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Choice of underwear and male fecundity in a preconception cohort of couples

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SUMMARY

Our objective was to investigate the relationship between male underwear-type worn during daytime/bedtime and male fecundity as measured by semen quality and time-to-pregnancy. We used data from a prospective preconception cohort conducted in 16 counties in Michigan and Texas, USA. 501 couples were enrolled and followed for 12 months of trying, which facilitated capture of time-to-pregnancy (in cycles), 6-cycle conception delay, and 12-month infertility. Male partners provided semen samples via in-home collection for next-day semen analysis comprised of 35 semen quality endpoints. At enrollment, men provided information on type of underwear worn during daytime and bedtime and were classified into 6 categories by underwear choice (n = 491): (i) briefs day/night, (ii) boxer-briefs day/night, (iii) boxers day/night, (iv) briefs day and boxers/none at night, (v) boxer-briefs day and boxers/none at night, (vi) boxers day and none at night. 473 (96%) men had semen analysis performed. Men switching from their usual daytime underwear to boxers/none for bed (groups 4, 5, 6) had the most evidence of change in semen quality endpoints (10 of 11 differences) relative to men wearing briefs day/night (group 1). Group 4 men had lower percent of sperm with coiled tail (β = −0.18, 95% CI: −0.35, −0.01), higher percent round (β = 0.22, 95% CI: 0.01, 0.42), number of immature sperm (β = 0.44, 95% CI: 0.11, 0.77), and amplitude head displacement (β = 0.57, 95% CI: 0.10, 1.03). Group 5 men had higher sperm head perimeter (β=0.17, 95% CI: 0.002, 0.34), amplitude head displacement (β = 0.47, 95% CI: 0.03, 0.91), percent cytoplasmic droplet (β = 0.44, 95% CI: 0.11, 0.77) and high DNA stainability (β=0.39, 95% CI: 0.01, 0.78). After false discovery rate control, no differences remained significant. No significant differences in time-to-pregnancy, conception delay, or infertility were

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AUTHORS' CONTRIBUTIONS

KJS formed the analytic plan, implemented analyses, and wrote the first draft. MLE and ZC assisted in forming the analytic plan, interpreting results, and provided substantive edits to the paper. SK assisted in forming the analytic plan, implementing analyses, interpreting results, and provided substantive edits to the paper. GMBL designed the study, assisted in forming the analytic plan, interpreting results, and provided substantive edits to the paper.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

observed. In summary, male underwear choice is associated with few differences in semen parameters; no association with time-to-pregnancy is observed providing reassurance to couples attempting pregnancy.

Keywords

infertility; lifestyle; semen quality; time-to-pregnancy; underwear

INTRODUCTION

Couples planning or trying for pregnancy are eager for information on lifestyles that may increase their chances for success. Recognizing that both partners contribute to successful pregnancy attempts, the Centers for Disease Control and Prevention now offers preconception guidance for both men and women, inclusive of quitting smoking, avoiding the use of alcohol and drugs, and maintaining a healthy weight (Centers for Disease Control and Prevention, 2015a and 2015b). The American Society for Reproductive Medicine (ASRM) and the United Kingdom's National Institute for Health and Care Excellence (NICE) also encourage these healthy habits for couples attempting pregnancy (American Society for Reproductive Medicine, 2012; United Kingdom National Institute for Health and Care Excellence, 2013). As both ASRM and NICE's guidance notes that elevated scrotal temperature is associated with decreased semen quality, a question commonly asked of clinicians by couples attempting pregnancy is about the male partner's choice of underwear to maximize conception probabilities. However, it remains unclear whether wearing loose underwear, which may lead to lower scrotal temperatures, affects fecundity.

Several observational studies have been conducted on the association of loose versus tight underwear and semen quality among men seeking infertility evaluations (Oldereid *et al.*, 1991; Parazzini *et al.*, 1995; Munkelwitz & Gilbert, 1998; Jung *et al.*, 2001; Povey *et al.*, 2012; Jurewicz *et al.*, 2013, 2014; Pacey *et al.*, 2014). Some studies report better semen quality parameters in men wearing loose compared with tight underwear (Parazzini *et al.*, 1995; Jung *et al.*, 2001; Povey *et al.*, 2012; Jurewicz *et al.*, 2013, 2014), though others have shown no association (Oldereid *et al.*, 1991; Munkelwitz & Gilbert, 1998; Pacey *et al.*, 2014). A few intervention studies have been conducted among fertile men comparing semen quality before and after the use of an underwear-type device to hold the testes close to (Shafik, 1992; Wang *et al.*, 1997; Ahmad *et al.*, 2012) or even inside (Mieusset & B'ujan, 1994) the body for reversible contraception. Most studies (Shafik, 1992; Mieusset & B'ujan, 1994; Ahmad *et al.*, 2012), though not all (Wang *et al.*, 1997), report reduced semen quality parameters along with higher scrotal temperature during compared with before use of the device, with one study reporting complete azoospermia after several months of use (Shafik, 1992) and another reporting higher high DNA stainability (HDS) and DNA fragmentation index (Ahmad *et al.*, 2012). Other studies have randomized men to wear boxers and then briefs or vice versa for several months with an observed benefit for loose underwear relative to semen quality parameters. However, these data are difficult to interpret as, in total, only 11 men completed these two studies (Sanger & Friman, 1990; Tiemessen *et al.*, 1996).

A distinct data gap is present regarding male choice of underwear type and semen quality among men in couples attempting pregnancy in the general population and also whether switching to looser underwear or none for bed impacts semen quality parameters. Furthermore, no data are available on male underwear type and time-to-pregnancy, conception delay or incident infertility. Using data from a population-based, preconception cohort of couples attempting pregnancy, we are able to empirically assess these knowledge gaps for the first time known to us. Specifically, we assessed the relationship between men's behavior related to underwear choice for daytime and bedtime and male fecundity measured by semen quality parameters, time-to-pregnancy, conception delay, and infertility; we did not measure scrotal temperature directly.

METHODS AND MATERIALS

Study population

In this study, 501 couples from 16 counties in Michigan and Texas (2005–2009) were recruited upon discontinuation of contraception into the Longitudinal Investigation of Fertility and the Environment (LIFE) Study, a population-based preconception cohort of couples attempting pregnancy [described in detail elsewhere (Louis *et al.*, 2011)]. Couples were followed daily until positive home pregnancy test or 12 months of trying; couples who became pregnant during the study were then followed through pregnancy loss or delivery.

The study aimed to be inclusive of the spectrum of couples attempting pregnancy and only excluded couples in which one or both partners reported clinically diagnosed infertility/sterility. The following constituted inclusion criteria: (i) in a committed relationship, (ii) ability to communicate in English or Spanish, (iii) male partner aged 18-years or older, (iv) female partner aged 18–40-years-old, (v) no use of injectable contraceptives in the past year, and (vi) menstrual cycle length 21–42 days. At enrollment, all women were administered a home pregnancy test to ensure that women were not pregnant so that trying time could be prospectively observed.

Exposure data collection

At enrollment, men completed in-person interviews with research assistants that included two separate questions on the usual type of underwear worn during the daytime and to bed. Men could respond none, briefs, boxer-briefs, boxers, or other. The replies of 'other' ($n = 23$, 5%) were followed by a free text response that was hand coded to one of the four alternate categories. Most 'other' replies were 'bikini', which was coded as 'briefs', or 'pajama bottoms' or 'pajama shorts', which was coded as none as we did not ask men about other clothing worn to bed. As men were not queried about their underwear choice at any other time point during the study, we assumed their choices did not change over the course of study.

For this analysis, we were interested not only in the type of underwear worn during the day but also whether men changed their underwear for bed. We assumed the primary manner in which underwear may affect semen quality is through elevated scrotal temperatures based on prior literature (Brindley, 1982; Jung *et al.*, 2005). Six groups were defined to capture the type of underwear and consistency of use from day to bedtime: (i) briefs during the daytime and bedtime, (ii) boxer- briefs during the daytime and bedtime, (iii) boxers during the daytime and bedtime, (iv) briefs during daytime and boxers/none at bedtime, (v) boxer-briefs during daytime and boxers/none at bedtime, (vi) boxers during daytime and none at bedtime. Men who wore none during the day ($n = 9$) or higher exposure at night ($n = 1$) were excluded as we were primarily interested in the *type of underwear* worn during the day and whether they maintained this choice for bedtime or switched to looser and presumably cooler underwear for bed. Here 491 (98%) men remained for the analysis. No further exclusions were made.

We collected other information during the interview regarding sociodemographic and lifestyle characteristics, urologic and reproductive history, and other heat exposures. Sociodemographic characteristics included age, race/ethnicity, household income, and self-reported current cigarette smoking and past year alcohol use frequency. Height and weight were measured by study personnel to calculate body mass index (BMI). Urologic history included data on any clinical diagnosis of cryptorchidism, hypospadias, or varicocele (any urologic problem) and whether surgery had been performed for these conditions (any urologic surgery). Reproductive history included ever fathering a pregnancy and any conception delay (time-to-pregnancy >6 months) in a past planned pregnancy. Heat exposures queried were hot tub/sauna use frequency in the past year, extreme heat at work (work environment warmer than 100°F), prolonged sitting at work (working in sedentary position for >6 h daily), and season of enrollment (based on month). We also included average high seasonal temperature at enrollment, which was a combination both of the month of enrollment as well as the site (Michigan or Texas) in recognition that the seasonal temperature in Michigan in January is much lower than in Texas and July in Texas is hotter than in Michigan (Weather Underground; Weather Underground). We also assessed female factors that may influence male underwear choice including age, race/ethnicity, education, BMI, current cigarette smoking and past year alcohol use frequency as these factors also may be important for time-to-pregnancy.

Semen collection and analysis

At enrollment and 1 month later, men were asked to give a semen sample for analysis. Samples were collected by men by masturbation without lubricants following a recommended 2-day period of abstinence. Men were supplied with a glass jar in which to collect the sample. The jar was equipped with a glass sperm migration straw (Vitrotubes #3520; VitroCom Inc., Mt. Lakes, NJ, USA) so that sperm distance traveled at time of collection could be read the next day. Straw distance is used as a global measure of motility to ensure motile sperm were present at the time of semen collection. The jar was also equipped with a temperature sensor (I-Button; Maxim Integrated, Jan Jose, CA, USA) to ensure the sample was maintained within acceptable temperature range from collection until analysis; all samples were found to be within quality assurance and control standards. Men mailed the sample in an insulated shipping container designed to preserve sperm integrity (Hamilton Research) via overnight shipping for next-day semen analysis. The semen analysis comprised 35 endpoints, including 5 general characteristics (volume, sperm concentration, total sperm count, straw distance, percent hypo-osmotic swollen), 8 motility measures, 12 morphometry measures, 8 morphology measures, and 2 sperm chromatin stability assay (SCSA) measures.

Upon arrival at the andrology laboratory at the National Institute for Occupational Safety and Health (NIOSH), an aliquot of semen was placed in a 20-µm deep chamber slide (Leja), and sperm motility was assessed using the HTM-IVOS (Hamilton Thorne, Beverly, MA, USA) computer-assisted semen analysis system. Sperm concentration was measured using the IVOS system and the IDENT stain (Zinaman *et al*., 1996), and sperm viability assessed using the hypo-osmotic swelling assay (Jeyendran *et al*., 1984). An aliquot of the whole semen was diluted in tris NaCl EDTA (TNE) buffer with glycerol and frozen for the SCSA analysis (Evenson *et al*., 2002). The SCSA procedure was conducted on a Coulter Epics Elite Flow Cytometer using the SCSA program (SCSA diagnostics, Brookings, SD, USA). Slides were prepared for sperm morphometry and morphology. Sperm morphometry was performed using the IVOS METRIX system at the NIOSH laboratory. Sperm morphology assessment was completed by Fertility Solutions, Inc. (Cleveland, OH, USA). Both laboratories had established quality assurance and quality control procedures in place.

In this study, 473 (96%) men provided one and 378 (80%) men provided two semen samples for analysis. The second sample only measured volume, sperm concentration, total sperm count, hypo-osmotic swollen, next-day motility, and sperm head morphology, with the primary goal of affirming azoospermia in the first sample and in light of budgetary constraints. Five men were azoospermic on both samples and were informed so they could seek medical care. These men are included in the analysis for volume, count, and concentration.

Fecundity measures

Time-to-pregnancy was measured in prospectively observed menstrual cycles, which were constructed using a combination of bleeding recorded by women in daily journals and the press of the ‘m’ button on digital fertility monitors (Louis *et al*., 2012). Any time off contraception prior to enrollment [one (12%) or two (18%) months] was added to the prospectively observed cycles. This approach does assume that months are equivalent to menstrual cycles; the median cycle length in the LIFE Study was 30 days. Conception delay and infertility were defined as 6 prospectively measured cycles or 12 months without pregnancy, respectively. To our knowledge, no couples sought clinical evaluation or care during the study. At study entry, couples were told that at the end of 12 months, if they had not achieved pregnancy, they would be provided with summary information from their digital fertility monitors and daily diaries to share with their physicians should they decide to seek medical care.

Statistical analysis

A key challenge is in evaluating whether other exposures or characteristics are indeed associated with both the type of underwear and semen quality or time-to-pregnancy; hence, meeting the criteria for confounding. Unfortunately, there are few data known to us on this topic and previous research has not differentiated between underwear worn during the day and night; thus, we used statistical testing of our data to guide our selection of covariates for the adjusted models of semen quality endpoints and time-to-pregnancy. We had an a priori hypothesis that these covariates would be associated with semen quality endpoints and time-to-pregnancy and would not lie on the pathway between male underwear and any of the outcomes. We used chi-square test for categorical and Kruskal–Wallis tests for continuous variables to determine significance at a two-sided *p*-value <0.05. Those covariates that were significantly different across patterns of underwear use were retained in multivariable models.

Owing to non-normal distributions, semen quality endpoints were Box-Cox transformed prior to modeling (Handelsman, 2002; Louis *et al.*, 2015). If men provided two semen samples, data from both samples were used to model semen quality endpoints. Specifically, linear mixed models were used for semen quality endpoints with a random effect for subject included to account for the correlation between two semen samples for the same man. Beta coefficients (β) and 95% confidence intervals (95% CI) were estimated for patterns of underwear use relative to wearing briefs during daytime/bedtime (referent) with negative values indicating a decrease and positive values indicating an increase change in the unit for each semen endpoint. Models were adjusted for seasonal temperature at enrollment (<60°F, 60–84°F, ≥85°F), race/ethnicity, and past year alcohol use frequency (none, less than weekly, weekly or more), which were the only characteristics significantly different by male underwear choice, hence meeting criteria for confounding. Three men were missing data on race/ethnicity and were not included in the adjusted models. Given the large number of comparison in our modeling of semen quality endpoints, we applied the Benjamini and Hochberg method to control for the false discovery rate (Glickman *et al.*, 2014).

Discrete time Cox proportional hazards models were used to estimate fecundability odds ratios (FOR) and 95% CI accounting for right-censoring (loss to follow-up or end of study) and left truncation (time off contraception before study entry), using the delayed entry option in PROC PHREG in SAS V9.3. The FOR is the relative odds of achieving pregnancy in a given cycle conditional on not achieving pregnancy in the prior cycle for the exposed compared with reference group. An FOR <1 indicates a longer time-to-pregnancy or reduced fecundity for the exposed group. These models were adjusted for seasonal temperature at enrollment (<60°F, 60–84°F, ≥85°F), race/ethnicity, and past year alcohol use frequency (none, less than weekly, weekly or more). We checked the proportionality assumption of the Cox model, and it was upheld. Generalized regression models with a log link and Poisson distribution were used to estimate risk ratios (RR) and 95% CI and generalized regression models with an identity link and Poisson distribution to estimate risk differences (RD) and 95% CI for conception delay and 12-month infertility where an RR >1 or RD >0 indicates greater risk or excess cases, respectively, of conception delay or infertility among the exposed group (Spiegelman & Hertzmark, 2005). These models were similarly adjusted for seasonal temperature at enrollment (<60°F, 60–84°F, ≥85°F), race/ethnicity, and past year alcohol use frequency (none, less than weekly, weekly or more).

Ethical approval

Institutional Review Board approval was obtained from all participating institutions, and all participants provided written informed consent prior to data collection.

RESULTS

During daytime, boxer-briefs were the most common underwear choice (39%) closely followed by boxers (35%) then briefs (26%) (Table 1). However, during bedtime, boxers became the predominant underwear (43%) followed by boxer-briefs (24%), none (20%), then briefs (13%). This is largely because men wearing boxers during the day maintain them at night (83%) and more men wearing briefs and boxer-briefs during daytime switched to boxers at bedtime (26 and 17%, respectively). Regardless of daytime underwear choice, one-third of men changed to a cooler option for bedtime.

Of the many sociodemographic/lifestyle characteristics, urologic and reproductive history, and various heat exposures we assessed across patterns of underwear use, only three were statistically significant: race/ethnicity, past year frequency of alcohol use, and average high seasonal temperature at enrollment (Table 2). Of note, none of the female characteristics were associated with male underwear choice (data not shown).

The description of semen quality for the overall cohort has been previously published (Louis *et al.*, 2014). In linear mixed models adjusted for race/ethnicity, past year alcohol use frequency, and average high seasonal temperature at enrollment, compared with briefs during daytime/bedtime, 11 differences in semen quality endpoints were noted across the other 5 patterns (Table 3). Of note, 10 of 11 differences occurred in men who switched to boxers or none for bed, particularly for sperm head morphometry (3 endpoints) and morphology (4 endpoints), though fewer parameters were suggestive of improved (2 endpoints) than diminished (4 endpoints) semen quality endpoints.

Specifically, across daytime underwear choice, no differences were observed for men wearing boxers compared with briefs during the day and to bed, and only an increase in amplitude head displacement (β = 0.51, 95% CI: 0.10, 0.92) was noted for boxer-briefs compared with briefs during the day and to bed. Compared with men wearing briefs during the day and to bed, men wearing briefs during the day and boxers/none to bed had four differences, including lower percent coiled tail (β = −0.18, 95% CI: −0.35, −0.01), suggestive of improved semen quality; higher percent round (β=0.22, 95% CI: 0.01, 0.42) and number immature (β = 0.44, 95% CI: 0.11, 0.77), both suggestive of lower semen quality; and higher amplitude head displacement (β = 0.57, 95% CI: 0.10, 1.03). Men wearing boxer-briefs during the day and boxers/none to bed had four differences observed, including higher percent cytoplasmic droplet (β = 0.39, 95% CI: 0.01, 0.78) and HDS (β = 0.24, 95% CI: 0.05, 0.44), both suggestive of lower semen quality, as well as increases in amplitude head displacement (β = 0.47, 95% CI: 0.03, 0.91) and sperm head perimeter (β = 0.17, 95% CI: 0.002, 0.34), whose clinical correlations are less certain. Men wearing boxers during the day and none to bed had two differences observed, including higher acrosome area of head (β = 2.22, 95% CI: 0.02, 4.42), suggestive of improved semen quality, and higher sperm head width (β = 0.09, 95% CI: 0.01, 0.16). After controlling for the false discovery rate, none of the observed differences remained significant.

Median time-to-pregnancy in this sample was four cycles (interquartile range: 2, 7). Incidence of conception delay and infertility were 27 and 11%, respectively. No significant differences in time-to-pregnancy, conception delay, or infertility were observed by pattern of male underwear use (Table 4).

DISCUSSION

In this preconception cohort of couples recruited from the general population, differences in specific semen quality endpoints were observed for some patterns of male underwear use. While minimal differences in semen parameters were identified based on daytime underwear type, most differences were seen when men changed their underwear type at bedtime to a cooler option. However, the findings were not all suggestive of improved semen quality endpoints as one might expect under the scrotal heat hypothesis for underwear. Most differences occurred in sperm head morphometry and sperm morphology: increase acrosome area of head and lower percent coiled tail both suggest improved semen quality whereas increases in percent round and cytoplasmic droplet and number immature are suggestive of diminished semen quality; increases in sperm head perimeter and width were also noted though their clinical correlation is uncertain. However, the clinical relevancy of sperm morphology for predicting time-to-pregnancy in couples attempting to conceive (Louis *et al.*, 2014) or in predicting IVF/ICSI success (van den Hoven *et al.*, 2015) is limited. No individual change in semen quality endpoint remained significant after control for false discovery rate. Prior studies on choice of underwear and semen quality in infertile populations reported on fewer semen quality endpoints than we do here. Using various definitions of abnormal sperm morphology, most studies report no association with underwear choice (Oldereid *et al.*, 1991; Munkelwitz & Gilbert, 1998; Pacey *et al.*, 2014), though a recent study reported fewer sperm neck abnormalities for men wearing boxers (Jurewicz *et al.*, 2013).

While semen quality as reflected in specific endpoints was associated with choice of underwear, we observed no differences in other fecundity outcomes including time-to-pregnancy, conception delay, or infertility. This is consistent with literature demonstrating individual semen quality endpoints may be associated with fecundity (Louis *et al.*, 2014), but taken together, semen quality has limited capacity to predict fertility (Louis *et al.*, 2014; Wang & Swerdloff, 2014). As this is the first study on male underwear and time-to-pregnancy, no prior literature exists with which we may contextualize our findings. However, previous studies have described self-reported longer time-to-pregnancy with occupational heat exposure in male partners (Rachootin & Olsen, 1983; Figa-Talamanca *et al.*, 1992; Thonneau *et al.*, 1997). It is plausible that the increase in scrotal temperature observed in men wearing tight underwear, about 1°C (Jung *et al.*, 2005), is sufficient to produce differences in semen quality endpoints but not marked enough to bring about delays in conception. This is encouraging news in light of market data that shows sales of tighter fitting underwear are rising as sales of looser fitting underwear are falling in the United States (The NPD Group, 2014).

Our study has several strengths. First, this was a large study population comprising couples recruited from the general population rather than men from occupational settings or those seeking fertility related services. Second, we had information on type of underwear worn during the daytime and to bed separately. In this way, we were able to explore not only the association of usual underwear worn during waking hours on semen quality endpoints, but also whether reducing exposure at night may be beneficial for semen quality. To our knowledge, we are the first to report on semen quality endpoints by the combination of underwear choice for daytime and bedtime. Third, we were able to measure 35 semen quality endpoints, including 2 SCSA measures, which have been investigated in only one prior study (Jurewicz *et al.*, 2013). Fourth, we were able to extend previous work on the reproductive outcomes associated with type of underwear use by measuring time-to-pregnancy in a preconception cohort of couples attempting pregnancy for up to 12 months of trying. Finally, we had rich information on demographic and lifestyle factors, self-reported medical history, occupational heat exposure, and other potential heat exposures so that we could evaluate potential confounding variables in both male and female partners.

We did not have information available on the material of the underwear, which some have posited to be a putative mechanism for decreased semen quality because of the electrostatic potential in synthetic materials (Shafik, 1992). This is an area for future investigation as performance-type underwear becomes a larger share of the underwear market (The NPD Group, 2014). We also did not ask about other types of clothing worn during the day (e.g. pants or shorts) or to bed (e.g. pajama bottoms), the use of blankets or other coverings at bedtime, or proportion of the day spent active or sedentary, all of which would impact scrotal temperature. We did not measure scrotal skin temperature, though others have investigated this previously (Jung *et al.*, 2005). This study addressed the relationship between male underwear choice and fecundity over a very short period of time. We only queried male underwear use at one time point and assumed that choice of underwear remained constant throughout the study period. We had no information on male underwear choice earlier in adulthood or during pre-pubertal development; the latter period may be a sensitive exposure window for male fertility. While the LIFE Study was powered to detect significant associations between exposures to environmental chemicals and fecundity, no formal power analysis was conducted in relation to male underwear types; post hoc power analyses have limitations that make their interpretation problematic and so were not conducted. For these reasons, we cannot rule out the possibility that the negative findings for conception delay and infertility are a result of low statistical power. Our semen samples are used for research and not diagnostic purposes. We recognize that in-home semen collection and next-day analysis are not interchangeable with analysis of samples collected at clinical centers. The methodologies for in-home collection and 24-hour analysis have been ongoing as reported by various authors (Stovall *et al.*, 1994; Royster *et al.*, 2000) and are suitable for volume, sperm count/concentration, morphology, and DNA integrity (Morris *et al.*, 2003; Huszar *et al.*, 2004). We developed a protocol that would generate reliable data for all semen endpoints other than motility outcomes. Recognizing that motility is challenged, men were instructed to place the glass straw in the jar after collection of the sample as a measure of sperm motility at the time of collection. An important point is that we report relative measures of association for semen quality by underwear choice. For bias to have affected our findings would require empirical evidence or a strong assumption that semen quality analysis varied systematically by choice of underwear. We are unaware of any empirical data, and we do not think this is a plausible assumption. Finally, these data were collected from couples in the general population and so may not be applicable to couples receiving infertility treatment. We also reiterate that the goal of this study was to determine if male underwear choice is associated with male fecundity as measured by semen quality endpoints, time-to-pregnancy, conception delay, and infertility; this work does not signify that scrotal temperature, which was beyond the scope of our study, is irrelevant for male fertility.

In the first observational study on male underwear and semen quality among the general population attempting pregnancy, we find that male underwear type is associated with differences in specific semen quality endpoints, though with no discernable pattern or any one consistently associated with diminished semen quality, and no differences remain significant after controlling for the false discovery rate. In the first study on male underwear and time-to-pregnancy or infertility, we do not find any significant differences in time-to-pregnancy, conception delay, or infertility, by underwear type. The style of the male partner's underwear does not seem to affect a couple's ability to achieve pregnancy. Thus, deferring to man's comfort for underwear choice appears a reasonable option for couples trying to conceive.

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Table 1

Type of underwear worn by male partners in the LIFE Study, in daytime and bedtime ($n = 491$)

	Bedtime				
Daytime	**Briefs** ***n* (%)**	**Boxer-briefs** ***n* (%)**	**Boxers** ***n* (%)**	**None** ***n* (%)**	**Total** ***n* (%)**
Briefs	64 (51)	0 (0)	33 (26)	29 (23)	126 (26)
Boxer-briefs	0 (0)	120 (63)	32 (17)	40 (21)	192 (39)
Boxers	0 (0)	0 (0)	144 (83)	29 (17)	173 (35)
Total	64 (13)	120 (24)	209 (43)	98 (20)	491 (100)

Shaded areas denote men who decreased their underwear use at bedtime.

Table 2

Male characteristics by pattern of male underwear use in daytime/change at bedtime (*n* = 491)

	Briefs/No change (*n* = 64, 13%)	Boxer-Briefs/No change (*n* = 120, 24%)	Boxers/No change (*n* = 144, 29%)	Briefs/ Decrease (*n* = 62, 13%)	Boxer-Briefs/ Decrease (*n* = 72, 15%)	Boxers/Decrease (*n* = 29, 6%)	
Sociodemographic/Lifestyle characteristics							
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	*p*-value
Age	32 (5)	32 (5)	31 (5)	33 (6)	32 (5)	32 (5)	0.25
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*p*-value
Race/ethnicity							
Non-Hispanic White	46 (12)	102 (26)	115 (30)	45 (12)	58 (15)	19 (5)	<0.01 **
Non-Hispanic Black	1 (4)	5 (22)	9 (39)	2 (9)	5 (22)	1 (4)	
Hispanic	11 (24)	8 (18)	13 (29)	8 (18)	4 (9)	1 (2)	
Other	6 (17)	5 (14)	7 (20)	5 (14)	4 (11)	8 (23)	
Income							
<$50,000	17 (23)	16 (21)	20 (27)	11 (15)	9 (12)	2 (3)	0.20
$50,000-99,999	29 (13)	60 (26)	71 (31)	26 (11)	31 (13)	14 (6)	
$≥100,000	15 (9)	42 (24)	51 (29)	23 (13)	31 (18)	13 (7)	
Cigarette smoking, baseline							
No	56 (13)	106 (25)	122 (29)	54 (13)	62 (15)	21 (5)	0.39
Yes	8 (11)	14 (20)	22 (31)	8 (11)	10 (14)	8 (11)	
Alcohol use frequency, past year							
None	14 (19)	21 (29)	17 (24)	10 (14)	9 (13)	1 (1)	<0.01 **
Less than weekly	25 (17)	28 (19)	33 (23)	25 (17)	25 (17)	8 (6)	
Weekly or more	25 (9)	71 (26)	92 (34)	27 (10)	38 (14)	20 (7)	
BMI category (kg/m^2)							
Underweight/normal (≤24.9)	12 (14)	17 (20)	33 (40)	12 (14)	6 (7)	3 (4)	0.27
Overweight (25.0–29.9)	26 (13)	53 (26)	55 (27)	26 (13)	27 (13)	15 (7)	
Obese (≥30.0)	24 (13)	44 (23)	54 (28)	21 (11)	36 (19)	11 (6)	
Site							
Michigan	17 (17)	23 (23)	29 (29)	14 (14)	11 (11)	7 (7)	0.67
Texas	47 (12)	97 (25)	115 (29)	48 (12)	61 (16)	22 (6)	

	Briefs/No change (*n* = 64, 13%)	**Boxer-Briefs/No change (*n* = 120, 24%)**	**Boxers/No change (*n* = 144, 29%)**	**Briefs/ Decrease (*n* = 62, 13%)**	**Boxer-Briefs/ Decrease (*n* = 72, 15%)**	**Boxers/Decrease (*n* = 29, 6%)**	
Urologic/Reproductive history							
Ever fathered prior pregnancy							
No	18 (8)	53 (25)	67 (32)	30 (14)	32 (15)	12 (6)	0.22
Yes	45 (16)	67 (24)	77 (28)	32 (12)	40 (14)	17 (6)	
Prior conception delay (>6 months)							
No	26 (17)	38 (25)	41 (27)	17 (11)	22 (14)	8 (5)	0.67
Yes	6 (14)	9 (20)	12 (27)	5 (11)	10 (23)	2 (4)	
No past planned pregnancies	31 (11)	73 (25)	91 (31)	40 (14)	39 (13)	19 (6)	
Any urologic problem							
No	62 (13)	113 (24)	136 (29)	60 (13)	69 (15)	29 (6)	0.73
Yes	2 (9)	7 (32)	8 (36)	2 (9)	3 (14)	0 (0)	
Any urologic surgery							
No	64 (13)	117 (24)	141 (29)	61 (13)	70 (15)	29 (6)	0.78
Yes	0 (0)	3 (33)	3 (33)	1 (11)	2 (22)	0 (0)	
Heat exposures							
Hot bath/sauna use, monthly							
No use in past year	39 (16)	58 (24)	69 (29)	23 (16)	38 (16)	14 (6)	0.32
Once a month	18 (10)	46 (24)	61 (32)	28 (15)	26 (14)	9 (5)	
2–4 times/month	5 (16)	8 (25)	4 (13)	6 (19)	5 (16)	4 (13)	
≥5 times/month	2 (8)	5 (20)	9 (36)	5 (20)	2 (8)	2 (8)	
Extreme heat at work							
No	45 (12)	93 (25)	114 (31)	45 (12)	52 (14)	21 (6)	0.49
Yes	17 (17)	22 (21)	24 (23)	15 (15)	17 (17)	8 (8)	
Prolonged sitting at work							
No	35 (14)	56 (23)	72 (29)	32 (13)	32 (13)	18 (7)	0.69
Yes	27 (12)	59 (26)	66 (29)	28 (12)	37 (16)	11 (5)	
Season of enrollment							
Winter	16 (12)	36 (28)	39 (30)	12 (9)	15 (12)	11 (9)	0.37
Spring	19 (13)	33 (22)	50 (34)	17 (11)	20 (13)	10 (7)	
Summer	19 (18)	21 (20)	30 (28)	16 (15)	17 (16)	4 (4)	

	Briefs/No change (n = 64, 13%)	Boxer-Briefs/No change (n = 120, 24%)	Boxers/No change (n = 144, 29%)	Briefs/ Decrease (n = 62, 13%)	Boxer-Briefs/ Decrease (n = 72, 15%)	Boxers/Decrease (n = 29, 6%)	
Fall	10 (9)	30 (28)	25 (24)	17 (16)	20 (19)	4 (4)	
Average high temperature at entry							
Low temperature at entry (<60°)	11 (22)	10 (20)	12 (24)	7 (14)	6 (12)	4 (8)	0.03 *
Moderate temperature (60-84°)	33 (10)	93 (28)	106 (32)	38 (11)	45 (13)	20 (6)	
High temperature at entry (≥85°)	20 (19)	17 (16)	26 (25)	17 (16)	21 (20)	5 (5)	

Some columns may not add to the total because of missing values. Season of enrollment depends only on month of enrollment, regardless of site (Michigan or Texas). Average high seasonal temperature at entry depends on month and site of enrollment; Texas temperatures were based on monthly average highs in Galveston and Michigan temperatures were based on monthly average highs in Kalamazoo. p-value based on chi-square test statistics for categorical variables and Wilcoxon rank sum test statistic for continuous variables.

* p-value<0.05,

** p-value<.01.

Table 3

Male choice of underwear type for daytime/bedtime[a] and semen quality endpoints – adjusted[b] linear mixed modeling results

Semen quality endpoint	Boxer-Briefs/no change		Boxers/no change		Briefs/decrease		Boxer-Briefs/decrease		Boxers/decrease	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
General characteristics										
Volume (mL)	0.06	−0.16, 0.28	0.19	−0.03, 0.40	0.09	−0.16, 0.34	0.11	−0.13, 0.35	−0.15	−0.46, 0.16
Sperm concentration (M/mL)	−0.23	−1.16, 0.71	−0.37	−1.29, 0.55	−0.36	−1.44, 0.72	−0.67	−1.69, 0.36	0.18	−1.16, 1.53
Total sperm count (M/ejaculate)	−0.05	−1.43, 1.33	0.30	−1.06, 1.65	−0.01	−1.59, 1.57	−0.44	−1.94, 1.06	−0.19	−2.16, 1.79
Hypo-osmotic swollen (%)	−0.02	−2.99, 2.95	−0.27	−3.21, 2.66	0.49	−2.93, 3.92	−0.51	−3.75, 2.73	2.94	−1.36, 7.23
Straw distance (mm)	0.05	−0.13, 0.24	0.05	−0.13, 0.23	0.10	−0.12, 0.32	−0.03	−0.23, 0.18	0.18	−0.10, 0.45
Sperm motility (24 h)										
Average path velocity (μm/sec)	2.85	−0.88, 6.58	0.93	−2.87, 4.44	2.28	−2.01, 6.58	0.98	−3.08, 5.04	−1.92	−7.31, 3.46
Straight line velocity (μm/sec)	2.08	−0.98, 5.14	0.61	−2.41, 3.62	1.25	−2.27, 4.78	−0.06	−3.38, 3.27	−2.41	−6.83, 2.01
Curvilinear velocity (μm/sec)	4.24	−2.17, 10.66	1.40	−4.93, 7.72	4.10	−3.29, 11.50	2.82	−4.16, 9.80	−3.55	−12.81, 5.71
Amplitude head displacement (μm)	**0.51**	**0.10, 0.92**	0.34	−0.07, 0.74	**0.57**	**0.10, 1.03**	**0.47**	**0.03, 0.91**	0.02	−0.57, 0.61
Beat cross frequency (Hz)	0.79	−1.27, 2.86	1.14	−0.90, 3.18	1.45	−0.93, 3.83	0.77	−1.47, 3.02	−1.38	−4.37, 1.61
Straightness (%)	3.17	−2.52, 8.85	1.30	−4.31, 6.90	2.96	−3.58, 9.51	−0.08	−6.26, 6.10	−4.99	−13.21, 3.22
Linearity (%)	2.20	−1.52, 5.93	0.72	−2.95, 4.40	1.25	−3.04, 5.54	−0.95	−5.00, 3.10	−3.21	−8.60, 2.18
Percent motility (%)	0.57	−0.27, 1.41	0.51	−0.32, 1.34	0.71	−0.26, 1.68	0.00	−0.91, 0.92	0.30	−0.91, 1.51
Sperm head measurements										
Length (μm)	0.00	−0.01, 0.02	0.00	−0.02, 0.01	0.00	−0.02, 0.01	0.02	0.00, 0.03	0.01	−0.02, 0.03
Area (μm^2)	0.02	−0.25, 0.28	0.12	−0.14, 0.39	−0.01	−0.31, 0.30	0.22	−0.07, 0.51	0.37	−0.01, 0.75
Width (μm)	0.00	−0.05, 0.06	0.05	−0.00, 0.11	0.01	−0.05, 0.08	0.01	−0.05, 0.07	**0.09**	**0.01, 0.16**
Elongation factor (%)	−0.45	−2.10, 1.21	1.10	−0.53, 2.73	0.35	−1.57, 2.26	−1.06	−2.87, 0.75	1.07	−1.31, 3.45
Perimeter (μm)	0.03	−0.13, 0.18	0.03	−0.12, 0.19	−0.01	−0.19, 0.17	**0.17**	**0.00, 0.34**	0.15	−0.08, 0.37
Acrosome area of head (%)	0.20	−1.33, 1.72	0.87	−0.63, 2.38	1.68	−0.08, 3.44	1.27	−0.39, 2.94	**2.22**	**0.02, 4.42**
Morphology										
Strict criteria (%)[c]	−0.03	−1.41, 1.34	0.72	−0.64, 2.09	0.17	−1.43, 1.78	0.09	−1.43, 1.61	1.79	−0.17, 3.76
Traditional criteria (%)[c]	−0.02	−4.13, 4.08	2.06	−2.01, 6.12	0.87	−3.91, 5.65	−0.04	−4.57, 4.48	4.71	−1.14, 10.57
Amorphous (%)	0.04	−0.29, 0.37	−0.10	−0.43, 0.22	0.22	−0.17, 0.61	−0.07	−0.43, 0.30	−0.45	−0.93, 0.02

Semen quality endpoint	Boxer-Briefs/no change		Boxers/no change		Briefs/decrease		Boxer-Briefs/decrease		Boxers/decrease	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Round (%)	0.01	−0.16, 0.19	0.05	−0.13, 0.22	**0.22**	**0.01, 0.42**	−0.11	−0.30, 0.09	0.08	−0.17, 0.33
Pyriform (%)	0.09	−0.17, 0.35	−0.16	−0.43, 0.09	−0.02	−0.33, 0.29	0.22	−0.07, 0.51	0.01	−0.36, 0.39
Bicephalic (%)	0.06	−0.12, 0.24	0.03	−0.15, 0.21	0.03	−0.18, 0.24	−0.06	−0.18, 0.14	0.05	−0.20, 0.31
Taper (%)	0.10	−0.12, 0.32	−0.05	−0.27, 0.17	0.01	−0.24, 0.27	0.06	−0.18, 0.30	−0.01	−0.33, 0.30
Megalo head (%)	0.06	−0.11, 0.22	0.13	−0.03, 0.30	0.04	−0.15, 0.24	0.00	−0.18, 0.18	0.01	−0.22, 0.25
Micro head (%)	0.14	0.00, 0.29	0.08	−0.07, 0.22	0.13	−0.04, 0.30	0.02	−0.14, 0.18	0.13	−0.08, 0.33
Neck/midpiece abnormalities (%)	0.04	−0.08, 0.15	−0.02	−0.14, 0.09	−0.01	−0.14, 0.13	0.02	−0.11, 0.15	−0.06	−0.23, 0.11
Coiled tail (%)	−0.10	−0.25, 0.04	−0.09	−0.24, 0.05	**−0.18**	**−0.35, −0.01**	−0.08	−0.24, 0.08	−0.10	−0.31, 0.11
Other tail abnormalities (%)	0.07	−0.12, 0.25	−0.03	−0.21, 0.15	−0.01	−0.22, 0.20	0.06	−0.14, 0.26	0.05	−0.21, 0.31
Cytoplasmic droplet (%)	0.26	−0.09, 0.61	0.03	−0.32, 0.37	0.36	−0.05, 0.77	**0.39**	**0.01, 0.78**	0.17	−0.33, 0.67
Immature sperm (#)	0.18	−0.10, 0.47	0.11	−0.17, 0.39	**0.44**	**0.11, 0.77**	0.13	−0.18, 0.44	0.22	−0.18, 0.63
Sperm chromatin stability assay										
DNA fragmentation index (%)	0.04	−0.13, 0.21	−0.10	−0.26, 0.07	−0.09	−0.29, 0.11	−0.19	−0.37, 0.00	−0.23	−0.47, 0.02
High DNA stainability (%)	0.16	−0.02, 0.34	0.16	−0.01, 0.34	0.11	−0.10, 0.31	**0.24**	**0.05, 0.44**	−0.05	−0.30, 0.21

Bold font indicates significant findings.

[a] Reference is men wearing briefs day and night.

[b] Adjusted by average high seasonal temperature at enrollment, male partner race/ethnicity and frequency of alcohol use.

[c] Traditional and strict criteria - differentials were conducted using the traditional morphology.

[#] means number.

Table 4

Male choice of underwear type for daytime/bedtime and fecundity

	Fecundability odds ratio (95% confidence interval)
Time-to-pregnancy	
Briefs/no change	1.00 (ref)
Boxer-briefs/no change	0.98 (0.66, 1.48)
Boxers/no change	0.88 (0.59, 1.31)
Briefs/decrease	0.81 (0.50, 1.30)
Boxer-briefs/decrease	0.89 (0.57, 1.39)
Boxers/decrease	0.99 (0.55, 1.79)

	Risk ratio (95% confidence interval)	Risk difference (95% confidence interval) Excess/fewer cases per 100 exposed men
6 cycle conception delay		
Briefs/no change	1.00 (ref)	0.00 (ref)
Boxer-briefs/no change	1.13 (0.61, 2.10)	3.56 (−12.90, 20.01)
Boxers/no change	1.08 (0.59, 1.97)	1.26 (−13.97, 16.49)
Briefs/decrease	1.25 (0.63, 2.45)	8.96 (−10.24, 28.17)
Boxer-briefs/decrease	1.17 (0.60, 2.29)	4.44 (−12.84, 21.73)
Boxers/decrease	0.95 (0.38, 2.35)	−4.75 (−26.20, 16.70)
12 month infertility		
Briefs/no change	1.00 (ref)	0.00 (ref)
Boxer-briefs/no change	1.00 (0.40, 2.54)	0.76 (−29.26, 30.78)
Boxers/no change	1.02 (0.42, 2.48)	−0.60 (−28.68, 27.47)
Briefs/decrease	0.88 (0.30, 2.54)	−1.27 (−37.02, 34.48)
Boxer-briefs/decrease	1.46 (0.57, 3.71)	5.35 (−25.37, 36.07)
Boxers/decrease	0.36 (0.04, 2.97)	−18.35 (−73.31, 36.61)

Reference is men wearing briefs day and night. Adjusted by average high seasonal temperature at enrollment, male partner race/ethnicity and frequency of alcohol use.