grant, Irwin, Standley, Shelling, and Chamley, 2008). This may mean that the ovum emerges, each menstrual or estrus cycle, already adapted to receive an X- or a Y-chromosome-bearing spermatozoon.

If replicated, such a mechanism would mean that mammalian mothers have some influence over the sex of the offspring they conceive, according to the level of maternal testosterone. If so, there should be differences which can be defined, observed and measured between mammalian mothers that conceive male offspring and those that conceive female offspring. In particular, in humans it should be possible to divide mothers in general (and mothers of single sex sibships in particular) into those more likely to conceive (or have conceived) male infants and those more likely to conceive (or have conceived) female infants, according to testosterone-related maternal differences.

Dominance and testosterone

Dominance is one of the "personality" characteristics that humans share with animals (Buss, 1988, p.2). In both male and female animals and humans, testosterone increases the likelihood that an individual will behave in a dominant way (Rose, Bernstein, and Holaday, 1971; Mazur and Booth, 1998; Grant and France, 2001; Grant, 2005). In animals this usually means displacement and intimidation of rivals. Highly dominant animals are controlling and use this characteristic to ensure priority access to desirable resources (Sapolsky and Ray, 1989). In humans dominance is correlated with being independent, tough, controlling, initiating and risk-taking (Sadalla, Kenrick, and Vershure, 1987). In human females documented within-sex differences attributable to variations in female testosterone give rise to individual differences in a variety of behaviors associated with dominance. These include self-directed and action-oriented behaviors (Baucom, Besch, and Callahan, 1985), a capacity for unprovoked violence (Dabbs, Ruback, Frady, Hopper, and Sgoutas, 1988), dominance-related low smiling and over-estimation of own rank (Cashdan, 1995) and masculinized behavior (Udry, Morris, and Kovenock, 1995). In other female primates, Beehner, Phillips-Conroy, and Whitten, (2005) found that dominance status was significantly correlated with testosterone, and Bouissou (1978) found the same in ungulates.

Although the chemistry and functions of hormones are extremely complex, especially where these interact between neurochemistry and reproductive physiology, there are some basic facts about female testosterone which can be called on to explore its

potential role in sex determination. Female serum testosterone levels are one tenth those of males, and assumed to be normally distributed (Jeffcoate, 1993). An individual's level of testosterone arises from both genetic and environmental factors (further divided into both uterine and post-uterine environments), and intra-individual differences occur as testosterone fluctuates over time according to both physiological (e.g. age) and environmental factors (Christiansen, 1998).

Within-sex differences in testosterone-related characteristics and behavior also appear, in part, to be consequent upon exposure to fetal and maternal testosterone *in utero*. For example, Hines et al (2002) found significant behavioral differences among 3.5 year old girls (n=337) according to testosterone exposure during gestation. Both between and within-sex testosterone-related cognitive differences have also been found (Grimshaw, Sitarenios, and Finegan, 1995; Knickmeyer and Baron-Cohen, 2006).

There is an important difference between males and females at the high end of the dominance/testosterone range. In males, high dominance and high testosterone occur together, but in females at the higher end of normal testosterone levels, dominance is attenuated by anxiety, increased emotionality and hypochondriasis (Cattell, Eber, and Tatsuoka, 1970, p.85). This phenomenon is explained at least in part by sex differences in the physiological origin of testosterone. In males it is generated in the testes, whereas in females it is manufactured in the peripheral tissues and is under the control of the adrenal glands (Christiansen and Hars, 1995). Thus in females, but not in males, testosterone is positively correlated with cortisol and the stress reaction (Banks and Dabbs, 1996).

The implications of this phenomenon may be far-reaching. If the female's reaction to chronic stressors in the environment includes, in addition to a rise in cortisol, a sustained rise in testosterone, this mechanism could provide the basis for both inter- and intra-individual variation in the hormonal secretions associated with a proximate mechanism for sex predetermination, thus providing the physiological vehicle by which the mother could achieve a measure of adaptive control of the sex of her offspring (Grant, 2007).

Methodological issues

The hypothesis is that mothers of sons (that is, females hypothesized to have levels of testosterone higher than the mean for females), would have testosterone-related characteristics that differentiated them from mothers of daughters (females hypothesized to have testosterone levels lower than the mean). This paper explores this question by asking if there is any existing evidence to suggest that mothers with characteristics associated with higher testosterone levels are more likely to conceive male offspring, and conversely if mothers with characteristics already shown to be related to lower levels of testosterone have an increased chance of conceiving female offspring.

If the sex of the offspring in mammals in general, and in humans in particular, were a matter of chance, it would be unlikely that mothers of sons could be reliably differentiated from mothers of daughters along any dimension. However, if maternal testosterone is implicated in sex-predetermination there should be evidence that mothers (particularly mothers of single sex sibships) differ in ways that can be predicted on the basis of differences in both their pre- and post-pregnant testosterone levels and the putative

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effects of these testosterone levels on their behavior.

Below is a summary of existing evidence for this hypothesis. Table 1 lists the characteristics and behaviors which have been shown to relate to sex-of-offspring differences between mothers. The numbers in Table 1 are repeated below. Item 1 has been documented across a wide range of species, including humans. Items 2 to 10 apply to human mothers only and are listed in chronological order of the mother's lifespan (i.e. from before the conception of her offspring until her maturity). Data have been drawn from a range of disciplines. Animal behaviorists, anthropologists, evolutionary biologists, cognitive, developmental and evolutionary psychologists and economists have all contributed data on atypical sex ratios. Researchers who find statistically significant differences in the secondary sex ratio in humans usually offer an explanation for their findings which does not involve a maternal influence; however explanations which draw on pre-existing maternal differences appear, in most cases, to be equally compatible with the data. In the examples cited below the findings have been reinterpreted to show how they could support the maternal dominance hypothesis.

Table 1. Characteristics showing sex-of-offspring differences between mothers according to dominance-related high or low testosterone (t.) (Numbers denote discussion in the text.)

<u>High t. mammalian mothers</u>	<u>Low t. mammalian mothers</u>
<i>More likely to conceive males</i> and 1. be dominant in behavior and thus more likely to be in good condition	<i>More likely to conceive females</i> and be non-dominant in behavior and thus more likely to be in poorer condition
<i>In addition, there may be further t.-related differences in human mothers</i>	
<u>High t. human mothers</u>	<u>Low t. human mothers</u>
<i>More likely to:</i> 2. be angry or anxious 3. score higher on spatial ability 4. stimulate baby 5. be anxious when baby 3 months 6. tolerate risk-taking behavior 7. have lower waist:hip ratio 8. have lower 2D:4D ratio 9. be politically right wing 10. not be divorced	<i>More likely to:</i> stay calm score lower on spatial ability respond to baby be calm when baby 3 months not tolerate risk-taking behavior have higher waist:hip ratio have higher 2D:4D ratio be politically left wing be divorced

1. Maternal dominance and good condition are related to the conception of male offspring.

One of the first studies in this area showed that dominant red deer hinds had more male offspring (Clutton-Brock, Albon, and Guinness, 1984). Most subsequent studies have also been done on ungulates (Sheldon and West, 2004), but there are also many studies of primates (Cameron, 2004), including humans (Grant, 1994a; Gibson and Mace, 2003). Almost all the studies indicate that females that are more dominant than the other females in their group are more likely to conceive male offspring.

In addition, “good condition” first implicated in sex allocation by Trivers and Willard (1973) is viewed by some as a precursor (Cameron, 2004) and by others as a consequence (Grant, 2003) of dominance in females. Recently, Cameron and Linklater (2007) found that a change in condition may be a better predictor of the sex of the offspring; that is, mares gaining condition were more likely to give birth to a male. An improvement in condition is also likely to play a part in the explanation for the wartime effect on secondary sex ratios in humans (Graffelman and Hoesktra, 2000). Although the wartime phenomenon has been known for decades (MacMahon and Pugh, 1954) it has recently been shown that these raised secondary sex ratios in humans occur only at the end of wars (Ellis and Bonin, 2004). Several different explanations have been offered for this effect. One is that at the end of war, mothers retain the excess numbers of stress-related, high-maternal- testosterone-induced male conceptions because of the improving conditions (Grant, 2007).

2. Mothers of sons are more likely to be angry and anxious

Field et al (2002) recruited 166 women during the second trimester of pregnancy, and measured “mood.” Based on the scores, they divided the whole group by median split into high and low-anger groups and found that a significantly greater number of angry, anxious mothers gave birth to male offspring even though there were more female than male babies born to the group as a whole. Low anger mothers had 35.2% male and 64.8% female babies; high anger mothers had 58.1% male and 41.9% female babies; $\chi^2(1) = 5.09$, $p < 0.02$. The angry–anxious mothers were also found to have significantly higher cortisol both pre- and post-natally as well as significantly higher levels of adrenaline and dopamine prenatally. If they also had more testosterone (as would be expected; Christiansen, 1998) both results would make sense. First, fewer angry–anxious mothers would agree to take part in the research in the first place, and of those that did, more would give birth to male infants.

3. Mother of sons scored higher on spatial ability

There is a considerable body of evidence documenting sex differences in cognitive ability, with males scoring higher on measures involving spatial manipulation and females scoring higher on many aspects of verbal ability. There is also evidence of within-sex

differences in these abilities. For example, Gouchie and Kimura (1991) found that normal women with higher than the average (for women) salivary testosterone levels did better than women with lower testosterone levels on tests associated with male superiority (mathematical reasoning and mental rotation tests).

If so, mothers of sons might differ from mothers of daughters along similar cognitive dimensions. Looking for evidence of “mental impairment” during pregnancy, jokingly referred to as “baby brain,” Vanston and Watson (2005) “tracked women’s cognitive performance from early pregnancy through to postnatal resumption of menstruation”(p. 779). They found that women pregnant with male fetuses ($n = 26$) performed significantly better than women pregnant with female fetuses ($n = 13$) on three difficult cognitive tasks - Computation Span [$F(1,37) = 9.414, p = 0.004$]; Listening Span [$F(1,37) = 7.315, p = 0.010$]; and the Shepard Metzler Mental Rotation Task [$F(1,37) = 5.419, p = 0.025$]. Although other tests showed no effect by sex of fetus, these tests showed “a large and enduring effect” (p. 779).

The authors were at a loss to explain their findings, having ruled out all explanations based on (other) pre-existing differences between the mothers. However, their results may be accommodated by the maternal dominance hypothesis which suggests that the very differences these authors found were part of a constellation of testosterone-related differences between women which may have led to an increased likelihood of conceiving a male in the first place.

4. Mothers of male infants initiate interactions with their neonates

From birth onwards there continue to be documented behavioral differences between mothers of sons and mothers of daughters, but there is also, post-natally, an important interpretive difficulty. To what extent do the differences in the mothers’ behaviors reflect sex-stereotyping and differential socialization of children, rather than differences in the mothers themselves? This problem has been fully described in a review of studies of mothers’ interactions with their newborn infants (Grant, 1994b). In an attempt to document the origins of sex-stereotyping, several independent teams of researchers (e.g.; Gottfried, Seay, and Wismar, 1987; Hwang, 1978; Lewis, 1972; Moss, 1967; Winberg and de Chateau, 1982;) studied mother-neonate and mother-infant interaction and found statistically significant differences in mothers’ behaviors according to the sex of their infants. For example Moss (1967) found that mothers of sons initiated interactions with their three week old infants, holding them upright by the trunk and stimulating them, even goading them into making a response; whereas the mothers of daughters interacted with their infants in a more responsive way, reflecting their infants’ vocalizations and setting up timed interactions with them, consistent with basic human communication patterns. Winberg and de Chateau (1982) reported very similar findings when the babies were 1-2 days old and again at 3 months. Hwang (1978), Robin (1982), Gottfried et al (1987) and Millot, Filiatre, and Montagner (1988) all found that mothers of daughters smiled and talked to their babies significantly more than mothers of sons did, as well as stroking them and having more skin-to-skin contact with them.

Although many of the authors believed they had found evidence of very early sex

stereotyping by the mothers, there is an alternative or additional explanation. Both these patterns of maternal behavior are consistent with the hypothesized dominant/non-dominant dichotomy between mothers of sons and mothers of daughters, with dominant mothers stimulating their babies more and initiating interactions with them, while the more nurturant, non-dominant mothers appeared to be more verbal and more socially responsive towards their infants.

5. Mothers of male infants have higher stress when baby is 3 months.

In a study of 90 pairs of mothers and fathers Scher and Sharabany (2005) found that mothers of 3-month-old baby boys reported a higher level of stress than mothers of 3-month old baby girls. Even though overall levels of parenting stress were low in this sample of normal babies and parents, the researchers found that mothers of sons' scores on a measure of parenting stress were significantly higher those of mothers of daughters, $F(1,88) = 8.36, p < .01$. Partner support, education, birth order and other relevant variables did not differ. Neither the mother's age, nor her years of schooling could account for the difference. The authors concluded that at the age of three months, "the child's gender plays a role in the parenting experience," (p. 203) with mothers of sons reporting "a higher level of stress than did mothers of daughters" (p. 211). The finding corroborated earlier work (e.g. Feldman, 2003) in which mothers were found to "express higher attunement when interacting with their daughters than they do with their sons"(p. 211). So far there has been little consensus concerning an explanation for these sex-of-infant differences in mother-infant interactions, but the maternal dominance hypothesis adds another dimension to the discussion by suggesting that the mothers themselves may differ. Male infants are known to be more irritable (Moss, 1967). Thus the effect found by Scher and Sharabany (2005) may have arisen from a reciprocal interaction between the mother and her baby – not only were the male babies likely to be more fractious, but their highly-strung mothers may have been more likely than the mothers of female babies to be made anxious by their inconsolable crying.

6. Mothers of sons tolerate more risk-taking behavior

In an ingenious experiment Morrongiello and Dawber (2000) showed videotapes of children performing risky behaviors to mothers with either two sons or two daughters (the older child being aged 6 – 8 years). They found that mothers of sons ($n=20$) made more statements encouraging risk-taking behaviors than did mothers of daughters ($n=20$). On viewing the risky behaviors, the average number of maternal verbalizations expressing caution for boys was 0.7 ($SD = 0.9$) and for girls 3.9 ($SD = 1.8$); the average number of maternal verbalizations expressing encouragement for boys was 3.0 ($SD = 2.6$), while for girls it was 0.5 ($SD = 1.2$). The average number of times the mothers stopped the tape for risk-taking behaviors (out of a possible 5) was 1.2 ($SD = 0.9$) for boys, and 4.4 ($SD = 0.6$) for girls. Overall mothers responded significantly more frequently to girls' than boys' risk-taking behaviors, $t(38) = 13.60, p < .001$.

The authors conceptualized these sex differences in risk taking behavior as "jointly

determined by biological and socialization influences,” (p. 101) citing the known effect of exposure to prenatal testosterone as a contributing factor to the risk-taking behavior of boys. The claim that mothers may be acting in stereotypic ways may be more persuasive as the children grow older, but here it is argued that although stereotypic views may be held by the mothers, this may not be the only reason for the differences in their behavior. Instead, or as well, the mothers themselves may be different. They may have higher testosterone levels and thus different attitudes to risk-taking behavior in their children, mothers with higher testosterone levels being more likely to take risks themselves and to tolerate, or even encourage, their sons to do so too. A second study using this methodology could help solve the problem of whether it is maternal differences or stereotypic socialization which is producing the effect (see Further Studies, below).

7. Mothers of sons have lower waist:hip ratios

Singh (1993) suggested there could be a universally attractive female body shape which reflected not only symmetry, but also a marked difference in circumference between the hips and the waist. In exploring the biological basis of these variations it was found that female testosterone was likely to be one of the main variables (Evans, Hoffmann, Kalkhoff, and Kissebah, 1983).

Recognizing that female testosterone was also likely to be related to the conception of male offspring, Manning, Anderton, and Washington (1996) measured weight, waist circumferences, and hip circumferences, and calculated waist:hip ratios in a sample of 102 women aged 35-55 years having between them 128 sons and 115 daughters. Their results showed that all the measures were positively correlated with the proportion of male offspring. Using multiple regression analysis, their analysis showed that waist circumference was a significant predictor of percent sons per family ($\beta = 0.75$, $t = 3.17$, $p = 0.002$). Singh and Zambarano (1997) replicated this study and also found that women with android body fat distribution were significantly more likely to have given birth to sons.

8. Mothers of sons have lower 2D:4D ratios

In another indicator of individual differences in testosterone likely to have originated from exposure to androgens in utero, researchers have measured the lengths of the second and fourth digits and again calculated a ratio, the 2D:4D ratio. In 2002, Manning, Martin, Trivers, and Soler conducted a large, ($n = 456$) cross-cultural study (Spanish, English, and Jamaican) that found a statistically significant relationship between the 2D:4D ratio and sex of offspring. Although both men and women took part, there was no significant difference in their 2D:4D ratios; in the Spanish sample results were identical. Both men and women with lower 2D:4D ratios had significantly higher offspring sex ratios. The women, assumed to have been exposed to higher levels of androgens in utero gave birth to significantly more sons.

9. Mothers of sons may be more politically right wing

Recently, economists have found statistically significant variations in the human secondary sex ratio related to social and political phenomena. In an extensive analysis of voting intentions in Great Britain (66,628 observations from 1991-2004) they found that the sex of the children “shaped their parents political preferences” (Oswald and Powdthavee, 2006, p. 1). The higher the number of daughters in the family, the more likely the parents would be left-wing voters, with the birth of each additional daughter increasing the likelihood by 2%-3%.

Oswald and Powdthavee (2006) suggested that “one way to rationalize the paper’s empirical findings” was to “appeal to evolutionary principles” (p. 5). They referred to the Trivers and Willard hypothesis but found no evidence of a predictive aspect to their data. However, what their data did show was that women, especially mothers of daughters, placed more emphasis on co-operation and care of others, while men (and to a lesser extent mothers of sons) placed more emphasis on competition and striving.

These differences were reflected in the economists’ findings that “the single most important issue to males is lower taxes” (p. 14). In contrast, the single most important issue for females was the quality of the National Health Service (Oswald and Powdthavee, 2006). Hence there was a tendency for parents of daughters, who presumably had their children’s best interests at heart, to switch to left wing voting, which favors higher taxes to pay for community benefits. Conversely, parents of sons had a tendency to switch to right wing voting, which favors lower taxes and more individual competition and independence.

10. Mothers of sons are less likely to divorce

Economists have also found that “having a son relative to having a daughter increases the likelihood that a marriage will remain intact” (Lundberg and Rose, 2003, p. 333). And in another large study of pooled population data ($n = 86,436$), Norberg (2004) found that there were significantly fewer boys than girls among children whose parents were living apart. Women who were living with their partner had 51.5% male offspring and women who were on their own had 49.9% male offspring, $\chi^2(1) = 16.77, p < 0.0001$.

Dahl and Moretti (2004) interpreted these findings as evidence of son preference, partly on the grounds that parents who knew they were having a boy (following ultrasound) were more likely to get married before the birth of the child than parents who were expecting a girl. Although some of the economists offered tentative explanations for their findings based on sex allocation theory and son preference, these may not be the only factors. Although unexplored at the present time, an additional contributor to these data, based on the maternal dominance hypothesis, would draw on the hypothesized differences between the mothers. The more dominant women may have put more pressure on their men to stay and support them (and their babies) than the less dominant women pregnant with girls. It is not unlikely that the same pressures could occur in marriages running into difficulties, thus suggesting an explanation for the over-representation of mothers of daughters in the divorce figures as well.

Further studies

Methodologically, studies of sex-of-offspring differences in human mothers could take (at least) two different forms. In the first, investigations might be carried out to establish whether or not there are, as suggested here, dominance and/or testosterone-related differences between mothers of sons and mothers of daughters. Since such investigations would, of necessity, be retrospective, it might be preferable to compare and work with women who have given birth to one sex only, i.e. mothers of single sex sibships, as they are more likely to have retained the physiological differences that originally predisposed them to conceive that sex. (Women who have given birth to both male and female infants are likely to be less clearly differentiated along the relevant dimensions.)

As always, the most interesting studies would be those which made it possible to discriminate between competing explanations for the findings. That is, if sex-of-offspring differences between mothers were found, a well-designed study might help establish whether these should be attributed to sex stereotyping or to maternal differences. An example of a study in which such differences might be disentangled would be a variation of the Morrongiello and Dawber (2000) study (7) in which a group of mothers was asked to respond to a videotape of a child performing risky behaviors; but instead of responding to a child of the same sex they were parenting, they could be asked to respond to a videotape showing a child of the opposite sex. Researchers would look to see if mothers of daughters continued to respond more frequently to risky behaviors when viewing a boy and vice versa. If mothers of daughters maintained their high intervention rate even when viewing boys, this might suggest a maternal, rather than a societal factor was operating.

A second group of studies might take a predictive form, thereby investigating the hypothesis that it is mothers' pre-conception testosterone levels that are relevant to the determination of the sex of their offspring. Prospective mothers could be tested for dominance, or any of its related characteristics, within eight weeks either side of conception. The earlier time limit is necessary to minimize the likelihood of environmental fluctuations causing differences in baseline testosterone levels leading up to conception, and the later time limit to avoid the possibility of a confounding effect of fetal and other hormones. For a model for this kind of study see Grant (1992).

If one of the roles of the psychologist is to point out to physiologists what there is to explain, then further information about the differences between mothers who conceive male infants and mothers who conceive female infants, could contribute to a resolution of the long-standing problem of what determines the sex of the offspring and ultimately to the overall problem of whether or not there is a mechanism for the adaptive control of the sex ratio in mammals.

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References

Banks, T. and Dabbs, J. M. (1996). Salivary testosterone and cortisol in a delinquent and

- violent urban subculture. *The Journal of Social Psychology*, 136, 49-56.
- Baucom, D. H., Besch, P. K. and Callahan, S. (1985). Relation between testosterone concentration, sex role identity and personality among females. *Journal of Personality and Social Psychology*, 48, 1218-1226.
- Beehner, J. C., Phillips-Conroy, J. E. and Whitten, P. L. (2005). Female testosterone, dominance rank and aggression in an Ethiopian population of hybrid baboons. *American Journal of Primatology*, 67, 101-119.
- Bouissou, M. F. (1978). Effects of testosterone propionate on dominance relationships in a group of cows. *Hormones and Behavior*, 11, 388-400.
- Brown, G. R. (2001). Sex-biased investment in nonhuman primates: Can Trivers and Willard's theory be tested? *Animal Behaviour*, 61, 683-694.
- Brown, G. R. and Silk, J. B. (2002). Reconsidering the null hypothesis: Is maternal rank associated with birth sex ratios in primate groups? *Proceedings of the National Academy of Science USA*, 99, 11252-11255.
- Buss, A. H. (1988). *Personality, evolutionary heritage and human distinctiveness*. Hillsdale, NJ: Lawrence Erlbaum.
- Cameron, E. Z. (2004). Facultative adjustment of mammalian sex ratios in support of the Trivers-Willard hypothesis: Evidence for a mechanism. *Proceedings of the Royal Society of London B*, 271, 1723-1728.
- Cameron, E. Z. and Linklater, W. (2007). Extreme sex variation in relation to change in condition around conception. *Biology Letters*, 3, 395-397.
- Cashdan, E. (1995). Hormones, sex and status in women. *Hormones and Behavior*, 29, 354-366.
- Cattell, R. B., Eber, H. W. and Tatsuoka, M. M. (1970). *Handbook for the Sixteen Personality Factor Questionnaire*, Princeton, NJ: Princeton University Press.
- Christiansen K. (1998). Behavioural correlates of testosterone. In E. Nieschlag and H. M. Behre (Eds.), *Testosterone: Action, deficiency substitution* (pp 107-142) (2nd ed) Heidelberg: Springer.
- Christiansen K. and Hars, O. (1995). Effects of stress anticipation and stress coping strategies on salivary testosterone levels. *Journal of Psychophysiology*, 3, 264.
- Clutton-Brock, T. H., Albon, S. D., and Guinness, F. E. (1984). Maternal dominance, breeding success and birth sex ratios in red deer. *Nature*, 308, 358-360.
- Dabbs, J. M., Ruback, R. B., Frady, R. L., Hopper, C. H. and Sgoutas, D. S. (1988). Saliva testosterone and criminal violence among women. *Personality and Individual Differences*, 9, 269-275.
- Dahl, G. B., and Moretti, E. (2004). The demand for sons: Evidence from divorce, fertility, and shotgun marriage. *NBER Working Paper w10281*, Cambridge, MA: National Bureau of Economic Research.
- Ellis, L., and Bonin, S. (2004). War and the secondary sex ratio: Are they related? *Social Science Information*, 43, 115-122.
- Evans, D. J., Hoffmann, R. G., Kalkhoff, R. K., and Kissebah, A. H. (1983). Relationship of androgenic activity to body fat topography, fat cell morphology, and metabolic aberrations in premenopausal women. *Journal of Clinical Endocrinology and Metabolism*, 57, 304-310.

- Feldman, R. (2003). Infant-mother and infant-father synchrony: The coregulation of positive arousal. *Infant Mental Health Journal*, 24, 1-23.
- Field T., Diego, M., Hernandez-Reif, M., Salman, F., Schanberg, S. Kuhn, C. Ynado, R., and Bendell, D. (2002). Prenatal anger effects on the fetus and neonate. *Journal of Obstetrics and Gynecology*, 2, 260-266.
- Gibson, M. A., and Mace, R. (2003). Strong mothers bear more sons in rural Ethiopia. *Proceedings of the Royal Society of London B (Suppl.)*, 270, S108-S109.
- Gottfried, N. W., Seay, B. M., and Wismar, K. (1987). Neonatal sex and birth-order effects on behaviors of mothers and temporary caretakers during bottle-feeding. *Journal of Genetic Psychology*, 148, 479-487.
- Gouchie C. T., and Kimura D. (1991). The relation between testosterone levels and cognitive ability patterns. *Psychoneuroendocrinology*, 16, 323-334.
- Graffelman, J., and Hoekstra, R. F. (2000). A statistical analysis of the effect of warfare on the human secondary sex ratio. *Human Biology*, 72, 433-445.
- Grant V. J. (1992). The measurement of dominance in pregnant women by use of the Simple Adjective Test. *Personality and Individual Differences*, 13, 99-102.
- Grant, V. J. (1994a). Maternal dominance and the conception of sons. *British Journal of Medical Psychology*, 67, 343-351.
- Grant, V. J. (1994b). Sex-of-infant differences in mother-infant interaction: A reinterpretation of past findings. *Developmental Review*, 14, 1-26.
- Grant, V. J. (2003). The maternal dominance hypothesis: questioning Trivers and Willard. *Evolutionary Psychology* 1, 96-107.
- Grant, V. J. (2005). Dominance, testosterone and psychological sex differences. In J.W. Lee (Ed.) *Psychology of Gender Identity*. New York: Nova Science. (pp. 1-28.)
- Grant, V. J. (2007). Could maternal testosterone levels govern mammalian sex ratio deviations? *Journal of Theoretical Biology*, 246, 708-719.
- Grant, V. J., and France, J. T. (2001). Dominance and testosterone in women. *Biological Psychology*, 58, 41-47.
- Grant, V. J., and Irwin, R. J. (2005). Follicular fluid steroid levels and subsequent sex of bovine embryos. *Journal of Experimental Zoology*, 303A, 1120-1125.
- Grant, V. J., Irwin, R. J., Standley, N. T. Shelling, A. N., and Chamley, L. W. (in press). Sex of bovine embryos may be related to mothers' preovulatory follicular testosterone. *Biology of Reproduction*.
- Grimshaw, G. M., Sitarenios, G., and Finegan, J. (1995). Mental rotation at 7 years: Relations with prenatal testosterone levels and spatial play experiences. *Brain and Cognition*, 29, 85-100.
- Hines M., Golombok, S., Rust, J., Johnston K. J., Golding, J., and Avon Longitudinal Study of Parents and Children Study Team. (2002). Testosterone during pregnancy and gender role behavior of preschool children: A longitudinal, population study. *Child Development*, 73, 1678-1687.
- Hwang, C.-P. (1978). Mother-infant interaction: Effects of sex of infant on feeding behavior. *Early Human Development*, 2, 341-349.
- Jeffcoate, W. (1993). *Lecture Notes on Endocrinology* (5th edition), Oxford: Blackwell Scientific, (p.204).

- Knickmeyer, R. C., and Baron-Cohen, S. (2006). Fetal testosterone and sex differences. *Early Human Development*, 82, 755-760.
- Lewis, M. (1972). State as an infant-environment interaction: An analysis of mother-infant interaction as a function of sex. *Merrill-Palmer Quarterly*, 18, 95-121.
- Lundberg, S., and Rose, E. (2003). Child gender and the transition to marriage. *Demography*, 40, 333-349.
- MacMahon, B., and Pugh, T. F. (1954). Sex ratio of white births in the United States during the Second World War. *American Journal of Human Genetics*, 6, 284-292.
- Manning, J. T., Anderton, R., and Washington, S. M. (1996). Women's waists and the sex ratio of their progeny: Evolutionary aspects of the ideal female body shape. *Journal of Human Evolution*, 31, 41-47.
- Manning, J. T., Martin, S., Trivers, R. L., and Soler, M. (2002). 2nd to 4th digit ratio and offspring sex ratio. *Journal of Theoretical Biology*, 217, 93-95.
- Mazur, A., and Booth, A. (1998). Testosterone and dominance in men. *Behavioral and Brain Sciences*, 21, 353-397.
- Millott, J. L., Filiatre, J. C., and Montagner, H. (1988). Maternal tactile behavior correlated with mother and newborn infant characteristics. *Early Infant Development*, 16, 119-129.
- Morrongiello B. A., and Dawber, T. (2000). Mothers' responses to sons and daughters engaging in injury-risk behaviors on a playground: implications for sex differences in injury rates. *Journal of Experimental Child Psychology*, 76, 89-103.
- Moss, H. A. (1967). Sex, age, and state as determinants of mother-infant interaction. *Merrill-Palmer Quarterly*, 13, 19-36.
- Norberg, K. (2004). Partnership status and the human sex ratio at birth. *Proceedings of the Royal Society of London B*, 271, 2403-2410.
- Oswald, A. J., and Powdthavee, N. (2006). Daughters and left-wing voting. Discussion Paper No. 2103, Institute for the Study of Labour (IZA), Bonn, Germany. <http://www.iza.org>
- Robin, M. (1982). Neonate-mother interaction: Tactile contacts in the days following birth. *Early Child Development and Care*, 9, 221-236.
- Rose, R. M., Bernstein, I.S., and Holaday, J. W. (1971). Plasma testosterone, dominance rank and aggressive behaviour in a group of male rhesus monkeys. *Nature*, 231, 366.
- Sadalla, E. K., Kenrick, D. T., and Vershure, B. (1987). Dominance and heterosexual attraction. *Journal of Personality and Social Psychology*, 52, 730-738.
- Sapolsky, R. M., and Ray, J. C. (1989). Styles of dominance and their endocrine correlates among wild olive baboons (*Papio anubis*). *American Journal of Primatology*, 18, 1-13.
- Scher, A., and Sharabany, R. (2005). Parenting anxiety and stress: Does gender play a part at 3 months of age? *Journal of Genetic Psychology*, 166, 203-213.
- Sheldon, B. C., and West, S. A. (2004). Maternal dominance, maternal condition, and offspring sex ratio in ungulate mammals. *The American Naturalist*, 163, 40-54.
- Singh, D. (1993). Adaptive significance of female physical attractiveness: Role of waist-to-hip ratio. *Journal of Personality and Social Psychology*, 65, 293-307.

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- Singh, D., and Zambarano, R. J. (1997). Offspring sex ratio in women with android body fat distribution. *Human Biology*, 69, 545-556.
- Trivers, R. L., and Willard, D. E. (1973). Natural selection of parental ability to vary the sex ratio of offspring. *Science*, 179, 90-92.
- Udry, J. R., Morris, N. M., and Kovenock, J. (1995). Androgen effects on women's gendered behavior. *Journal of Biosocial Science*, 27, 359-368.
- Vanston, C. M., and Watson, N. V. (2005). Selective and persistent effect of foetal sex on cognition in pregnant women. *Neuroreport*, 16, 779-782.
- Winberg, J., and de Chateau, P. (1982). Early social development: Studies of infant mother interaction and relationships. In W. W. Hartup (Ed.), *Review of Child Development Research* (Vol. 6) Chicago: University of Chicago Press.