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ORIGINAL RESEARCH

FEMALE SEXUAL FUNCTION

Differences in Perceived and Physiologic Genital Arousal Between Women With and Without Sexual Dysfunction

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ABSTRACT

Background: Many sexual psychophysiologic studies have failed to find differences in physiologic genital arousal between women with and those without sexual dysfunction. However, differences in self-reported (ie, perceived) measures of genital responses between these 2 groups of women have been noted.

Aims: To determine whether women with and without sexual dysfunction differ on measures of physiologic and perceived genital arousal based on type of analytic technique used, to explore differences in perceived genital arousal, and to assess the relation between physiologic and perceived genital arousal.

Methods: Data from 5 studies (N = 214) were used in this analysis. Women were categorized into 3 groups: women with arousal-specific sexual dysfunction (n = 40), women with decreased sexual function (n = 72), and women who were sexually functional (n = 102). Women viewed an erotic film while their physiologic genital arousal was measured using a vaginal photoplethysmograph. After watching the film, women completed a self-report measure of perceived genital arousal.

Outcomes: There were differences in vaginal pulse amplitude (VPA) levels and association of VPA with perceived genital sensations based on level of sexual function.

Results: Commonly used methods of analysis failed to identify significant differences in VPA among these groups of women. When VPA data were analyzed with hierarchical linear modeling, significant differences emerged. Notably, women with arousal-specific dysfunction exhibited lower VPA than sexually functional women at the beginning of the assessment. As the erotic film progressed, women with arousal-specific dysfunction became aroused at a faster rate than sexually functional women, and these 2 groups ultimately reached a similar level of VPA. Sexually functional women reported the highest levels of perceived genital responses among the 3 groups of women. No significant relation between VPA and perceived genital arousal emerged.

Clinical Translation: Women's perception of their genital responses could play a role in women's experience of sexual dysfunction and might be more clinically relevant for women with sexual dysfunction than genital blood flow.

Strengths and Limitations: This study's large sample is unique in sexual psychophysiology, and it strengthens the credibility of the findings. However, this study is limited in that arousal-specific dysfunction was determined with self-report measures, not by a clinician-administered assessment.

Conclusion: These findings suggest distinct response trajectories in women with and without sexual dysfunction, and although perceived genital responses are important for women who are experiencing problems with arousal, they do not seem to be related to objective measures of physiologic arousal. **Handy AB, Stanton AM, Pulverman CS, Meston CM. Differences in Perceived and Physiologic Genital Arousal Between Women With and Without Sexual Dysfunction. J Sex Med 2018;15:52–63.**

Key Words: Vaginal Photoplethysmography; Sexual Arousal; Female Sexual Dysfunction; Female Sexual Arousal Disorder; Perceived Arousal

INTRODUCTION

Vaginal photoplethysmography is the most commonly used measurement of genital sexual arousal in women. The vaginal photoplethysmograph contains a light-emitting diode or transistor that emits infrared or incandescent light. The light reflects

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off blood in the vaginal canal and is subsequently detected by the probe.[1,2] Vaginal photoplethysmography has been shown to be a sensitive and reliable index of women's physiologic sexual arousal.[3] Research has consistently found that vaginal pulse amplitude (VPA), the corresponding unit of physiologic sexual arousal, increases specifically during exposure to erotic stimuli. Exposure to anxiety-provoking stimuli, which also produces physiologic activation (eg, increased heart rate, galvanic skin response), does not increase VPA,[3] suggesting that VPA is uniquely sensitive to sexual arousal as opposed to general bodily arousal.

Several studies have suggested that VPA also might be sensitive to treatment effects of drugs intended to increase a woman's sexual arousal response. Meston and Worcel[4] found an increase in VPA response to erotic stimuli in women treated for sexual dysfunction with combined L-arginine glutamate plus yohimbine but not in women treated with placebo or yohimbine alone. Similarly, ginkgo biloba extract increased VPA to a greater extent than placebo in women with a diagnosis of female sexual arousal disorder (FSAD).[5,6] In postmenopausal women taking tibolone hormone therapy, Laan et al[7] found significant increases in VPA responses compared with women given placebo. Laboratory studies also have shown increases in genital responding with sildenafil[8,9] and combination testosterone plus vardenafil[10] (but see a review by Chivers and Rosen[11] for exceptions).

Despite several studies indicating VPA is a sensitive marker of sexual-specific arousal and drug treatment effects, the degree to which VPA can reliably discriminate between women with and those without sexual dysfunction is questionable. Using VPA percentage of change* scores as a means of measurement, several studies have not found differences in genital responsiveness between women with and those without sexual dysfunction.[12–14] In a large well-controlled study, Laan et al[15] did not find significant differences in the mean† or maximum‡ VPA scores between women with and those without FSAD.[5] To this end, Laan et al suggested that genital blood flow might not play a critical role in women's sexual arousal problems. Rather, they suggested that women's access to effectively arousing stimuli at home, negative affect related to sexual stimuli, or a lack of awareness of genital arousal could explain, in part, the lack of differences in genital blood flow between women with and those without FSAD. In other words, if women cannot obtain sufficiently arousing stimuli, or if sexual stimuli evoke negative feelings or anxiety, or if women with FSAD are unaware of genital changes associated with sexual arousal (cf Handy and Meston[16]), then they might present with symptoms of sexual arousal dysfunction.

In contrast to these null findings, Meston et al[17] reported differences in VPA based on theoretical sexual arousal dysfunction subtypes using hierarchical linear modeling (HLM), an analytic technique designed to handle a large number of data points. Women with genital arousal disorder had notably lower levels of VPA than did women with subjective (also known as "mental") arousal disorder and women who were sexually functional. They proposed that, in addition to the potential explanations described by Laan et al,[15] methodologic limitations might have contributed to the null findings of previous studies; using VPA mean, maximum, or percentage of change condenses continuous data into a single datum, thus compromising the richness and variability in the data. Condensing many data points into a single average value could mask potential fluctuations in VPA that might be clinically relevant and can be detected only when analyzing data continuously over time. HLM fits models to continuous, nested, multilevel data and estimates coefficients based on the unique slopes and intercepts of each subject.[18] This technique allows for the analysis of group data while still accounting for individual variability. Similarly, smoothing regression splines, a non-parametric form of regression, balances the fit between continuous data points with the number of contours in the modeled trajectory by minimizing the differences between actual and predicted y values.[19] Smoothing regression splines analysis is sensitive enough to detect category specificity in heterosexual women,[20] an effect that was previously undocumented in the literature.[21] However, most sexual psychophysiology studies rely on analyses of variance (ANOVAs) with just 1 average per film or condition. Although ANOVAs can be expanded using multiple observations (which would make better use of the continuous nature of VPA and would increase statistical power), these analytic techniques typically examine group, rather than individual, changes in VPA. HLM analyzes changes within individuals to determine the strength of the overall relation. An individual approach is particularly beneficial when examining VPA data, because VPA has no absolute values. Therefore, examining change within individuals allows for each woman to serve as her own control.

The studies cited earlier focused on objective measurements of genital responding (ie, vaginal photoplethysmographic recordings of genital responses). Interestingly, in the study conducted by Laan et al,[15] women with and without FSAD differed in their *perception* of their genital responses, although they did not differ in objective measurements of genital responding. Specifically, when asked whether they perceived any genital responses (eg, genital pulsing, throbbing, tingling, and wetness) during exposure to the erotic stimulus, women with FSAD reported significantly lower levels of genital responses compared with healthy controls. In addition, objective measurements of genital responding (VPA mean and maximum) were meaningfully related to perceived genital responses only in sexually functional women. Laan et al's finding suggests that FSAD might be more related to a lack of *perceived* genital responses than to problems with decreased genital responding (ie, decreased vasocongestion).

* A change score is a participant's mean VPA during the erotic film minus her mean VPA during the neutral film, divided by her mean VPA during the neutral film, and then multiplied by 100.

† A mean VPA score is a participant's mean VPA during the erotic film minus her mean VPA during the neutral film.

‡ A maximum VPA score is a participant's highest 30-second epoch of VPA during the erotic film minus her mean VPA during the neutral film.

The question of whether women with and without sexual arousal concerns differ in their perceptions of genital responses and/or their actual recording of genital responses using vaginal photoplethysmography has important theoretical, methodologic, and clinical implications. As such, the present study had 3 aims: (i) to compare objective measurements of genital responding (ie, VPA) in women with arousal-specific dysfunction, women with decreased sexual function, and women who were sexually functional using statistical techniques that use condensed and continuous VPA data; (ii) to compare perceived genital responses among these 3 groups of women; and (iii) to assess potential differences in the relation between objective (ie, VPA) and perceived genital responses among these 3 groups of women. We developed the following hypotheses:

H1 When analyzing continuous VPA data, women with arousal-specific dysfunction will show the smallest increases in VPA, whereas sexually functional women will show the greatest increases; no differences will emerge when analyzing condensed VPA data.

H2 Compared with sexually functional women, women with arousal-specific dysfunction will show lower levels of perceived genital sensations. Women with decreased sexual function will have lower levels of perceived genital responses than sexually functional women but higher levels than women with arousal-specific dysfunction.

H3 A positive correlation between VPA and perceived genital responses will emerge only for sexually functional women; no relation will be found for women with decreased sexual function or arousal-specific dysfunction.

METHODS

Participants

Data from 5 studies, 4 published[16,22,23] and 1 unpublished (N = 214 women; sexually functional, n = 102; decreased sexual function, n = 72; arousal-specific dysfunction, n = 40), were compiled. Recruitment for these studies took place from 2014 to 2016. No participant's data was used more than once. In each study, participants were recruited from the local community (n = 154) and/or undergraduate courses in psychology (n = 60). Potential participants were screened over the phone to ensure that they met the inclusion and exclusion criteria of each study. Inclusion criteria for all studies were age at least 18 years, premenopausal, fluent in reading and writing in English, heterosexual or bisexual, and currently sexually active. Exclusion criteria for each study are listed in Table 1.

Table 1. Inclusion and exclusion criteria for each study

Inclusion criteria	
≥18 y old	
Premenopausal	
Fluent in reading and writing in English	
Heterosexual or bisexual	
Currently sexually active	
Exclusion criteria	**n**
Handy and Meston (2016)	26
History of sexual trauma	
Current sexual dysfunction	
Stanton and Meston (2016)	33
History of sexually transmitted diseases	
Current pelvic, vaginal, or urinary tract infection	
Past pelvic surgery leading to nerve damage	
Neurologic impairment	
Diagnosis of depression, bipolar disorder, or schizophrenia	
History of sexual trauma	
Current sexual dysfunction	
Handy and Meston (in press)	26
History of sexual trauma	
Taking medications likely to affect sexual arousal	
Not currently experiencing FSAD	
Stanton et al (in press)	13
History of sexually transmitted diseases	
Current pelvic, vaginal, or urinary tract infection	
Past pelvic surgery leading to nerve damage	
Neurologic impairment	
Diagnosis of depression, bipolar disorder, or schizophrenia	
History of sexual trauma	
Taking medications likely to affect sexual arousal	
Not currently experiencing FSAD	
Pulverman and Meston (unpublished)	116
Pregnant or breastfeeding	
History of sexually transmitted diseases	
Current pelvic, vaginal, or urinary tract infection	
Past pelvic surgery leading to nerve damage	
Neurologic impairment	
Diagnosis of bipolar disorder or schizophrenia	
Taking medications likely to affect sexual arousal	

FSAD = female sexual arousal disorder.

Measures

Genital Sexual Arousal

A vaginal photoplethysmograph was used to assess VPA during the film presentation. The VPA signal was sampled at a rate of 200 samples per second throughout the entire 120 seconds of the neutral film presentation and the entire 360 seconds of the erotic film presentation. Each wave was recorded in millivolts, bandpass filtered (0.5−30 Hz), and recorded on a computer in the next room using AcqKnowledge III 3.8.1 and a Model MP150 data acquisition unit (BioPac Systems, Inc, Santa Barbara, CA, USA) for analog-to-digital conversion.

Perceived Genital Responses

The Film Scale of Heiman and Rowland[24] was used to retrospectively assess participant's perceived genital responses

during the erotic film. The Film Scale contains 15 items that measure perceptions of physiologic arousal, subjective sexual arousal, and affect related to sexual arousal. Items are rated on a 7-point Likert scale ranging from 1 ("not at all") to 7 ("intensely"). Relevant to the present study are the 5 items that specifically assess perceived genital responses, including genital "warmth," "wetness/lubrication," "pulsing/throbbing," "tenseness/tightness," and "any genital feeling." Responses to these 5 items were summed to create a composite score of perceived genital responses.

Sexual Function

Sexual function was determined using the Female Sexual Function Index (FSFI), a 19-item self-report questionnaire assessing desire, arousal, lubrication, pain, orgasm, satisfaction, and overall sexual functioning.[25] Total scores range from 2 to 36, where poorer sexual function is represented by lower scores. Previous research has found the FSFI to have good internal reliability ($r = 0.89-0.97$), test-retest reliability ($\alpha = 0.79-0.88$), and confirmed discriminant validity in discriminating between women with and those without sexual complaints.[25] Women with FSFI scores at or below 26.55, the clinical cutoff for sexual dysfunction,[26] were categorized has having decreased sexual function. This categorization created a heterogeneous group of sexual difficulties to explore whether potential differences were related to a general decrease in sexual function. Women scoring above the cutoff point were categorized as sexually functional. To determine whether any differences were unique to women with arousal-specific dysfunction compared with women with decreased sexual dysfunction more generally, participants in 3 of the studies[16,22,27] also were screened for arousal-specific dysfunction using a brief screening tool developed by the investigators to assess for FSAD based on the *International Classification of Diseases, 10th Revision* (ICD-10) criteria.[28] Women were categorized as having an arousal-specific dysfunction if they reported experiencing (i) decreased or absent genital arousal sensations for at least the past 6 months; (ii) they self-identified as having an arousal problem; (iii) their problem was generalized rather than situational in nature; (iv) they were distressed by their problem; and (v) they scored below the clinical cutoff point on the FSFI.

Procedure

All 5 studies were conducted within the same laboratory and followed the same general procedure. In each study, after providing informed consent, participants were instructed in the proper use of the vaginal photoplethysmograph by a female experimenter. When the experimenter left the room, the participant inserted the vaginal photoplethysmograph on her own. Participants viewed an 8-minute film presentation composed of a neutral (2-minute) followed by an erotic (6-minute) film clip while their genital sexual arousal was measured. The erotic films depicted a heterosexual couple engaging in foreplay, oral sex, and vaginal intercourse. The erotic films were equivalent in the type and duration of sexual acts. After the film presentation, participants completed the Film Scale[24] to capture their perceived genital responses. Further details on the procedures can be found in Handy and Meston[16,22] and Stanton and Meston.[23,25] Participants were compensated with $25 to $50 or with course credit, depending on the study completed. Each study was approved by the institutional review board at the University of Texas Austin.

Data Reduction and Analysis

Genital Sexual Arousal

Genital sexual arousal data (ie, VPA) from 3 studies[23,27,29] ($n = 162$) were exported from AcqKnowledge 3.9.3 to Excel (Microsoft, Redmond, WA, USA) for processing. Movement artifacts in the data were identified and removed by an automatic processing procedure[30] that has been shown to effectively remove outliers and provide results that are comparable to visual inspection. This automatic processing procedure is conducted within the R environment[31] using the MGCV package for generalized additive modeling.[32] For a more comprehensive explanation of this data-reduction procedure, see Pulverman et al.[20] The VPA data from the remaining 2 studies[16,22] ($n = 52$) were assessed for movement artifacts through visual inspection, and artifact smoothing was performed manually. Across all datasets, VPA data were binned in 5-second epochs representing mean peak-to-peak VPA response, yielding a total of 96 data points per participant.

Changes in genital arousal were calculated using VPA mean, maximum, percentage of change, and HLM. Percentage of change was calculated by subtracting mean genital arousal during the neutral film from mean genital arousal during the erotic film, dividing this value by mean genital arousal during the neutral film, and multiplying by 100 to yield a percentage of change score. VPA mean, maximum, and percentage of change were analyzed in separate ANVOAs. HLM analyses were conducted in R 3.2.3[31] using the NLME package for linear and non-linear mixed effects.[33] 2 models were used to assess the between-group hypotheses related to change in genital arousal. In each of these models, the slopes and intercepts were modeled as random, thus allowing them to vary across participants.[34] The first model to test the relation between VPA and sexual function status used the following formula:

$$Y(VPA)_{ij} = \beta_0 + \beta_1(function)_i + r_{ij}$$

where $Y(VPA)_{ij}$ is the ith participant's VPA at the jth time point to assess the ways in which VPA varies across participants. In this example, $(function)_i$ has 3 values representing sexual function (0 = sexually functional, 1 = decreased sexual function, 2 = arousal-specific dysfunction) for the ith participant. Sexual function is treated as a level 2 variable, because it does not vary within individuals. Rather, it reflects interindividual differences. In addition, β_0 is the participant-specific intercept, β_1 is the participant-specific slope, and r_{ij} represents the residuals.

A second model was run to examine whether a second level 2 variable, time, could influence the results. The following equation was used:

$$Y(VPA)_{ij} = \beta_0 + \beta_1(time)_{ij} + \beta_2(function)_i + \beta_3(time \times function)_i + r_{ij}$$

In this model, time is treated as a level 1 variable and the between-subjects factor of sexual functioning is a level 2 variable.

Perceived Genital Responses

To compare perceived genital responses across the 3 groups, the dependent variable (ie, the composite perceived genital responses score) was entered into a univariate ANOVA, with sexual functioning status (ie, sexually functional, decreased sexual function, or arousal-specific dysfunction) entered as the independent variable. If a significant difference were to emerge, then exploratory multivariate ANOVAs were planned to determine whether the perception of specific genital responses differed among groups. The α values were Bonferroni adjusted in all analyses.

Relation Between Objective (VPA) and Perceived Genital Responses

The relation between VPA and perceived genital responses was measured using Pearson correlations and HLM. Only Pearson correlations of r greater than or equal to 0.30 (medium effect) are reported. The following HLM equation was used:

$$Y(responses)_{ij} = \beta_0 + \beta_1(VPA)_{ij} + \beta_2(function)_i + \beta_3(VPA \times function)_i + r_{ij}$$

In this model, VPA is treated as a level 1 variable and the between-subjects factor of sexual functioning is entered as a level 2 variable. Follow-up analyses to determine the relations between specific perceived genital sensations (eg, warmth, lubrication, etc) and VPA were planned in the event of a statistically significant result.

RESULTS

Participant Characteristics

Data from 214 women 18 to 47 years old (mean = 25.2, SD = 7.2) were included in the present analyses. The sample was predominately Caucasian (49.1%), 10.7% were Hispanic or Latina, 9.8% were Asian, 6.1% were African American, and 24.3% reported another ethnicity. Most women (57.5%) reported being in a committed dating relationship, 14.9% reported being married, 16.6% reported being single, and 1% reported a relationship status of "other." The sample consisted largely of women who had completed some college (41.6%); of the remaining subjects, 20.6% held a college degree, 14.0% held an advanced degree, 20.1% held a high school diploma, and 3.7% reported attending some high school. Table 2 presents the demographic information.

Based on FSFI score (mean = 25.24, SD = 6.06), 47.7% of the sample were considered sexually functional and 33.6% were categorized as having decreased sexual function. The brief screener based on the eligibility ICD-10 criteria for FSAD[28] indicated that 40 women (18.7% of total sample) met the diagnostic criteria and thus were considered to have an arousal-specific dysfunction. The final group samples were 102 sexually functional women, 72 women with decreased sexual function, and 40 women with arousal-specific sexual dysfunction. Table 3 presents the FSFI results.

Genital Arousal

VPA: Mean, Maximum, Percentage of Change

To assess whether genital responses differed among groups using widely used analytic techniques that condense VPA data into a single datum, differences in mean and maximum VPA during the neutral and erotic films and differences in percentage of change in VPA from the neutral to the erotic film were examined. There were no significant differences among sexually functional women, women with decreased sexual function, and women with arousal-specific dysfunction for VPA mean, maximum, or percentage of change scores (Table 4).

VPA: HLM

To assess whether VPA differed among the 3 groups using continuous data, a set of HLM analyses was conducted. When only sexual functioning status was entered as a predictor of VPA, no notable differences emerged. Follow-up analyses that included time (in seconds) as an additional predictor of VPA indicated a significant group-by-time interaction ($\beta = 0.001$, t = 5.588, $P < .001$). Table 5 presents results of the HLM analysis that included time as a level 1 variable. Although women with arousal-specific dysfunction initially exhibited lower VPA than did sexually functional women or women with decreased sexual functioning, the trajectory of their VPA was notably steeper than that of the other groups. As such, by the conclusion of the erotic film, women with arousal-specific dysfunction did not show lower levels of VPA than the other 2 groups. Women with decreased sexual functioning displayed significantly higher levels of genital arousal over time than did sexually functional women, although less than that of

Table 2. Participant characteristics

	Sexually functional, mean (SD)	Decreased sexual function, mean (SD)	Arousal-specific dysfunction, mean (SD)	F	Entire Sample, mean (SD)
Age	23.03 (6.33)	24.99 (6.20)	31.15 (7.84)	21.82†	25.21 (7.21)
Age of sexual debut	17.11 (2.76)	17.41 (2.08)	16.62 (2.47)	0.87	17.13 (2.49)
Relationship length (mo)	32.55 (42.18)	40.86 (46.48)	72.82 (56.89)	8.84†	43.02 (48.79)
	n	n	n	χ^2	n
Relationship status				23.73*	
Single (not dating)	15	12	0		27
Single (casually dating)	15	6	9		30
In committed relationship	63	42	18		123
Married	8	11	13		32
Other	1	1	0		2
Hormonal birth control use				1.00	
Yes	23	26	11		60
No	41	46	29		116
Antidepressant use				0.32	
Yes	3	3	1		7
No	61	69	39		169
Highest level of education				27.78*	
High school degree or GED	4	3	1		8
Some college	39	9	10		58
College degree	49	36	19		
Advanced degree (eg, MA)	10	24	10		44
Race and ethnicity				40.76†	
African American or black	3	5	13		21
Asian	13	9	1		23
Caucasian or white	48	39	18		105
Hispanic or Latin American	32	13	6		51
Native American or aboriginal	0	0	1		1
Pacific Islander	6	6	1		13

GED = Graduate Equivalency Diploma.
*Less than 0.01 (Bonferroni-adjusted α).
†Less than 0.001.

women with arousal-specific dysfunction. Interestingly, sexually functional women had the flattest slope of the 3 groups. Figure 1 presents a visualization of these trajectories.

Perceived Genital Responses

Group differences in perceived genital responses were assessed with univariate ANOVA. A main effect of group was found for the composite measure of perceived genital responses ($F_{2,\ 206} = 3.239$, $P = .041$). Follow-up analyses indicated that sexually functional women reported greater perceived genital responses than did the other 2 groups of women. Planned exploratory analyses were conducted to determine whether a specific item or a combination of items was driving this effect. Results indicated a main effect of group for the items "genital

Table 3. Descriptive statistics from the Female Sexual Function Index reported by sexual function group

	Sexually functional, mean (SD)	Decreased sexual function, mean (SD)	Arousal-specific dysfunction, mean (SD)	F	Entire sample, mean (SD)
Desire	4.37 (0.89)	3.53 (1.26)	2.83 (0.93)	34.83*	3.80 (1.19)
Arousal	5.10 (0.72)	3.20 (1.21)	2.91 (0.79)	131.06*	4.06 (1.40)
Lubrication	5.56 (0.57)	4.22 (1.11)	3.35 (1.11)	98.97*	4.69 (1.25)
Orgasm	4.72 (1.14)	3.09 (1.32)	2.45 (1.02)	66.46*	3.75 (1.52)
Satisfaction	5.16 (0.88)	2.91 (1.12)	3.00 (1.09)	124.48*	3.98 (1.49)
Pain	5.25 (1.07)	4.32 (1.81)	4.92 (1.25)	8.97*	4.86 (1.46)
Total	30.73 (2.30)	21.29 (3.95)	19.55 (4.26)	223.24*	25.24 (6.06)

*Less than 0.001.

Table 4. Comparison of VPA data using mean, max, and percentage of change*

	MANOVA results†				VPA data‡		
Variable	Type III sum of squares	Mean square	F	*P* value	Sexually functional	Decreased sexual function	Arousal-specific dysfunction
Max VPA							
Neutral	6.027	3.013	0.110	.896	9.520	9.836	9.412
Erotic	139.732	69.866	0.965	.383	12.945	14.760	13.968
Mean VPA							
Neutral	3.354	1.667	0.113	.893	6.915	7.192	6.960
Erotic	87.427	43.714	1.613	.202	8.958	10.254	8.760
Change, %	8464.014	4232.007	1.327	.268	39.036	46.920	28.838

MANOVA = multivariate analysis of variance; max = maximum; VPA = vaginal pulse amplitude.
*In the MANOVA, sexual function status is entered as the independent variable and VPA is entered as the dependent variable.
†Results from MANOVA with sexual function status as the predictor variable.
‡VPA data in millivolts.

warmth" ($F_{2, 206} = 3.794$, $P = .024$) and "wetness/lubrication" ($F_{2, 206} = 4.337$, $P = .014$). No main effect was found for the items "genital pulsing/throbbing," "tenseness/tightness," or "any genital feeling" (Table 6).

Bonferroni-corrected post hoc analyses indicated that women with arousal-specific dysfunction reported significantly lower levels of genital warmth ($P = .038$) and marginally lower levels of genital wetness or lubrication ($P = .053$) than sexually functional women. Women with decreased sexual function reported significantly lower levels of genital wetness or lubrication ($P = .048$) than did sexually functional women.

Relation Between VPA and Perceived Genital Responses

Correlations between VPA using VPA mean, maximum, and percentage of change and the composite measure of perceived genital responses were not significant for any group of women. Similarly, HLM analyses yielded no significant relations between VPA and the composite measure of perceived genital responses among these groups of women.

DISCUSSION

This study sought to (i) assess potential differences in an objective index of genital arousal (ie, VPA) in women with varied levels of sexual functioning using commonly used statistical techniques that condense data and a statistical technique that examines changes in continuous data within individuals and to (ii) examine differences in perceived genital responses across the 3 groups of women. (iii) This study also sought to determine the relation, if any, between objective and perceived genital responses in these women. With respect to the 1st aim, we hypothesized that sexually functional women would show the greatest increase (ie, steepest slope) in VPA among the 3 groups of women, but only when analyzing VPA data with HLM. In line with our hypothesis, we failed to detect differences in VPA among the 3 groups of women (ie, arousal-specific dysfunction, decreased sexual function, and sexually functional) using commonly implemented methods of analysis that condensed VPA data. This result replicates the findings of previous research[13,15] and suggests that, when analyzing condensed VPA data, there might not be large differences in women's genital response based on sexual function.

Because widely used methods of analysis condense continuously collected data into a single data point to create a mean or maximum VPA value, potentially meaningful fluctuations in the data over time can be disguised. As such, Meston et al[17] suggested that these types of analysis might be insufficient for detecting the differences that occur over time among subgroups of women with sexual difficulties. HLM, a form of analysis that allows for the assessment of continuous nested data, preserves these temporal patterns by using multiple data points. Indeed, in the present study, when VPA data were analyzed over time using HLM, distinct genital arousal trajectories emerged; women with arousal-specific dysfunction started at a slightly lower level of VPA but exhibited a significantly steeper slope than did sexually functional women (Figure 1). Counter to our hypothesis, women with arousal-specific dysfunction did *not* show lower levels of VPA than the other 2 groups. Although women with arousal-specific dysfunction might begin with lower levels of baseline VPA, in time they might "catch up" to levels comparable to those of sexually functional women. This finding suggests that

Table 5. Results from HLM analysis examining change in vaginal pulse amplitude over time

Predictor	β	SE	df	t-ratio	*P* value
Intercept	6.823	0.436	18428	15.641	.000
Function	−0.196	0.415	192	−0.472	.637
Time	0.007	0.001	18428	38.4885	.000
Function × time	0.001	0.001	18428	5.588	.000

df = degrees of freedom; function = sexual function status (0 = sexually functional, 1 = decreased sexual function, 2 = arousal-specific dysfunction); HLM = hierarchical linear modeling; SE = standard error.

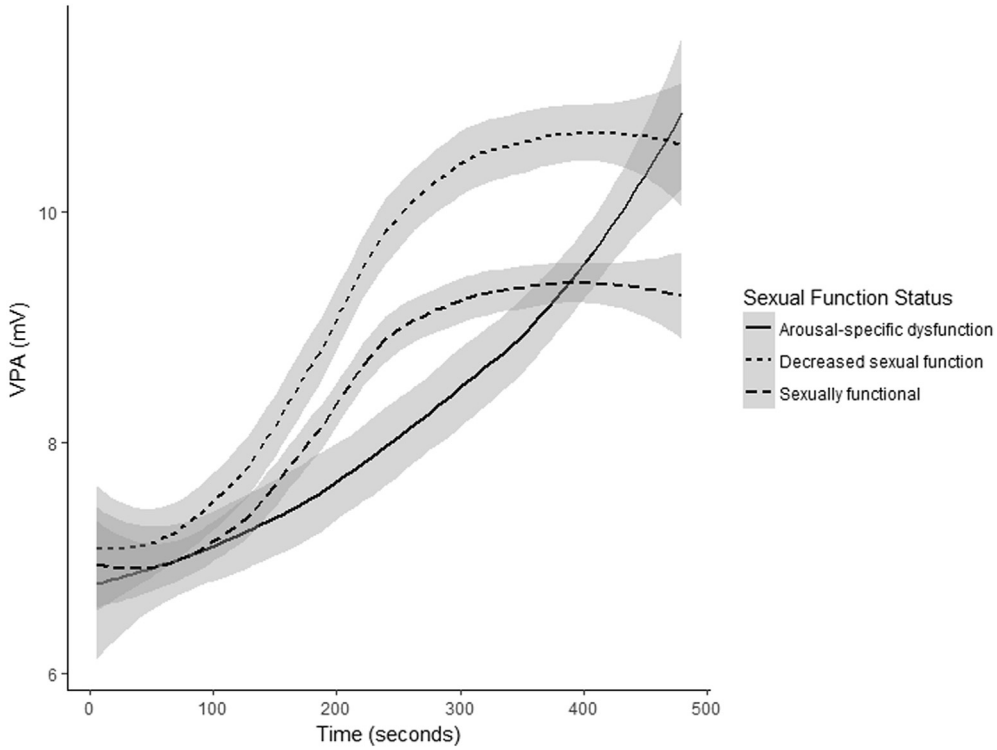

Figure 1. Smoothed conditional means of participants' VPA over the course of the film sequence. Grey bands indicate 95% confidence intervals. VPA = vaginal pulse amplitude.

considering the temporal context of VPA data is important, especially because VPA is typically measured as a response to a continuously changing stimulus. If the present study had relied solely on means and percentage of change scores, then these differences would not have been detected.

This is not the first study to identify differences in the trajectories of genital arousal among groups of women. Meston et al[17] found similar results when using HLM to analyze genital arousal between women with and those without sexual dysfunction. When women with different forms of sexual dysfunction were grouped and compared with sexually functional women, no main effect of sexual function status was detected. However, when separating out these groups and assessing genital arousal patterns over time, Meston et al[17] found distinct between-group differences: women with genital arousal disorder and women with subjective arousal disorder had significantly lower levels of VPA than did sexually functional women. Interestingly, Meston et al[17] found that women with combined genital and subjective arousal disorder had significantly higher levels of VPA than did controls. In the present study, we did not separate women by theoretical subtype of FSAD (ie, genital, subjective, or combined), which could explain why women with arousal-specific dysfunction did not show lower levels of VPA responding than sexually functional women, as in the study by Meston et al.

Table 6. Results from analysis of variance with sexual function status entered as the independent variable and perceived genital responses as the outcome variable

Variable	Type III sum of squares	Mean square	F	*P* value
Warmth	18.023	9.011	3.794	.024
Wetness or lubrication	22.677	11.339	4.337	.014
Pulsing or throbbing	9.306	4.653	1.400	.249
Tenseness or tightness	9.125	4.563	1.445	.238
Any genital feeling	15.137	7.569	2.861	.059
Total genital responses	340.957	170.479	3.239	.041

Alternatively, these differences could be a function of sexual psychophysiologic studies taking place in contrived laboratory settings. A study comparing laboratory and ambulatory (ie, at home) assessments of genital arousal found that sexually functional women exhibited significantly higher levels of VPA at home compared with in the laboratory, whereas women with sexual dysfunction showed similar levels in the 2 settings.[35] Bloemers et al[35] suggested that sexually functional women felt more at ease and less inhibited at home, whereas women with sexual dysfunction did not. In addition, they proposed that women with sexual dysfunction might face cues that activate or sustain inhibitory mechanisms in the home setting (eg, negative memories of experiences in the bedroom) and in the laboratory setting. If this pattern were true of data in the present study, then this could help explain why sexually dysfunctional women did not ultimately show lower levels of VPA than their sexually

functional counterparts. Thus, the VPA of sexually functional women might have been inhibited in the laboratory setting, and the expected differences between groups (ie, lower VPA levels among sexually dysfunctional women) might emerge in real-life settings.

The study conducted by Bloemers et al[35] is unique in that it developed an ambulatory psychophysiology laboratory that allowed women to measure their VPA from home; there are few studies that assess genital measures of sexual arousal outside the laboratory. Because context-dependent differences in VPA have emerged between sexually functional women and women with sexual dysfunction, it is important for researchers to develop additional, more ecologically valid methods of assessing genital arousal. For example, researchers could consider measuring levels of lubrication, an important component of sexual arousal for women, with devices (eg, litmus paper) that can easily be taken home. By highlighting differences between VPA levels taken in a laboratory setting and those taken outside that setting, sex researchers might be able to bridge the gap between the laboratory and the home.

Much like women with arousal-specific dysfunction, women who were categorized as having decreased sexual function based on the FSFI cutoff criteria initially exhibited slightly lower levels of VPA than sexually functional women. Eventually, the VPA levels of these 2 groups intersected, and women with decreased sexual function reached a higher VPA level than sexually functional women by the end of the film. This suggests that the pattern of low baseline genital arousal with a more rapid increase might not be unique to women with an arousal-specific dysfunction; rather, it could be an aspect of decreased sexual function more generally.

The 2nd aim of the present study was to assess differences in perceived genital responses among the 3 groups of women. Although there were no large, overall differences in VPA among the 3 groups (slight differences in VPA trajectory did emerge), women's perceived genital responses did vary according to sexual function status. This lack of large group differences in VPA suggests that deficits in genital blood flow might not fully explain the experience of sexual dysfunction in women. Women's perception of their genital responses also could play a role in women's experience of sexual dysfunction and could be of greater importance in these groups of women than genital blood flow. As hypothesized, sexually functional women reported significantly higher levels of total genital responses than did the other 2 groups of women. Women in the arousal-specific dysfunction group reported deficits in perceived genital warmth compared with women in the 2 other groups. In line with previous research,[15,26,36] women with arousal-specific dysfunction and decreased sexual function reported perceiving genital responses to a lesser degree than did sexually functional women; perceived wetness or lubrication was significantly lower in these 2 groups. For women in general, lubrication might be one of the most obvious markers of sexual arousal. Messages relayed by the media and the pornography industry emphasize that women are "turned on" or highly aroused when they are "wet." Therefore, when women do not perceive an increase in wetness or lubrication during sexual activity, they might conclude that they have an arousal problem, although they are experiencing increased or adequate vasocongestion in the genitals. A similar conclusion could be drawn for perceived levels of genital warmth.

In aggregate, these findings suggest that perceptions of genital responses likely play an important role in women's conceptualizations of their own arousal concerns. However, it is currently unknown whether these perceptions (or lack thereof) might be rooted in physiologic impairments (eg, vaginal dryness) or whether decreased perceptions reflect an inability to perceive sensations that are indeed present. Future research should examine these 2 hypotheses, because they have different treatment implications. Although it is premature to make clinical inferences based on the findings from this single study, if replicated, these results might suggest that for women with genital arousal concerns, it might be more important to focus on altering their perception of genital arousal than on increasing their overall genital blood flow response. For example, treatments such as mindfulness and biofeedback training aim to enhance women's awareness of various bodily functions and sensations. Silverstein et al[37] found that, after mindfulness training, sexually functional women were significantly faster at reporting states of bodily arousal after exposure to sexual images than women who did not receive this training. Thus, mindfulness training also might enhance women's perception of specific genital responses.

The 3rd aim was to examine potential differences in the relation between VPA and perceived genital responses in women with varied levels of sexual function. Counter to our hypothesis, no significant relations emerged between VPA and the composite measure of perceived genital responses, regardless of sexual function status or analytic technique. There are 2 conclusions that can be drawn from this finding. (i) Items on the Film Scale[24] might not adequately relate to changes in VPA. Although it is understood that an increase in blood flow to the genitals results in increases in vaginal lubrication[38] and genital temperature,[39] the questionnaire lacks an item specifically assessing perceived genital blood flow or engorgement. An item assessing one of these constructs might better reflect VPA. (ii) Women might not be attending to or be "in tune" to genital changes associated with sexual arousal. If women are unaware of these changes, then the use of self-report measures could result in an under-reporting of genital responses. A study found that women are, indeed, aware of changes in their genitals during states of sexual arousal.[22] A problem with drawing conclusions from that study is that women were specifically instructed to attend to their genitals. Thus, it is unclear whether women are typically "in tune" with their genital changes or if the results of Handy and Meston[22] are an artifact of the instruction set.

It is important to note the limitations of the present study. Data included in this study were collected from 5 different experiments. Therefore, although the procedures of the physiologic portions of these studies were similar, the study experiences were not the same. The data reduction techniques also varied: in 3 of the studies, an automated data reduction technique was used; in 2 studies, the artifacts were extracted manually. However, research has found that these 2 methods of data reduction produce comparable results.[30] We also chose to analyze continuous VPA data using HLM, rather than repeated-measures ANOVA, which limits our ability to conclude that it was the continuous, and not the nested, nature of HLM that led to the present results. In a future study, implementing a repeated-measures ANOVA, which typically does not analyze data at the individual level, would bolster the claim that it is critical to analyze continuous rather than condensed VPA data. Future research should compare the use of HLM and repeated-measures ANOVAs in the context of sexual psychophysiology.

In addition, as stated earlier, the lack of an item on the Film Scale[24] that specifically assesses genital blood flow or engorgement limits the interpretability of the analyses that failed to find a significant relation between VPA and perceived genital responses. These results should be interpreted cautiously. Moreover, although there was a wide age range (18–47 years old) included in this study, roughly 60% of participants were younger than 25 years. Therefore, any effects of age might have been masked in this relatively young sample. Future research should explore the relation between VPA and perceived genital responses across the lifespan. Further, women in the arousal-specific dysfunction group were categorized based on self-report; clinical interviews were not conducted. Because women in this study did not receive a formal clinical diagnosis, the generalizability of these findings to clinical populations might be limited.

In conclusion, there do not appear to be large differences in VPA between women with and those without sexual arousal-specific dysfunction. Rather, there might be subtle differences in the genital arousal trajectories of these women. These findings suggest that considering the temporal nature of genital arousal by using continuous data is critical for VPA analysis. It is important to note that these findings reflect changes in genital arousal in women who have not undergone some intervention. Some studies have found that group differences in VPA emerge only under conditions when arousal is heightened. For example, Meston and Gorzalka[40] found no significant differences in VPA responses to erotic films between sexually functional women and women with desire or orgasm difficulties. However, when women with these concerns were subjected to an exercise manipulation, significant group differences emerged. Future research should examine whether the differences found in the present study are more pronounced under conditions of heightened arousal that might better approximate arousal levels experienced in real-life sexual scenarios. Our findings also suggest that women's perceived genital response is a critical aspect of women's experience of sexual arousal. Perceived arousal could be of greater importance to these women than actual genital blood flow. Therefore, perceived genital response might be an important treatment target for women with arousal-specific dysfunction.

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