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The human penis as a semen displacement device

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Abstract

Inanimate models were used to assess the possibility that certain features of the human penis evolved to displace semen left by other males in the female reproductive tract. Displacement of artificial semen in simulated vaginas varied as a function of glans/coronal ridge morphology, semen viscosity, and depth of thrusting. Results obtained by modifying an artificial penis suggest that the coronal ridge is an important morphological feature mediating semen displacement. Consistent with the view of the human penis as a semen displacement device, two surveys of college students showed that sexual intercourse often involved deeper and more vigorous penile thrusting following periods of separation or in response to allegations of female infidelity.

Keywords: Penis morphology; Paternity; Semen displacement; Sperm competition; Sexual behavior

1. Introduction

To maximize the likelihood of paternity, human males have evolved several strategies. Daly and Wilson (1998) list mate guarding, as a means of minimizing the chances of the female becoming involved in an extra pair copulation, and using the degree to which children show paternal resemblance to assess paternity. There is a third class of putative paternal assurance tactics. In the event of extra pair copulation, strategies on the part of

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the resident male for preventing conception by an interloper may involve different parameters of sperm competition. Baker and Bellis (1989) have shown that the less often a man sees his partner over a 3-day period, the higher his sperm count upon resuming sexual intercourse, implicating mechanisms that may function to compete with sperm of rival males.

While the first few drops of ejaculate facilitate sperm transport, the last few have spermicidal properties (Baker & Bellis, 1995). Therefore, in the event of a double mating, the second male's sperm would be met with a spermicidal layer left by the first. Men with prostate or seminal vesicle dysfunction sometimes have a reversed seminal fluid sequence and are often rendered infertile (Kvist, 1991). The first few drops of ejaculate also function to protect sperm from spermicide left by previous males, and therefore improve the second male's chances of achieving conception (Lindholmer, 1973).

Species differences in genital morphology can arise by sexual selection (Dixson, 1987; Eberhard, 1996; Verrell, 1992). Thus, the morphology of the human penis itself may have been influenced by sperm competition. Relative to other primates, the human penis is larger in both width and length, roughly twice as long and wide as that of our closest living relative, the chimpanzee (Short, 1980). The shape of the human penis also differs from many other primates because the glans is more exaggerated and uniquely configured (Izor, Walchuk, & Wilkins, 1981). The diameter of the posterior glans is larger than the penis shaft itself, and the coronal ridge, which rises at the interface between the glans and the shaft, is positioned perpendicular to the shaft. The human penis may displace seminal fluid from other males in the vagina by forcing it back around the glans. The effect of thrusting, according to this analysis, would be to draw foreign semen back away from the cervix. Because of its elasticity, the vagina expands around the penis during intromission creating suction that may further enhance this effect. If a female copulated with more than one male within a short period of time, this would allow subsequent males to "scoop out" semen left by others before ejaculating (Baker & Bellis, 1995).

Although there are no empirical data that bear on the semen displacement hypothesis, some behavioral implications of sperm competition in humans have been examined. Shackelford et al. (2002) found that after separation, males in committed relationships rate their partners as more attractive, show greater interest in copulating with them, and think that their partners are more sexually interested in them.

To test the displacement hypothesis, we measured the magnitude of semen displacement affected by various artificial genitals, different simulated semen recipes, different semen viscosities, and different depths of thrusting. Two surveys were also conducted to corroborate and extend the results obtained using laboratory analogs.

2. Experiment 1

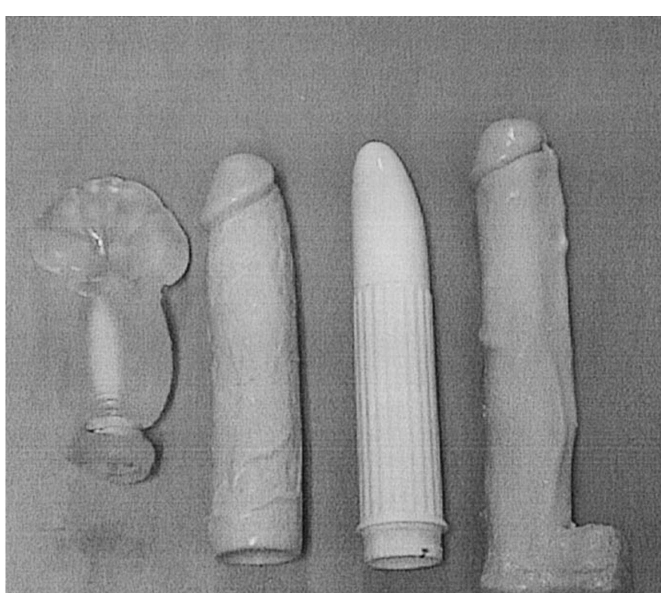
In the first experiment, sexual encounters were simulated using artificial genitals and the magnitude of artificial semen displacement was measured as a function of penis size, shape, and depth of thrusting.

2.1. Methods

The genital models are depicted in Fig. 1. The latex phallus B was 155 mm long and 33 mm in diameter (Hollywood Exotic Novelties) with a coronal ridge extending approximately 5 mm from the shaft. The latex phallus D was the same length, but was 27 mm in diameter with a coronal ridge extending 3 mm from the shaft (Hollywood Erotique Novelties). The plastic shaft C lacked a coronal ridge, measured 155 mm in length with a diameter of 29 mm, and was used as a control phallus. These dimensions are well within human parameters. The typical erect human penis ranges from 127 mm to 178 mm in length, with a diameter of 24.5 mm (Masters & Johnson, 1966; Wessells, Lue, & McAninch, 1996).

The artificial vagina (California Exotic Novelties), marketed as a male masturbation device, measured 113 mm in length, with a 51-mm vaginal barrel, and was 26 mm in diameter. The vagina (labeled A) consisted of a hollow tube of highly flexible elastic material, which when stretched measured approximately 102 mm in length. As shown in Fig. 1, the "cervical" end of this tube was closed with a rubber band to prevent semen leakage during displacement trials. Simulated semen was created by mixing 7 ml of water at room temperature with 7.16 g of cornstarch and stirring for 5 min. After trying different mixtures of cornstarch and water, this recipe was judged by three sexually experienced males to best approximate the viscosity and texture of human seminal fluid. To avoid thickening of the semen over time, new mixtures of artificial semen were created after every two to three trials.

Five displacement trials were conducted with each phallus. For each trial, the vagina was weighed after applying several drops of water-based lubricant (California Exotic Novelties) to



A B C D

Fig. 1. Genital models: vagina A, phallus B, control phallus C, phallus D.

the vaginal opening and inserting 2.6 ml of simulated semen into the vagina with a syringe. The volume of human ejaculate ranges from 2 to 6 ml with an average of 3 ml (Belsey, Eliasson, & Gallegos, 1999). After being loaded with semen, the vagina was stretched and held against a fiberglass base positioned at an angle of 45° (see Fig. 2), while a phallus was fully inserted into the vagina and withdrawn. Upon withdrawing a phallus to within 25 mm from the opening, the vaginal wall below the glans was pinched closed to prevent semen from flowing back into the vagina. The amount of semen pulled to the outer portion of the vagina was then removed and the vagina was weighed. The percentage of semen displaced was calculated as follows:

$$\frac{(\text{weight of vagina with semen} - \text{weight of vagina following insertion and removal of phallus})}{(\text{weight of vagina with semen} - \text{weight of empty vagina})} \times 100$$

In the second phase of this experiment, the B phallus was inserted into the vagina at different depths (25%, 50%, 75%, and 100%) to assess the effect of thrusting depth on semen displacement. Displacement was measured in the same way and the percentage of semen displaced was calculated over five trials for each depth.

2.2. Results

As shown in Fig. 3, the magnitude of displacement varied as a function of penis morphology. Phalluses B and D each displaced approximately 91% of the simulated semen, but phallus C, with no coronal ridge, displaced only 35.3% [$F(12)=41.56$, $P<.0001$].

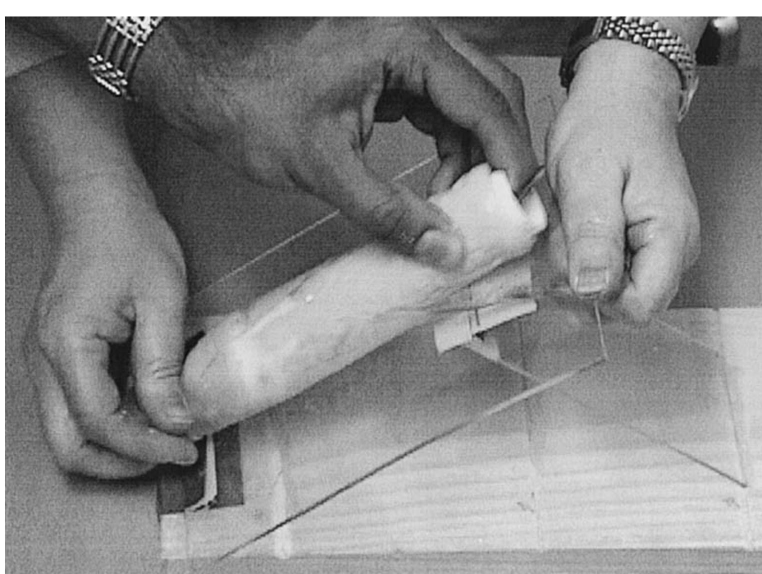


Fig. 2. A typical semen displacement trial with phallus B. Note the collection of semen behind the coronal ridge.

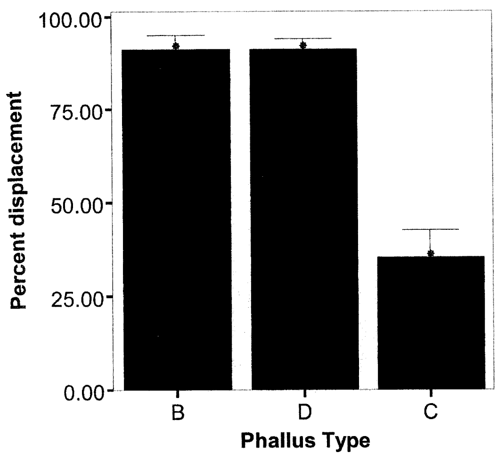


Fig. 3. Mean percent semen displacement as a function of phallus type.

Videotapes of the trials revealed that when either penis B or D was fully inserted into the vagina, rather than forcing the semen over the coronal ridge, the semen flowed back under the penis through the frenulum and then collected over the top of the anterior shaft behind the coronal ridge (see Fig. 2).

As shown in Fig. 4, variation in depth of thrusting was associated with significant variation in semen displacement [$F(16) = 330.74$, $P < .0001$]. When phallus B was inserted all the way into the vagina, 90% of the semen ($M = 90.44\%$, S.D. = 9.89) was displaced, whereas insertion three fourths of the way only displaced about one third (38.95%) of the semen ($P < .001$). There was no semen displacement under conditions of more shallow thrusting (see Fig. 4). The correlation between depth of thrusting and semen displacement was $r = .927$ ($P < .0001$).

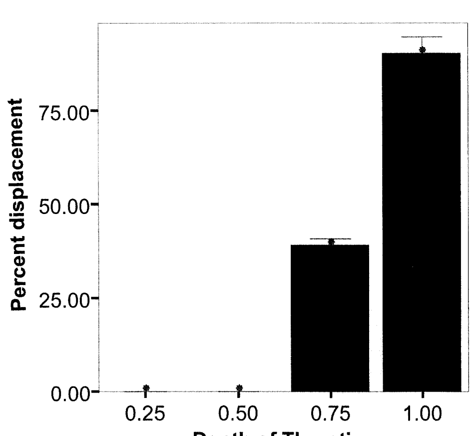


Fig. 4. Mean percent semen displacement as a function of depth of thrusting.

3. Experiment 2

Using a different artificial vagina and a different semen recipe, a second experiment was conducted to replicate and extend these effects. Displacement was measured across two levels of semen viscosity, and the coronal ridge was removed from one phallus to assess the effect on semen displacement.

3.1. Methods

As shown in Fig. 5, a different artificial vagina (New Concepts) measuring 138 mm in length and 43 mm in diameter was used. Because it was longer than vagina A, the cervical end of vagina E was tied off with a rubber band so that when stretched it was the same length (i.e., 102 mm). The same three phalluses were deployed in this experiment. A new recipe for simulating semen (see Acknowledgements) consisted of 18.8 g of sifted, white, unbleached flour mixed with 250 ml of water. This mixture was brought to a boil, simmered for 15 min while being stirred, and allowed to cool. The procedures for loading the vagina with semen, inserting the phallus, and measuring displacement were the same as in the previous experiment.

In the first phase, five displacement trials were conducted with each of the three phalluses. In the next phase, semen viscosity was manipulated by diluting the flour and water mixture with additional water to produce two levels of viscosity. The thick semen consisted of approximately 0.147 g flour/ml water, and the thin semen consisted of 0.126 g flour/ml water. To compensate for evaporation, small amounts of water were added

Fig. 5. Additional genital models: phallus D – and vagina E.

periodically to each semen mixture during testing to maintain the original viscosities. Three sexually experienced males rated the dilute (thin) semen as the closest approximation to human semen. Five trials were conducted with each level of semen viscosity using vagina E and each of the three phallus types.

In the final phase of Experiment 2, we assessed the effect of the coronal ridge on semen displacement. Using a knife, the coronal ridge was removed from phallus D taking care not to destroy the glans. Fine sandpaper and an emory board were used to smooth the area that had been cut away, and the resulting phallus (designated D −) is depicted in Fig. 5. Using the low-viscosity flour and water semen mixture, five displacement trials were conducted with both the intact and modified phallus.

3.2. Results

As was true for cornstarch, the dilute semen lead to comparable displacement effects as a function of phallus morphology. Phallus B displaced an average of 97.8%, phallus D 86.7%, and phallus C 28.9% [($F(12) = 61.66$, $P < .0001$]. The effects of semen viscosity and phallus type were examined using a 3 × 2 factorial design. As shown in Fig. 6, there was a main effect of Phallus Type [$F(2,29) = 108.15$, $P < .0001$], a main effect of Semen Viscosity [$F(1,29) = 13.49$, $P < .001$], but no Phallus Type × Semen Viscosity interaction.

As shown in Figs. 3 and 6, the displacement effect held up well across the two different vaginas. Although there appeared to be slightly greater displacement effects for vagina A, the differences between A and E were not statistically significant.

The two latex phalluses (B and D) differed from the plastic control phallus (C) not only in terms of morphological features (e.g., the glans/coronal ridge), but also in terms of texture (see Fig. 1). In an attempt to resolve this problem and isolate the critical semen displacement feature, the coronal ridge was removed from phallus D. The magnitude of displacement using

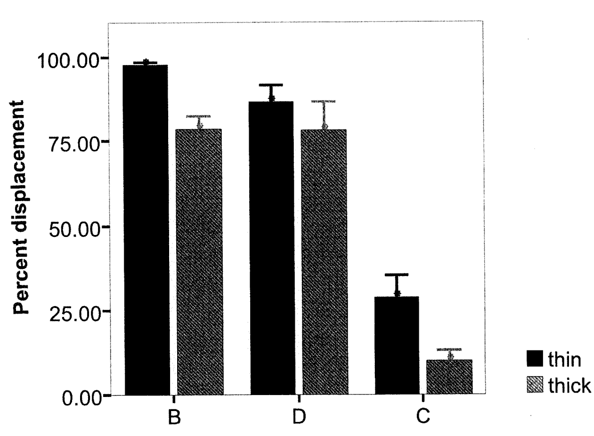


Fig. 6. Mean percent semen displacement as a function of semen viscosity and phallus type.

thin viscosity flour semen was substantially affected. Phallus D, with an intact coronal ridge, displaced over twice as much semen (86.69%) than did the same phallus (D –) without the coronal ridge (40.03%) [$t(8) = 7.49$, $P < .0001$].

4. Survey 1

The results obtained with prosthetic genitals suggest that the magnitude of in vivo semen displacement would also be expected to vary as a function of the depth of thrusting. An anonymous survey was used to determine if allegations of female infidelity affect parameters of intercourse in ways that are consistent with the results obtained using inanimate analogs.

4.1. Methods

Three hundred and thirty-six undergraduate college students (131 males, 205 females) at the State University of New York at Albany responded to an anonymous written questionnaire (approved by the Institutional Review Board). Forty-one respondents never had sexual intercourse and were excluded from the analysis, leaving 122 males and 173 females.

The survey posed questions to participants about their sexual experiences, including contexts in which they or their partner had ever been accused of cheating or being unfaithful. They were asked if they had intercourse following allegations of infidelity, and if so, how long intercourse lasted, how quickly thrusting occurred, and how deep thrusting

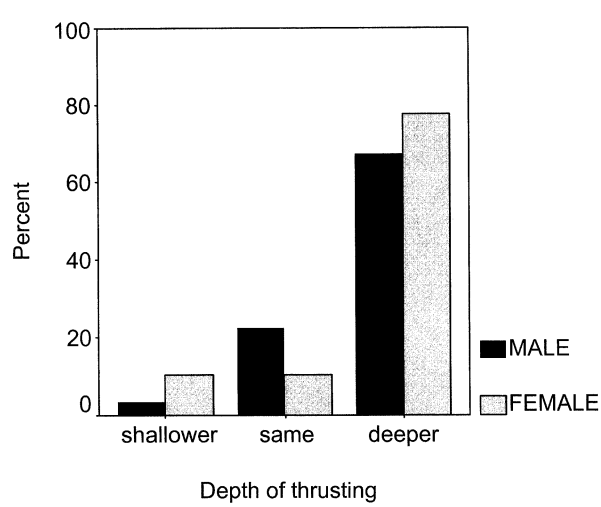


Fig. 7. Percent of males and females reporting changes in depth of thrusting following allegations of female infidelity.

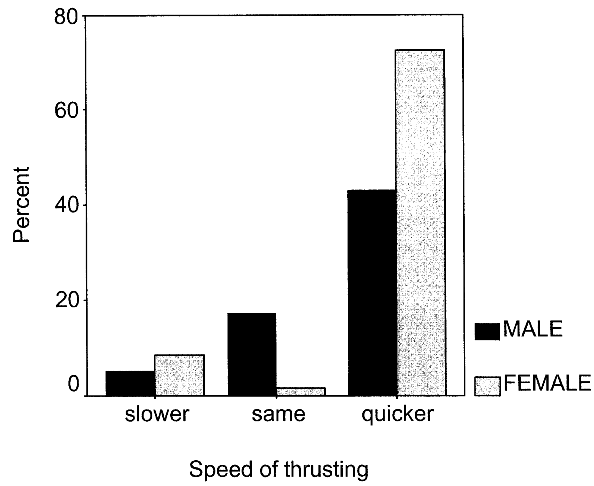


Fig. 8. Percent of males and females reporting changes in speed of thrusting following allegations of female infidelity.

was. Subjects were asked to rate changes in their sexual behavior compared to typical or normal intercourse using three-point scales (-1 = *less*; 0 = *no change*; 1 = *greater*).

4.2. Results

Not all participants answered all questions. Of those who experienced intercourse following allegations of female infidelity, just over half (54 males and 68 females) reported noticing a difference in sexual behavior. As shown in Figs. 7 and 8, a greater proportion of males and females who noticed a difference reported deeper thrusting after allegations of infidelity [one-sample t test, M = .685, $t(110) = 11.968$, $P < .0001$], and the same was true for speed of thrusting [one-sample t test, M = .686, $t(85) = 9.983$, $P < .0001$]. Duration of intercourse and length of orgasm, however, did not differ from typical encounters.

Broken down by sex, males reported that after allegations of infidelity, they thrust deeper [one-sample t test, M = .685, $t(53) = 9.266$, $P < .0001$] and faster [one-sample t test, M = .579, $t(37) = 5.557$, $P < .0001$]. Females also reported that males thrust deeper [one-sample t test, M = 98.685, $t(56) = 7.839$, $P < .0001$] and quicker [one-sample t test, M = .771, $t(47) = 8.517$, $P < .0001$].

5. Survey 2

Another survey was used to determine if periods of separation between couples change sexual behavior in ways consistent with the displacement hypothesis.

5.1. Methods

Two hundred and eighty-six undergraduate college students (91 males, 195 females) at the State University of New York at Albany responded to an anonymous questionnaire approved by the University Institutional Review Board.

Participants were asked whether they were sexually active, if they were currently in a sexual relationship, and how long it had lasted. They were also asked about instances in which they and their partner had been separated, and if they had intercourse following reunion, how long intercourse lasted, how quickly thrusting occurred, how deep and vigorous thrusting was, the approximate number of thrusts, and the intensity of orgasm. Subjects rated changes in their sexual behavior compared to normal encounters using five-point scales (-2 = *much less*; -1 = *less*; 0 = *no change*; 1 = *greater*; 2 = *much greater*). Forty-four respondents never had sexual intercourse and two who declined to answer the question were excluded from the analysis, leaving 81 males and 159 females.

5.2. Results

Not all participants answered all questions. Almost three out of four (73.3%, $N = 176$) reported having intercourse with their partner following a period of separation. Length of separation ranged from 1 to 438 days, with an average (mode) of 14 days. Of those who experienced a sexual encounter following separation, 7 out of 10 (69.3%, 34 males, 88 females) noticed a difference in their own or their partner's sexual behavior.

Using one-sample t tests (see Figs. 9 and 10), both sexes who noted a difference reported that thrusting was deeper [$M = .856$, $t(166) = 13.684$, $P < .0001$], quicker [$M = .566$, $t(167) = 8.396$, $P < .0001$], more frequent [$M = .633$, $t(165) = 9.613$, $P < .0001$], and more

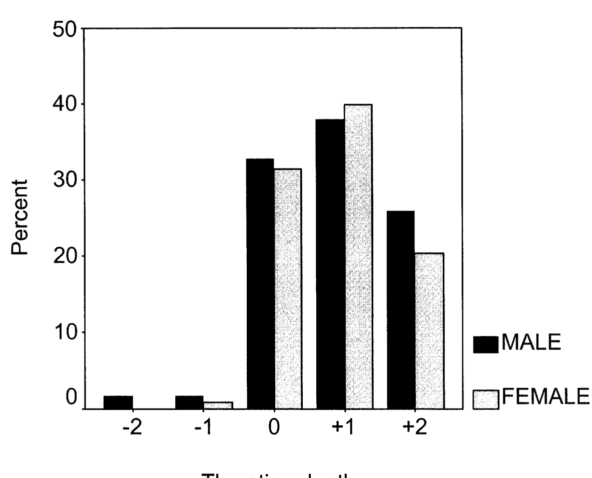


Fig. 9. Percent of males and females reporting changes in depth of thrusting following periods of separation.

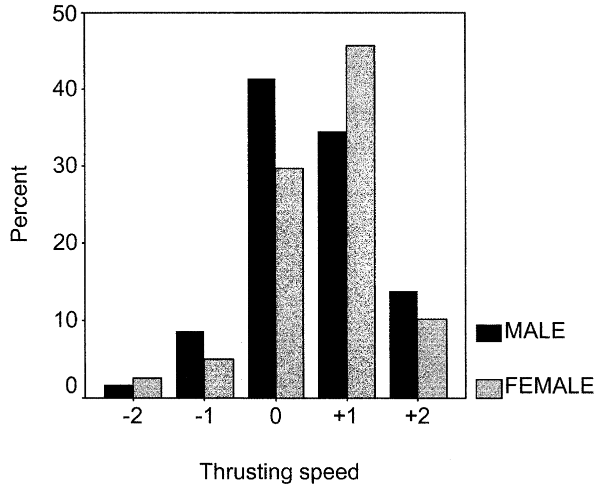


Fig. 10. Percent of males and females reporting changes in speed of thrusting following periods of separation.

vigorous [$M = .524$, $t(163) = 7.437$, $P < .0001$] following separation. When broken down by sex, males reported deeper [$M = .845$, $t(57) = 7.193$, $P < .0001$], faster [$M = .500$, $t(57) = 4.216$, $P < .0001$], and more vigorous [$M = .418$, $t(54) = 3.543$, $P < .0001$] thrusting, as well as more thrusts [$M = .597$, $t(56) = 4.984$, $P < .0001$] after a separation. Females also reported deeper [$M = .863$, $t(108) = 11.794$, $P < .0001$], faster [$M = .600$, $t(109) = 7.327$, $P < .0001$], and more vigorous [$M = .578$, $t(108) = 6.589$, $P < .0001$] thrusting by their partners, as well as more thrusts [$M = .651$, $t(108) = 8.286$, $P < .0001$].

6. Discussion

Simulating a sexual encounter in vitro, we found that phalluses with a glans/coronal ridge configuration that approximated a human penis resulted in appreciable displacement of simulated semen. Depth of thrusting was also an important parameter, with significant displacement occurring only when the penis was inserted 75% or more of the way into the vagina, forcing the semen under the frenulum and causing it to flow back around the shaft and collect behind the coronal ridge (see Fig. 2).

A limitation of our attempts to model semen displacement was the greater rigidity of the prosthetic as compared to real genitals. The artificial vaginas did not expand as readily as real vaginal tissue nor did the phalluses compress, and, as a result, semen displacement was assessed on the basis of a single insertion. The effects, however, were robust and generalized across different artificial phalluses, different artificial vaginas, different types of simulated semen, and different semen viscosities. In spite of variation in diameter and coronal ridge configuration, phalluses B and D (see Fig. 1) produced roughly equivalent displacement, suggesting that comparable effects would be obtained over a variety of prosthetic genital parameters. Severing the glans from phallus D diminished displacement to levels commensurate with those obtained for control phallus C, thus implicating the coronal ridge as an important semen displacement feature.

Whereas the different semen recipes led to comparable displacement effects, magnitude of displacement varied with semen viscosity (see Fig. 6). Individual differences in semen viscosity among males are associated with differences in fertility. Semen hyperviscosity impairs sperm motility (Mendeluk, Munuce, Carizza, Sardi, & Bregni, 1997). Our data, relating the magnitude of displacement to viscosity, suggest that the penis is more effective at displacing low-viscosity, more mobile semen.

Masters and Johnson (1966) reported ballooning of the cervical end of the vagina during intercourse, which, if true, might diminish a displacement effect. However, Weijmar-Schultz, van Andel, Sabelis, and Mooyart (1999) recently conducted a magnetic resonance imaging study of male and female genitals during coitus. Their results show that during complete penetration, the penis can stretch the anterior wall of the vagina and even raise the uterus, but they found no evidence of a ballooning effect.

While only suggestive, the data from both behavioral surveys are consistent with the semen displacement hypothesis. Following separation from their partners, or when males were sexually jealous, thrusting was rated as being deeper and more vigorous. Although speed and duration of thrusting were not manipulated using prosthetic genitals, these have been implicated in displacing vaginal secretions (O'Hara & O'Hara, 1999). Thus, many males appear to alter their sexual behavior in ways that may displace a rival male's semen in the event of infidelity on the part of their partners. Baker and Bellis (1995) speculated that the longer the duration of intercourse, the more material would be removed from the vagina. But this assumes that number of thrusts vary with duration of intercourse. We found no differences in duration of intercourse, but males and females both reported quicker, more vigorous thrusting that could increase the number of thrusts per encounter.

The surveys have limitations. First, periods of separation may be confounded with time since the last ejaculation. This assumes, of course, that males do not pursue alternative means of achieving ejaculation during the interim. Because males often use masturbation as a copulation substitute, this assumption may be unfounded. Moreover, time since the last copulatory ejaculation poses the same adaptive problem even if the couple has not been formally separated. Just as the likelihood of infidelity on the part of the female could vary as a function of extended separation, the same would apply during briefer periods of informal separation throughout the day (e.g., going to the store, work, or school). Unless the female is sequestered and guarded on a continuous basis, as the time since last ejaculation increases so would the risk of sperm competition. Thus, deeper, more vigorous thrusting as a function of time since the last copulatory ejaculation could function as a more generalized sperm competition mechanism.

Another potential problem with the survey results are demand characteristics; i.e., males may think that deeper, more vigorous thrusting is a more appropriate response following separation or female infidelity. If true, however, the mere existence of such a cognitive bias would be consistent with our hypothesis. In addition, the accounts given by females of different features of sexual behavior following separation or allegations of female infidelity were the same as the males'. Also, contrary to demand characteristics, changes in sexual behavior were specific to features related to semen displacement; i.e., there were no reported differences in the duration of intercourse or incidence of orgasm.

Taken together, the results of the surveys along with the data derived from the artificial genitals suggest that the genital anatomy and copulatory behavior of human males has been shaped by a history of sperm competition.

Acknowledgments

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