HHS Public Access

Author manuscript

Environ Res. Author manuscript; available in PMC 2019 July 01.

Published in final edited form as:

Environ Res. 2018 July ; 164: 109–113. doi:10.1016/j.envres.2018.02.017.

Maternal use of personal care products during pregnancy and risk of testicular germ cell tumors in sons

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Abstract

Background—The etiology of testicular germ cell tumors (TGCT) is poorly understood, however, exposure to endocrine disrupting chemicals (EDCs) may be related to increased risk. Personal care products, some of which contain EDCs, are widely used on a daily basis and are known to cross the placenta, be present in breastmilk, and are capable of inducing reproductive tract abnormalities. To determine the association between personal care product use during pregnancy and breastfeeding and TGCT risk, an analysis among mothers of TGCT cases and controls was conducted.

Methods—The US Servicemen's Testicular Tumor Environmental and Endocrine Determinants (STEED) study enrolled TGCT cases and controls and their mothers between 2002 and 2005. The current analysis examined personal care product use during pregnancy among 527 mothers of TGCT cases and 562 mothers of controls. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated using unconditional logistic regression adjusting for identified covariates.

Results—Maternal use of face lotion more than one time per week was associated with a significantly increased risk of TGCT (OR: 1.42, 95% CI: 1.08-1.86, p-trend: 0.01). None of the other products examined (perfume, hairspray, nail polish, hair dye, permanent wave, body lotion, deodorant, sunscreen) were associated with TGCT risk.

Conclusions—Frequent exposure to face lotion during pregnancy and while breastfeeding may be associated with increased TGCT risk. Further investigation into the endocrine disrupting effects of personal care products is warranted.

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The authors declare no conflicts of interest or financial disclosures

Keywords

testicular cancer; TGCT; EDCs; endocrine-disrupting chemicals; STEED; personal care products

INTRODUCTION

With an incidence rate of approximately 8 per 100,000 (1), testicular germ cell tumors (TGCT) are rare tumors in the general population, but are the most commonly occurring cancer among men between the ages of 15 and 44 years in the United States (US) (2). The etiology of TGCT is poorly understood; the only well-described risk factors include cryptorchidism, prior history of TGCT, family history of TGCT, and increased adult stature (3). The positive association of cryptorchidism with TGCT, as well as the similarity between primordial germ cells and testicular germ cell neoplasia *in situ* (formerly called carcinoma *in situ*) suggests that TGCT may be determined very early in life and may have a hormonal etiology (4–8). The ability of some environmental chemicals to act as estrogens and anti-androgens has led to the hypothesis that endocrine disrupting chemicals (EDCs) may be associated with the risk of TGCT and other male reproductive disorders (cryptorchidism, hypospadias, and impaired spermatogenesis) which together comprise the Testicular Dysgensis Syndrome (TDS) (9, 10).

Commonly used personal care products are known to contain EDCs such as phthalates, bisphenol A (BPA), perfluorinated chemicals, triclosan, and parabens (11, 12). Many personal care products are applied directly to the body allowing EDCs to be absorbed through the skin and to reach the circulatory system. Personal care product use is much more common among women than men (13), and the fetuses of pregnant women may be especially vulnerable to the risks of EDCs. EDCs are able to cross the placenta (14) and may adversely affect placental functioning and/or fetal development. Postnatally, infant exposure may occur via breastfeeding as EDCs have been found in breastmilk (15) and have been reported to affect endogenous reproductive hormones (16). EDCs can transfer by passive diffusion from the blood stream into the mammary alveolar gland where they then can become incorporated into breastmilk at concentrations which are comparable to other fatty parts of the body (15).

EDCs have been shown to have estrogenic and/or anti-androgenic effects (17, 18). It has been suggested that that exposure to EDCs during gestation could result in reproductive tract abnormalities in the fetus and TGCT later in life through a relative excess of estrogen (19). Furthermore, exposure to EDCs in postnatal life through breastmilk may interfere with germ cell development (16). To determine the association between maternal personal care product use during pregnancy and TGCT risk, we conducted an analysis among mothers of cases and controls in The US Servicemen's Testicular Tumor Environmental and Endocrine Determinants (STEED) study.

METHODS

A detailed description of the STEED study has been reported previously (20). In brief, between April 2002 and January 2005, men between the ages of 18-45 years who had at

least one serum sample stored in the US Department of Defense Serum Repository (DoDSR, Silver Spring, MD, USA) were eligible to participate in the study. The DoDSR has been storing serum samples from military personnel since 1985. A person-specific identifier is used in the DoDSR database to link the serum samples to the Defense Medical Surveillance System (DMSS) (21) and to other military medical databases to determine which military personnel develop medical conditions. Men who developed TGCT while on active duty were eligible to participate as cases whereas men who did not develop TGCT were eligible to participate as controls. Diagnoses of TGCT were limited to classic seminoma or nonseminoma (embryonal carcinoma, yolk sac carcinoma, choriocarcinoma, teratoma, mixed germ cell tumor), as spermatocytic tumors (formerly known as spermatocytic seminomas) are thought to be etiologically distinct from other TGCTs. The diagnoses were based on the original pathology reports or on review of the pathology slides.

The STEED study was designed as a matched case-control study. Eligible controls were individually matched to cases on the following factors: age at diagnosis (within 1 year), race (white, black, other), and date when serum was donated (within 30 days). Each participant was asked for permission to contact his mother to enroll her in the study. A total of 1,247 mothers were contacted: 43 were found to be ineligible, 28 were incompletely enrolled at study completion, and 16 could not be located. Of the 1,160 eligible mothers contacted, 72 refused to participate. Overall, 527 case mothers and 562 control mothers were completely enrolled in the study. Participating mothers were interviewed by a female interviewer over the telephone. Supervising interviewers listened in, at random, to the interviews, to assure that the interviews were conducted in a similar fashion across all the mothers.

The computer-assisted telephone interview was composed of nine modules. Select questions from the demographic history and personal care product use sections were used for the present analysis. Mothers of both cases and controls were asked to report on use and the frequency of use for the following personal care products during their pregnancy and while they breastfed: perfume, hairspray, nail polish, hair dye, perm/relaxer, face lotion, body lotion, deodorant/antiperspirant, and sunscreen. The study was approved by the institutional review boards of the National Cancer Institute (Bethesda, MD, USA) and the Walter Reed Army Institute of Research (Silver Spring, MD, USA).

Statistical Analysis

Frequency of personal care product use was categorized into usage groups (never, ≤ once/week, > once/week). Cohen's kappa statistic was calculated to measure the agreement between frequency of exposures to each personal care product category during pregnancy and exposures while breastfeeding, which showed moderate to very good agreement of frequency of personal care product use during pregnancy and breastfeeding. Thus, duration of exposure was simply calculated as the duration of pregnancy plus the duration of breastfeeding in weeks.

Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) were calculated to estimate the association between the exposures and TGCT risk in sons. Mothers who didn't complete a questionnaire were not included in the study. As the mothers themselves were not matched to one another, unmatched analyses were performed using unconditional logistic regression.

Risk estimates were initially minimally adjusted, taking into account only two of the matching factors (age at diagnosis, race). Serum samples were not used in the present analysis therefore no adjustment was made for the third matching factor (date of serum collection). The fully adjusted models also included adjustment for known TGCT risk factors (cryptorchidism, family history of TGCT) and maternal factors (age at delivery, weight gain during pregnancy, duration of personal care product use). Conditional logistic regression models produced similar results, thus, only the unconditional logistic regression models are presented. Tests for interaction were conducted among all exposures and races, as personal care product usage may vary by race (22). All statistical tests were two sided with $p < 0.05$ defined as statistically significant, although consideration of the false discovery rate, which considers multiple comparisons, was made. All statistical analyses were performed using SAS, version 9.3 (SAS Institute, Inc., Cary, NC).

RESULTS

The distributions of characteristics among case and control mothers are shown in Table 1. The majority of study participants were white (88.6% of cases; 89.7% of controls) and gave birth to their sons between ages 20-29 years (59.6% of cases, 66.7% of controls). Maternal weight gain during pregnancy was similar in the case and control mothers; 50.5% of case mothers gained more than 25 pounds during their pregnancies, as did 48.2% of control mothers. The majority of sons were diagnosed with TGCT between ages 20-29 years (64.9%). Approximately 32% of case mothers and 26% of control mothers breastfed their sons. The number of different personal care products used by each woman during pregnancy followed a normal distribution with 3 to 4 products being most commonly used.

Table 2 shows patterns of usage among the different personal care products by race. Both during pregnancy and breastfeeding, black women reported using nail polish and body lotion more frequently than did white and women of other races. In contrast, black women were less likely to use hairspray and reported no sunscreen use in comparison to white and other women. Use of other personal care products was similar among white, black and women of other races, both during pregnancy and while breastfeeding.

Supplementary Table 1 shows the distribution of characteristics among case and control mothers who breastfed. The distribution of characteristics was similar to that of the overall study population. Cohen's kappa statistic (κ) for agreement of exposure between the pregnancy and breastfeeding stages (Table 3) found that four products (hair dye, face lotion, body lotion, and deodorant) had very good agreement ($\kappa \geq 0.80$), three products (hairspray, nail polish, and permanent wave) had good agreement (κ between 0.60 and 0.80), and only two products (perfume, sunscreen) had moderate agreement (κ between 0.40-0.60).

The association between frequency of use of selected maternal exposures and the risk of TGCT is presented in Table 4. The use of face lotion more than one time per week was associated with a significantly increased risk of TGCT (OR: 1.42, 95% CI: 1.08-1.86, p-trend: 0.01) compared to no use. None of the other products examined were associated with TGCT risk. In addition, there were no statistically significant interactions between race and use of any of the products.

DISCUSSION

The present study found that face lotion use was significantly associated with an increased risk of TGCT in sons. A possible explanation for this finding may be the common inclusion of parabens as preservatives in face lotions. Parabens have estrogen-like properties and can be absorbed through the skin (23). Although studies on the use of personal care products during pregnancy are few, one US study found higher concentrations of parabens in the urine of pregnant mothers who used lotions during pregnancy compared to non-users (24). Another study found that parabens can accumulate in the placenta and possibly lead to fetal exposure *in utero* (25). Parabens are also used as additives in food, beverages, and pharmaceuticals; these additional contributions to exposure may explain the increased risk we observed with face lotion use in the present study. To date, however, epidemiological studies have not shown a direct link between parabens and human health.

Other common EDCs found in face lotions include phthalates. Human and animal studies have shown that phthalates have estrogenic and anti-androgenic properties that can inhibit testosterone synthesis (26, 27). Phthalate exposure is widespread through the environment and exposure to the fetus during pregnancy through the placenta has been well documented (28, 29). In 2005, Swan and colleagues reported that maternal phthalate exposure was associated with shorter anogenital distance (AGD) in sons (27). Urinary monoethyl phthalate (MEP), monobutyl phthalate (MBP), monobenzyl phthalate (MBzP), and mono-isobutyl phthalate (MIBP) levels were all associated with shorter than normal AGD, a marker of anti-androgenic exposures. In 2008, the same study team reported a significant association between shorter AGD and urinary levels of three Bis (2-ethylhexyl) phthalate (DEHP) metabolites: Mono (2-ethylhexyl) phthalate MEHP, mono-(2-ethyl-5-oxohexyl) phthalate (MEOHP), and mono-(2-ethyl-5-hydroxyhexyl) phthalate (MEHHP) (30). A direct inverse association was also found between exposure to DEHP metabolites (mainly MEHP) and cryptorchidism (30), a significant risk factor for TGCT. Similarly, a study of maternal phthalate exposure in the workplace found a significant association with risk of hypospadias (31). In contrast, a study conducted by Huang and colleagues found no association between AGD in newborn boys and maternal urinary levels of MBP, MEHP, MEP, MBzP, and monomethyl phthalate (MMP) (32).

Studies examining the presence of phthalates in human breastmilk have found a wide variation in concentration (16, 33). A prospective Danish-Finnish cohort study of cryptorchidism found that while there was no association between phthalate levels in breastmilk and cryptorchidism, there were significant correlations between breastmilk phthalate levels and circulating levels of sex-hormone-binding-globulin (SHBG), luteinizing hormone (LH), and the LH: free testosterone ratio (16). The study results suggest that human Leydig cell development and function may be vulnerable to perinatal exposure of phthalates. In contrast, a study from the Bavarian Monitoring of Breast Milk cohort suggests that while a wide variety of phthalates are present in breastmilk, it is not likely that an infant’s exposure to phthalates from breastmilk poses any significant health risks (33).

The association between excess estrogen exposure during gestation and testicular cancer was first hypothesized by Henderson in 1979 (34). In 1993, Sharpe and Skakkebaek

hypothesized that several male reproductive tract abnormalities, including cryptorchidism, hypospadias, impaired spermatogenesis and TGCT, share a common in utero etiology and that environmental estrogenic exposures may play a key role in increasing risk (19). To date, there are still a limited number of studies linking male reproductive disorders with exposure to environmental chemicals, which may be due to difficulties in obtaining such data or the genuine absence of an effect (35).

Strengths of the current study include the large sample size and the inclusion of only pathologically confirmed TGCT cases in the original study. Potential limitations of the study include that women were asked to remember events from several decades in the past (from the early 1960s to mid-1980s), so their responses could be recalled imperfectly. Both case and control mothers, however, were asked to recall events after the same period of time. In addition, the extent to which the case mother's recall could be biased (if at all) by a diagnosis of TGCT in an adult son is unknown; we are unaware of any studies that have data to study this type of bias (rumination bias). As most study participants were white, the results of the study may be difficult to extrapolate to non-white populations, where personal care product-related chemical exposures may be different. One study found that compared to white women, women of color had higher levels of personal care product-related chemicals in their bodies (36). However, it should be noted that TGCT incidence rates are considerably higher among white men compared to men of other races. Finally, the formulation of personal care products has changed over time, and as such, there is the potential for heterogeneity in exposures over time. We were unable to examine this further, however, as information on specific name brands of personal care products was not collected. After controlling for multiple comparisons using the false discovery rate (FDR) method, the association between face lotion use and TGCT no longer attained statistical significance ($q=0.09$). Given the small number of comparisons made in the study ($n=9$) however, the FDR correction may be too conservative.

In conclusion, exposure to certain personal care products during pregnancy may affect TGCT risk in sons. Further investigation is warranted concerning specific chemicals in personal care products that might affect TGCT risk. Combinations of chemicals should also receive further scrutiny, as a most women in the current study reported using more than one type of personal care product. Future studies would benefit from a more detailed assessment of personal care product use during pregnancy and breastfeeding.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors thank Ms. Emily Carver of IMS for her contributions to data management.

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Highlights

- Use of face lotion during pregnancy and breast feeding was associated with an increased risk of testicular germ cell tumors in sons.
- A possible explanation for the association is that face lotions may contain endocrine disrupting chemicals.
- Identification of associations with specific chemicals and combinations of chemical formulations of face lotion is warranted.

Table 1

Distribution of characteristics among study participants, The STEED Study, 2002-2005

	Mothers of sons with TGCT (Cases) (n = 527) mean (sd)	**Mother of sons without TGCT (Controls) (n = 562) mean (sd)**	
Mother's age at son's birth (yrs)	24.0 (5.1)	24.3 (4.9)	
Son's age at TGCT diagnosis (yrs)	27.1 (5.7)	27.1 (5.7)	
Maternal weight gain during pregnancy (lbs.)	29.7 (14.1)	28.6 (13.3)	
	n (%)	n (%)	p-value
Mother's age at son's birth (yrs)			0.10
<20	118 (23.2)	89 (16.4)	
20-29	314 (61.7)	375 (69.2)	
≥30	77 (15.1)	78 (14.4)	
Son's age at TGCT diagnosis (yrs)			0.91
<20	26 (4.9)	22 (3.9)	
20-24	176 (33.4)	197 (35.1)	
25-29	166 (31.5)	170 (30.3)	
30-34	85 (16.1)	99 (17.6)	
35-39	57 (10.8)	56 (10.0)	
≥40	17 (3.2)	18 (3.2)	
Race			0.64
White	467 (88.6)	504 (89.7)	
Black	12 (2.3)	15 (2.7)	
Other	48 (9.1)	43 (7.7)	
Breastfed son			0.02
Yes	170 (32.3)	148 (26.3)	
No	357 (67.7)	414 (73.7)	
Number of Products Used			0.92
0	19 (3.6)	15 (2.7)	
1	40 (7.6)	46 (8.2)	
2	84 (15.9)	97 (17.3)	
3	108 (20.5)	128 (22.8)	
4	118 (22.4)	114 (20.3)	
5	88 (16.7)	84 (14.9)	
6	41 (7.8)	49 (8.7)	
7	23 (4.4)	23 (4.1)	
8	5 (0.9	4 (0.7)	
9	1 (0.2)	2 (0.4)	
Maternal weight gain during pregnancy (lbs.)			0.21
<20	159 (32.9)	168 (32.0)	
20-24	80 (16.6)	104 (19.8)	
25-34	113 (23.4)	136 (25.9)	

	Mothers of sons with TGCT (Cases) (n = 527) mean (sd)	Mother of sons without TGCT (Controls) (n = 562) mean (sd)
≥35	131 (27.1)	117 (22.3)

Abbreviations: SD = Standard Deviation

Table 2

Distribution of personal care product use by race, The STEED Study, 2002-2005

	White Mothers		Black Mothers		Other Mothers	
	Pregnancy (n=967)	Breastfeeding (n=274)	Pregnancy (n=24)	Breastfeeding (n=8)	Pregnancy (n=98)	Breastfeeding (n=36)
	n (%)		n (%)		n (%)	
Perfume						
> Once/week	357 (38.5)	52 (19.3)	12 (50.0)	2 (25.0)	37 (37.8)	10 (27.8)
≤ Once/week	277 (29.9)	36 (13.3)	9 (37.5)	1 (12.5)	25 (25.5)	5 (13.9)
No use	293 (31.6)	182 (67.4)	3 (12.5)	5 (62.5)	36 (36.7)	21 (58.3)
Hairspray						
> Once/week	374 (40.7)	79 (29.6)	2 (8.3)	1 (12.5)	30 (30.6)	5 (13.9)
≤ Once/week	112 (12.2)	17 (6.4)	0 (0.0)	0 (0.0)	16 (16.3)	3 (8.3)
No use	434 (47.2)	171 (64.0)	22 (91.7)	7 (87.5)	52 (53.1)	28 (77.8)
Nail Polish						
> Once/week	40 (4.3)	1 (0.4)	4 (16.7)	2 (25.0)	7 (7.1)	3 (8.8)
≤ Once/week	276 (29.8)	58 (21.3)	11 (45.8)	1 (12.5)	39 (39.8)	3 (8.8)
No use	609 (65.8)	213 (78.3)	9 (37.5)	5 (62.5)	52 (53.1)	28 (82.4)
Hair Dye						
> Once/week	1 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.1)	0 (0.0)
≤ Once/week	101 (10.7)	22 (8.1)	3 (12.5)	0 (0.0)	10 (10.3)	1 (2.8)
No use	839 (89.2)	250 (91.9)	21 (87.5)	8 (100.0)	86 (88.7)	35 (97.2)
Permanent Wave						
> Once/week	2 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.0)	0 (0.0)
≤ Once/week	204 (22.4)	29 (11.1)	7 (29.2)	1 (12.5)	21 (21.4)	4 (11.1)
No use	704 (77.4)	232 (88.9)	17 (70.8)	7 (87.5)	76 (77.6)	32 (88.9)
Face Lotion						
> Once/week	315 (33.8)	90 (33.6)	10 (41.7)	3 (42.9)	36 (36.7)	13 (37.1)
≤ Once/week	14 (1.5)	4 (1.5)	1 (4.2)	1 (14.3)	1 (1.0)	2 (5.7)
No use	603 (64.7)	174 (64.9)	13 (54.2)	3 (42.9)	61 (62.2)	20 (57.1)
Body Lotion						

	White Mothers		Black Mothers		Other Mothers	
	Pregnancy (n=967)	**Breastfeeding (n=274)**	**Pregnancy (n=24)**	**Breastfeeding (n=8)**	**Pregnancy (n=98)**	**Breastfeeding (n=36)**
		n (%)		**n (%)**		**n (%)**
> Once/week	305 (32.5)	90 (33.5)	13 (54.2)	5 (62.5)	40 (40.8)	13 (37.1)
≤ Once/week	34 (3.6)	7 (2.6)	0 (0.0)	0 (0.0)	3 (3.1)	1 (2.9)
No use	601 (63.9)	172 (63.9)	11 (45.8)	3 (37.5)	55 (56.1)	21 (60.0)
Deodorant						
> Once/week	899 (95.2)	245 (90.4)	22 (91.7)	7 (87.5)	86 (87.8)	29 (80.6)
≤ Once/week	10 (1.1)	2 (0.7)	0 (0.0)	0 (0.0)	1 (1.0)	0 (0.0)
No use	35 (3.7)	24 (8.9)	2 (8.3)	1 (12.5)	11 (11.2)	7 (19.4)
Sunscreen						
> Once/week	34 (3.6)	5 (1.8)	0 (0.0)	0 (0.0)	2 (2.1)	0 (0.0)
≤ Once/week	81 (8.7)	11 (4.0)	0 (0.0)	0 (0.0)	3 (3.1)	0 (0.0)
No use	819 (87.7)	257	24 (100.0)	8 (100.0)	91 (94.8)	35 (100.0)

Table 3

Correlations between pregnancy and breastfeeding among personal care products

Personal Care Product	Kappa Coefficient
Perfume	0.41
Hairspray	0.76
Nail Polish	0.72
Hair Dye	0.80
Permanent Wave	0.60
Face Lotion	0.95
Body Lotion	0.83
Deodorant	0.82
Sunscreen	0.59

Table 4

Frequency of maternal use of personal care product use and TGCT risk, The STEED Study, 2002–2005.

	Mothers of sons with TGCT (Cases) (n = 527) n (%)	Mothers of sons without TGCT (Controls) (n = 562) n (%)	Odds Ratio* (95% CI)	p-trend
Perfume				0.44
> Once/week	191 (37.8)	214 (39.2)	0.89 (0.65–1.20)	
≤ Once/week	146 (28.9)	166 (30.4)	0.91 (0.66–1.26)	
No use	168 (33.3)	166 (30.4)	1.00 (referent)	
Hairspray				0.25
> Once/week	203 (40.4)	203 (37.2)	1.17 (0.89–1.55)	
≤ Once/week	68 (13.5)	66 (12.1)	1.24 (0.82–1.88)	
No use	232 (46.1)	277 (50.7)	1.00 (referent)	
Nail Polish				0.98
> Once/week	29 (5.8)	24 (4.4)	1.11 (0.62–2.01)	
≤ Once/week	153 (30.5)	180 (32.9)	0.95 (0.72–1.26)	
No use	319 (63.7)	344 (62.8)	1.00 (referent)	
Hair Dye				0.37
> Once/week	2 (0.4)	1 (0.2)	**	
≤ Once/week	57 (11.2)	71 (12.8)	0.80 (0.54–1.18)	
No use	450 (88.4)	483 (87.0)	1.00 (referent)	
Permanent Wave				0.18
> Once/week	3 (0.6)	1 (0.2)	**	
≤ Once/week	124 (24.9)	117 (21.4)	1.18 (0.86–1.62)	
No use	372 (74.6)	428 (78.4)	1.00 (referent)	
Face Lotion				0.01
> Once/week	194 (38.2)	168 (30.4)	1.42 (1.08–1.86)	
≤ Once/week	9 (1.8)	15 (2.7)	0.77 (0.31–1.91)	
No use	305 (60.0)	369 (66.9)	1.00 (referent)	
Body Lotion				0.09
> Once/week	190 (37.1)	169 (30.5)	1.27 (0.97–1.67)	
≤ Once/week	23 (4.5)	22 (4.0)	1.20 (0.63–2.26)	
No use	299 (58.4)	364 (65.6)	1.00 (referent)	
Deodorant				0.09
> Once/week	488 (95.3)	518 (93.5)	1.80 (0.94–3.44)	
≤ Once/week	6 (1.2)	6 (1.1)	**	
No use	18 (3.5)	30 (5.4)	1.00 (referent)	
Sunscreen				0.09
> Once/week	14 (2.8)	22 (4.0)	0.74 (0.37–1.49)	
≤ Once/week	31 (6.1)	54 (9.8)	0.63 (0.39–1.02)	
No use	462 (91.1)	475 (86.2)	1.00 (referent)	

*Models adjusted for maternal age at delivery, race, duration of product use, weight gain during pregnancy, son's age at diagnosis, family history of TGCT, and cryptorchidism.

** Odds ratio not calculated due to small numbers.