

# Length of the follicular phase, time of insemination, coital rate and the sex of offspring

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**The penetrability of cervical mucus improves over the follicular phase. When the length of the follicular phase varies due to variation in the timing of the luteinizing hormone surge, mucus penetrability will also improve as the phase lengthens. As selection for Y spermatozoa decreases with improvements in mucus penetrability, sex ratios at conception should decline in longer follicular phases. Sex ratios should also decline as the time of insemination approaches ovulation unless hormonally-induced improvements in penetrability are reduced by the debris left by earlier inseminations.**

**Key words:** cervical mucus/coital rate/follicular length/sex of offspring/time of insemination

## Introduction

Weinberg *et al.* (1995) report data in which the sex of human offspring varies with the length of the follicular phase. They report a mean phase length of 15.4 days in 69 menstrual cycles which produced males and a mean of 17.6 days in 64 cycles producing females. This statistically significant difference raises two interrelated questions. First, what accounts for the association between length of the follicular phase and sex of offspring and, secondly, how do these findings relate to data which suggest that the sex of offspring varies with (i) the time of insemination relative to ovulation (Guerrero, 1974; Perez *et al.*, 1982; France *et al.*, 1984) and with (ii) coital rate (MacMahon and Pugh, 1954; Brewis, 1993; Underwood, 1993; Borgerhoff Muldur, 1994; Martin, 1994; Wadley and Martin, 1997).

Weinberg *et al.* (1995) suggest a number of mechanisms which might link the length of the follicular phase to the sex of the baby. One of these is that the properties of cervical mucus may differ in cycles with longer as against shorter follicular phases and that these differences and differences in sperm motilities separate X and Y spermatozoa. Models of sperm selection in which the properties of X and Y spermatozoa interact with the properties of cervical mucus to affect the sex of offspring have been offered before. Roberts (1978) has suggested that decreases in the viscosity of cervical mucus in the late follicular phase and the superior motility of Y spermatozoa may account for data (Guerrero, 1974) in which the male:female sex ratio at birth declines as the day of responsible insemination approaches ovulation day.

The present paper extends these ideas and those advanced recently by the present author (Martin, 1995). The paper argues that, while the penetrability of cervical mucus may improve as ovulation approaches, debris left in the cervix by previous inseminations may impede the passage of spermatozoa inseminated later, thereby dampening any hormonally-induced improvement in mucus penetrability. Y selection may thus be affected by the patterning and frequency of coitus in the fertile period. It is then suggested that hormonally-induced changes in mucus penetrability, the effects of the coital pattern and the superior motility of some Y spermatozoa account for the differences between those studies in which the sex of offspring varies with time of insemination and those in which it does not. The paper then concludes with a discussion of the variables which control the duration of the follicular phase, showing that mucus penetrability increases and Y-selection decreases in longer follicular phases.

## Mucus penetrability and sperm selection

Roberts' (1978) idea that selection for Y-spermatozoa decreases as mucus penetrability improves towards the end of the follicular phase has received little acceptance. Among the reasons for this are (i) subsequent workers could not replicate the finding of Ericsson *et al.* (1973) that Y spermatozoa migrate more readily through an albumin gradient (Martin, 1994) and (ii) the sex of offspring does not always vary with the time of insemination. However, a recent study (Pyrsak, 1994) is consistent with earlier studies (Ericsson *et al.*, 1973; Rohde *et al.*, 1973; Broer *et al.*, 1976; Beernink *et al.*, 1993; Ericsson, 1994) which find that some Y spermatozoa migrate more readily through a variety of media, including cervical mucus, and it answers the criticisms of Ericsson's work. Pyrsak (1994) reports that, from a population comprising 50% Y spermatozoa, Y spermatozoa make up 66–71% of the first 10% of the spermatozoa which swim through an albumin gradient. When more than 10% of the original population passes through the filter, the Y/X ratio approaches that of the original population. The studies which failed to replicate Ericsson's results recovered more than the first 10% and their failure to find Y selection was therefore to be expected.

Pyrsak's findings in conjunction with those of Ericsson *et al.* (1973), Rohde *et al.* (1973), Broer *et al.* (1976) and Beernink *et al.* (1993) suggest that Y selection should increase with the severity of filtration by the cervical mucus. It is well known (Moghissi, 1973; Odeblad, 1973; Speroff *et al.*, 1989; Wood, 1994) that the penetrability of cervical mucus improves over the latter stages of the follicular phase, then deteriorates after ovulation when the corpus luteum begins producing more

progesterone. Selection for Y spermatozoa should thus be highest when the mucus first begins to open up 4 days or so before ovulation (Moghissi, 1973; Wood, 1994), decline rapidly with the surge in mucus penetrability over the day or two leading up to ovulation (Templeton *et al.*, 1982), and then rise again after ovulation.

However, while Weinberg *et al.* (1995) report an association between sex ratios and length of the phase, they do not find that the sex ratio at birth declines significantly as the time of responsible insemination approaches ovulation. Moreover, there are other studies in which the sex of offspring does not vary with time of insemination. Spira *et al.* (1993) find no association between sex of the baby and time of insemination in a study of over 1000 births and, contrary to some interpretations (James, 1994, 1995; Weinberg *et al.*, 1995; Jongbloet *et al.*, 1996), Harlap's (1979) data also fail to show any significant relation between time of insemination and sex of offspring (Martin, 1995).

Martin (1995) argues that the differences between the studies in which sex of offspring does correlate with time of insemination (Guerrero, 1974; Perez *et al.*, 1982; France *et al.*, 1984) and those in which it does not (Harlap, 1979; Spira *et al.*, 1993; Weinberg *et al.*, 1995) are a function of coital rate. He notes that Baker and Bellis (1993) find that the penetrability of cervical mucus is affected by more than its hormonally-controlled viscosity, vibrosity, water content and flow. In addition to its hormonally-induced properties, the penetrability of mucus is a negative function of the density of sperm cells, leukocytes and other debris left in the cervix by previous inseminations. Over time such debris is flushed from the cervix by the flow of fresh mucus. If insemination occurs before the cervix is cleansed, any exogenously-produced decline in mucus penetrability may be exacerbated. Insemination early in the fertile period may thus both raise the probability that any conception will be due to the earlier rather than a later insemination and increase Y selection in later inseminations. Increasing the coital rate should therefore dampen or eliminate any association between sex of offspring and time of insemination which would otherwise follow from hormonally-induced improvements in mucus penetrability (Martin, 1995).

The revised or synthetic idea is thus that lower mucus penetrability selects for Y spermatozoa and that mucus penetrability is controlled by hormonal factors, which increase penetrability toward the end of the phase, and by coital rate which, when raised, lowers mucus penetrability. This idea is consistent with the data on sex of offspring and time of insemination and it may also account for the propensity for sex ratios at birth to decline as the follicular phase lengthens (Weinberg *et al.*, 1995). The rest of the paper is given over to documenting these claims.

### Coital rate, time of insemination and sex of offspring

There are two studies in which the sex of offspring varies significantly with the time of insemination. These two studies (Guerrero, 1974; Perez *et al.*, 1982) both involve births which result from failures in the rhythm method of birth control.

When this method fails because an error or a longer than normal follicular phase leads a couple to resume coitus too soon, the initial coital act in the fertile period will follow a period of abstinence during which time the cervix will have been cleared of debris and it will occur near the end of the fertile period. If the act is pre-ovulatory, endogenous mucus penetrability will also be good and Y selection will be at the minimum. If the act is post-ovulatory but within the fertile period, the thickening mucus should result in a higher level of Y selection.

If, on the other hand, a couple inadvertently continues intercourse into the beginning of the fertile period, the acts in the fertile period will follow previous acts which may have left debris in the cervix and will occur while endogenous mucus penetrability is still poor. Aggregating conceptions which result from rhythm failures should thus produce a distribution in which the percentage of male births is quite high when insemination is early and which then declines as the time of insemination approaches ovulation before rising after ovulation. The data in these two studies are consistent with these expectations. The 875 births in Guerrero's study (1974) are attributed to inseminations which occurred as early as 9 days before ovulation and as many as 3 days after ovulation. The percentage of male offspring declines significantly ( $\chi^2$  for a linear trend = 17.0,  $P < 0.001$ ) from day -8 to ovulation. After ovulation the percentage of male offspring rises, but not significantly. However, it is unlikely that inseminations more than 6 days before or 2 days after ovulation will produce conceptions. This and the fact that the subjects in this study were using the unreliable shift in basal body temperature method to estimate the time of ovulation suggest that these conceptions actually resulted from inseminations closer to the time of ovulation. When the births are grouped into those attributed to inseminations before the most fertile period (days  $\leq -2$ ), the most fertile period (-1, 0) and post-ovulatory inseminations ( $\geq 1$ ), the percentages of male offspring are 57.3, 45.3 and 50.0. This distribution is still statistically significant ( $\chi^2 = 10.45$ ,  $P < 0.01$ ) and, consistent with expectations, it is U-shaped.

The smaller ( $n = 52$ ) study of Perez *et al.* (1982) reveals a similar pattern. The percentage of males in births produced by inseminations before day -1 is 70. The percentage is 36.8 for days -1, 0 and rises to 85 for days  $\geq 1$ . There are too few of the post-ovulatory inseminations to evaluate statistically, but when the data are aggregated into the groups days -1, 0 and the rest, the differences are statistically significant ( $\chi^2 = 7.65$ ,  $P < 0.01$ ).

A similar, but not significant U-shaped regression of the percentage of male offspring over time of insemination is reported by France *et al.* (1984). In that small study ( $n = 33$ ) the subjects engaged in coitus only once in the fertile period. Under these conditions we should expect the percentage of males to decline and then rise in response to hormonally-induced changes in mucus penetrability. While there is but one birth credited to post-ovulatory inseminations, the percentage of males does decline from 83.3 for days -5 and -4 to 76.9 for days -3 and -2 and to 53.8 for days -1 and 0. The researchers report that a Wilcoxon-Mann-Whitney rank order test produces

**Table I.** Coital pattern, time of insemination and sex of offspring

Study	Day of insemination	Births			Significance	Coital pattern
		M	F	% M		
Guerrero, 1974	≤-2	235	175	57.3	$\chi^2 = 10.45$ $P < 0.01$	Rhythm failure
	-1, 0	139	168	45.3		
	≥1	79	79	50.0		
Perez <i>et al.</i> , 1982	≤-2	14	6	70.0	For -1.0 vs rest $\chi^2 = 7.65$ $P < 0.01$	Rhythm failure
	-1, 0	7	12	36.8		
	≥1	11	2	85.0		
France <i>et al.</i> , 1984	≤-2	15	4	78.9	For -1, 0 vs rest $\chi^2 = 1.59$ $P > 0.10$	One insemination in fertile period
	-1, 0	7	6	53.8		
	≥1	0	1	0.0		
Harlap, 1979	≤-2	2728	2423	53.0	$\chi^2 = 0.92$ $P > 0.90$	Abstain through menstruation plus at least 7 days, then multiple inseminations
	-1, 0	788	739	51.6		
	≥1	464	424	52.3		
Spira <i>et al.</i> , 1993	-6, -5	-	-	56.3		Seeking conception, multiple inseminations
	-3	-	-	38.7		
	-2	-	-	58.5		
	-1	-	-	44.1		
	0	-	-	53.9		
	+1	-	-	45.4		
	+2, +3	-	-	46.8		
Weinberg <i>et al.</i> , 1995	≤-2	15	11	57.7	For ≤-2, and -1, 0 $\chi^2 = 0.43$ $P > 0.50$	Seeking conception, multiple inseminations
	-1, 0	51	50	50.5		
	≥1	-	-	-		

a Z score of 1.87,  $P = 0.06$ . The  $\chi^2$  for days -1 and 0 versus the rest is 1.59,  $P > 0.10$ . The data from these three studies are summarized in Table I. Table I also includes data from three studies in which multiple acts in the fertile period should have dampened any association between time of insemination and sex of offspring. In the large ( $n = 1052$ ) GEFCO study (Spira *et al.*, 1993) and the smaller ( $n = 127$ ) study of Weinberg *et al.* (1995) women were trying to conceive. When this is the intention, the probability of intercourse increases as the time of ovulation is approached. In the Weinberg study women engaged in coitus a mean of 2.5 times in the period day -5 through ovulation day. Under these conditions spermatozoa inseminated early in the fertile period face poor endogenous mucus penetrability and, perhaps, debris from earlier inseminations. They also then dampen the improvements in mucus penetrability which normally occur nearer the time of ovulation. Y-selection should thus be high for spermatozoa inseminated early and only marginally less for those introduced later and there should be little if any systematic variation in the percentage of males by time of insemination.

The data from both these studies are consistent with this expectation. In the Weinberg study the percentage of male offspring is 57.7 (15 M, 11 F) for days ≤-2 and 50.5 for days -1 and 0 ( $\chi^2 = 0.43$ ,  $P > 0.50$ ). Spira *et al.* (1993) report only sex ratios for days -6, -5 and -3 through ≥2. The values for these days, expressed as percentage of males, are 56.3, 38.7, 58.5, 44.1, 53.9, 45.4, and 46.8. The authors conclude that there is no relationship between time of insemination and sex of offspring.

Harlap (1979) has data on 7566 births to women who claimed to have abstained from intercourse during menstruation

and for at least 7 days thereafter. If they indeed did do this, the first inseminations after the resumption of intercourse were unaffected by debris from previous inseminations. The sex ratio among conceptions from these initial acts should therefore reflect endogenous mucus penetrability and form a U-shaped regression over the days of insemination. Spermatozoa inseminated subsequently would face debris from the earlier coital acts, however, and the sex ratio among conceptions due to subsequent pre-ovulatory inseminations would decline less as the time of insemination approached ovulation than it would had there been no previous acts. Debris from earlier pre-ovulatory inseminations would also exacerbate the strong, hormonally-induced decline in mucus penetrability which immediately follows ovulation and reduce the probability of conception from post-ovulatory inseminations. Conceptions which do arise from post-ovulatory inseminations should thus come largely from coital acts which are not preceded by earlier acts in that fertile period. Sex ratios among conceptions due to those late inseminations should therefore be affected by only endogenous mucus penetrability.

The births in Harlap's study are classified according to when, relative to ovulation, intercourse was resumed. The time of ovulation is estimated by subtracting 14 days from the mid-point of the lengths of the last three menstrual cycles. If the fertilizing act was always the initial act, the percentage of males among Harlap's 7566 births should form a U-shaped regression over the day of insemination. The percentage of males for cycles classified by the days in which intercourse was resumed are 52.8, 53.3, 53.3, 49.3, 50.2, 65.5 and 49.3. These are for 3 or more days before ovulation through days ≥ 3. The distribution is not U-shaped. However, Harlap

excludes from the analysis the 430 births (percentage of males = 49.3) from days  $\geq 3$  after ovulation and the 3478 births (52.8% male) from days  $\leq -3$ . This leaves a distribution in which the percentage of male offspring declines from 53.3 on days  $-2$  and  $-1$  to 49.3 and 50.2 on days  $0$  and  $+1$  and which then rises to 65.5 on days  $+2$ . The variation in this roughly U-shaped distribution is statistically significant and it is the distribution which some authors (James 1994, 1995; Weinberg *et al.*, 1995; Jongbloet *et al.*, 1996) consider consistent with the proposition that regression of the sex ratios at birth over time of insemination is U-shaped.

Harlap discards the 430 births from days  $\geq 3$  because she believes the estimated days of insemination to be in error, probably because inseminations 3 or more days after ovulation are not likely to produce conceptions. However, this improbability also extends to inseminations in cycles in which coitus was resumed on day  $+2$ . The appropriate procedure in these cases would be either to discard all these data or, better, pool them with the conceptions from cycles in which intercourse was initiated on day  $+1$ . Either procedure, however, flattens the distribution of sex ratios and eliminates the statistical significance ( $\chi^2 = 4.09$ ,  $P > 0.30$  and  $\chi^2 = 3.33$ ,  $P > 0.50$ , respectively).

Harlap's reason for also discarding the 3478 births from cycles where intercourse was resumed 3 or more days before ovulation is that, after several weeks of abstinence, couples were likely to engage in intercourse on successive days. In these cases conceptions may have resulted from inseminations closer to ovulation than day  $-3$ . However, this reasoning may also apply to cycles in which intercourse was resumed on days  $-2$  and  $-1$ . If, in recognition of these possibilities, days  $\leq -3$  and  $-2$  are pooled as are days  $-1$  and  $0$ , the percentages male for days  $\leq -2$ ,  $-1$ ,  $0$  and  $\geq 1$  are 53.0, 51.6 and 52.3. The differences are not statistically significant ( $\chi^2 = 0.92$ ,  $P > 0.90$ ).

Thus, the differences between those studies in which the sex of offspring varies significantly with the time of insemination and those in which it does not, seem to rest in the effects of the coital rate just before and during the fertile period. This is evident when the data from Guerrero (1974), Perez *et al.* (1982) and France *et al.* (1984) are aggregated and compared with the data of Harlap (1979) and Weinberg *et al.* (1995). Multiple inseminations just before and early in the fertile period among the first group raise the percentage of male offspring for the days  $\leq -2$  to 58.8, significantly higher ( $\chi^2 = 5.61$ ,  $P = 0.018$ ) than the 53.0% in the second group, in which Y selection in the early period is largely a function of endogenous sperm penetrability. At the same time, coitus near the time of ovulation is less frequent in the first group than it is in the second and the percentage of male offspring for days  $-1$  and  $0$  is also significantly lower in the first group (45.1 versus 51.5;  $\chi^2 = 4.60$ ,  $P = 0.032$ ).

These variations in sex ratios thus seem to result from variations in mucus penetrability. In the cases at hand, coital patterns and hormonally-induced changes over the course of the follicular phase appear to be the major determinants of mucus penetrability. However, the length of the follicular phase may also affect mucus penetrability and account for the

finding that longer follicular phases are associated with lower secondary sex ratios.

### Length of the follicular phase and sex of offspring

There are a number of theories concerning the variables which control the duration of the follicular phase. The first of these suggests that the factors underlying variation in the length of the phase are different concentrations of follicle stimulating hormone (FSH) in the latter stages of the previous luteal phase and in the very early follicular phase. While initial follicular growth appears to occur independently of FSH, luteinizing hormone (LH) and oestradiol, a rise in FSH (and LH) following the decline in progesterone and oestradiol in the previous luteal phase stimulates further follicular development (Speroff *et al.*, 1989). A varying number of follicles are stimulated to begin development, of which one, perhaps the largest, emerges as the primary follicle. As the primary follicle grows, it produces increasing quantities of oestradiol which, in turn, begin to suppress the production of FSH by the pituitary. Because the intrafollicular concentration of oestradiol in the primary follicle is high and because that high concentration of oestradiol previously induced more FSH receptors and oestradiol-producing granulosa cells, the primary follicle continues to grow at an exponential rate even as its production of oestradiol continues to suppress FSH production by the pituitary. The smaller follicles, on the other hand, have fewer FSH receptors, fewer oestradiol-producing granulosa cells, and more androgen-rich intrafollicular environments. Therefore, as FSH production declines in response to the growth of the primary follicle and its increasing production of oestradiol, the smaller follicles slow their growth and then become atretic (Speroff *et al.*, 1989; Fowler and Templeton, 1996).

This is significant for present concerns because the small follicles produce gonadotrophin surge inhibiting or attenuating factor (GnSIF) (Fowler and Templeton, 1996). GnSIF is believed to reduce pituitary responsiveness to increases in the pulse frequency and amplitude of gonadotrophin-releasing hormone (GnRH). In this model, increases in GnRH pulse frequency normally occur after oestradiol rises continuously for 2–4 days (WHO, 1980) and/or surpasses a concentration of  $\geq 200$  pg/ml for  $\sim 60$  h (Speroff *et al.*, 1989; Shoham *et al.*, 1995). However, for the pituitary to respond to the rise in GnRH pulse frequency with the LH surge which reinitiates meiosis and is the precursor to ovulation, the effects of GnSIF produced by small follicles must be overcome. This occurs as the oestradiol concentration surges, producing higher GnRH pulse frequencies, and with a decline in the production of GnSIF as the small follicles atrophy (Shoham *et al.*, 1995; Fowler and Templeton, 1996).

Accordingly, when higher concentrations of FSH in the previous luteal phase and the early follicular phase produce greater numbers of small follicles, GnSIF concentrations are higher, take longer to decline, and are associated with and require more sustained and higher amounts of oestradiol to induce the LH surge. When the number of FSH-induced small follicles reaches supra-normal concentrations, the LH surge may be inhibited altogether and the cycle will be anovulatory.

Conversely, if there are fewer small follicles, earlier and even premature LH surges may be induced. The latter can also result in anovulation or in an inadequate luteal phase (Sherman and Korenman, 1974; Messinis and Templeton, 1986; Mroueh *et al.*, 1996).

The point here is that, from this interpretation, the number of small follicles may shorten or lengthen the follicular phase by advancing or retarding the LH surge. When the LH surge is advanced ovulation occurs earlier. Correlatively, oestradiol concentrations will be lower and will not have been sustained for as long. As mucus penetrability parallels the rise in the concentration of oestradiol, shorter follicular phases induced by fewer small follicles should be associated with a shorter period of mucus penetrability and mucus of poorer quality. Conversely, if higher concentrations of GnSIF produced by larger numbers of small follicles retard but do not attenuate the LH surge, the follicular phase will be longer and will be associated with longer periods of high oestradiol production and more penetrable cervical mucus. In summary, if variations in the length of the follicular phase are due to variations in the number of small follicles, shorter phases will be associated with shorter periods of penetrable mucus and higher proportions of Y spermatozoa reaching the uterus. Conversely, longer phases will be associated with more penetrable mucus over longer periods of time and lower proportions of Y spermatozoa in the uterus.

There is a second, less complex, model of the timing of the LH surge and ovulation. Levran *et al.* (1995) found that in 65 women with ovarian failure the LH surge occurred after a cessation of the increase in serum oestradiol. This was achieved by administering incremental doses of oestradiol valerate for 4–8 days. The LH surge did not occur as long as the oestradiol concentration was increasing; LH surges occurred only after treatment was suspended and oestradiol concentrations moderated. Since these women had no ovarian follicles, it does not appear that GnSIF could have played any role in the inhibition of the LH surge. This finding, that it is a decline or levelling off of oestradiol production which induces the LH surge, has the advantage of simplicity and is also consistent with the general propensity for oestradiol to inhibit LH secretion. However, in both of these models longer follicular phases imply longer periods of increasing oestradiol production and more penetrable cervical mucus.

Variations in the length of the follicular phase which stem from stress-induced alterations of reproductive functions produce similar results. It is well known that acute, transient stress may stimulate an LH surge and, derivatively, ovulation. Long term or chronic stress, on the other hand, seems to suppress LH production by increasing corticotrophin-releasing factor (CRF) and the corticotrophins in turn inhibit the secretion of GnRH by the hypothalamus (Rivier and Rivest, 1991). Transient stress is thus capable of advancing the LH surge while chronic stress can retard it and even result in anovulation. Chronic stress may result from poor nutrition, intense physical activity, or emotional or psychological factors. As an example of the latter and its effect on the timing of the LH surge, Peyser *et al.* (1973) report on two regularly ovulating women admitted to the hospital just prior to when they were due to

ovulate. Over the next 7 and 10 days respectively their blood was sampled every 4 h. Neither produced an LH surge while hospitalized, but both did so within 48 h of being discharged. The stress associated with hospitalization and blood sampling prolonged the follicular phase by at least 7 days in one case and 10 in the other.

In summary, because the LH surge can be advanced or retarded relative to the degree of follicular development and production of more penetrable mucus, mucus penetrability should vary with the length of the phase. Shorter phases should be associated with less penetrable mucus and a higher proportion of males among offspring, longer phases with longer periods of more penetrable mucus and a lower proportion of males.

More frequent inseminations, which can reduce or eliminate the connection between time of insemination and sex of offspring, should not materially affect this relationship. Increased coital rates will raise Y selection in both longer and shorter phases. For a higher coital rate to reduce the difference in sex ratio between longer and shorter phases, it would have to raise the male:female ratio in the longer phase proportionally more than it raised it in the shorter phase. This seems unlikely, particularly given that the higher rate of flow of cervical mucus in the longer phase should cleanse the cervix faster.

## Conclusions

Evidence exists that less penetrable mucus selects for Y spermatozoa and that such selection decreases as mucus penetrability improves. Endogenous or hormonally-induced mucus penetrability improves over the late follicular phase and with the length of the follicular phase. However, there is also evidence that debris from previous inseminations reduces mucus penetrability for subsequent inseminations. Higher or increasing coital rates should therefore decrease mucus penetrability for later inseminations in both shorter and longer phases. When insemination occurs only once over the 6 or so days before ovulation, or when the coital rate is declining over that period, hormonally-induced improvements in mucus penetrability should result in male:female ratios which decline as the time of insemination approaches the end of the phase and as the phase is lengthened. If intercourse is frequent in the period before ovulation, there should be less or no association between time of insemination and sex of offspring. However, while more frequent intercourse should raise the sex ratio among offspring in both longer and shorter phases, it should not alter the propensity for longer phases to be associated with a lower proportion of male offspring because the coital rate affects both longer and shorter phases.

While the discussion here includes an interactive factor, coital rate, it fails to consider any purely male factors such as the Y/X ratios in the inseminate and to assess the effects of early spontaneous abortions. Hence, while the factors under consideration may offer some understanding of sources of variability in sex ratios, they cannot account for specific levels, especially when sex ratios are lower than the Y/X ratio in the inseminate.

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