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Is Pelvic Floor sEMG a Measure of Women's Sexual Response?

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ABSTRACT

Introduction: Pelvic floor surface electromyography (sEMG) is often used in the assessment and treatment of individuals with pelvic floor abnormalities to measure muscle tone and neural control of the pelvic floor muscles (PFM); however, little is known about the role of the PFM in sexual arousal.

Aim: The aim of this pilot study was to examine whether changes in deep and superficial PFM activity—assessed with sEMG—can be observed during the presentation of sexual stimuli.

Methods: Deep PFM sEMG activity was assessed with a vaginal probe. Superficial PFM activity was assessed with sEMG electrodes placed over the bulbocavernosus and perianal muscles. 15 sexually healthy women (mean age 27 years) watched a series of neutral, anxiety-evoking, and sexually explicit films. Continuous subjective sexual arousal was measured using a handheld arousometer.

Main Outcome Measure: Changes in microvolts were measured by sEMG sensors, from neutral to anxiety-evoking and neutral to sexually explicit films.

Results: There was an increase in intravaginal and perianal sEMG for both the erotic and anxiety films. Bulbocavernosus sEMG responses did not differ among the 3 films. Concordance between self-reported continuous sexual arousal for the erotic film and bulbocavernosus sEMG ($r = 0.349$) was not significantly different than concordance using intravaginal sEMG ($r = 0.293$) or perianal sEMG ($r = 0.236$).

Clinical Implications: Understanding more about which parts of the PFM respond specifically to sexual stimuli may have implications for measuring the effects of treatments aimed at improving sexual response in women.

Strength & Limitations: The results of this pilot study provide a preliminary understanding of which pelvic floor muscles respond to sexual stimuli. A limitation of this study was the small sample size.

Conclusion: Taken together, these findings suggest that intravaginal and perianal sEMG respond to erotic stimuli, whereas bulbocavernosal sEMG responses do not. **Hannan-Leith MN, Dayan M, Hatfield G, et al. Is Pelvic Floor Surface Electromyography a Measure of Women's Sexual Response? A Pilot Study. J Sex Med 2019;16:70–82.**

Key Words: Pelvic Floor; Electromyography; sEMG; Sexual Arousal; Psychophysiology

Genital measures are frequently used to assess sexual arousal in women.[1] One common measure is the vaginal photoplethysmograph (VPP), a tampon-shaped probe that is inserted into the vagina and measures variations in blood flow and blood volume in the vaginal wall via changes in light reflectance.[2,3] Despite its popularity, researchers have long been interested in validating other aspects and measures of sexual response. The pioneering research of Masters and Johnson[4] in the 1950s and 1960s revealed that, in addition to blood flow, there are other physiological changes associated with sexual arousal that can be

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measured with heart rate, respiration rate, and muscle tension. Recognizing that sexual arousal progressed through stages of intensity, they believed that muscle tension was a feature of more advanced stages of sexual arousal, corresponding with increased sympathetic nervous system activity, whereas vaginal lubrication was a feature of early stages of sexual arousal.

Critical to understanding muscle tension that may occur with sexual arousal is the involvement of the pelvic floor. The pelvic floor consists of a bed of muscles underneath the pelvis, and it provides structural support for the internal organs. Consisting of both superficial and deep muscles, the pelvic floor prevents urinary and fecal incontinence (leakage) but can become damaged with pregnancy, vaginal delivery, and pelvic surgeries. There is a large body of literature examining the role of the pelvic floor muscles (PFMs) in sexual function.[5−7] Early research identified the PFMs as being critical to sexual function,[8,9] with more recent technologies (ie, magnetic resonance imaging) showing that the PFMs are activated during sexual arousal.[10] In women, the deep PFMs, consisting of the levator ani muscle (pubococcygeus and iliococcygeus muscles), coccygeus, and puborectalis muscles are involved in sexual response by stretching and widening during vaginal penetration, and contracting during orgasm.[11−13] PFM strength in women is positively related to sexual satisfaction and arousal.[12] In part, this may be because the PFM influences the position of the clitoral erectile tissue, particularly the contraction of the superficial PFMs (eg, ischiocavernosus and bulbocavernosus muscles), and PFM activity is associated with clitoral stimulation.[14]

Among the different methods of measuring the activity of the pelvic floor muscles, pelvic floor surface electromyography (sEMG) has been studied the most.[15] sEMG is also one of the most commonly used clinical tools in the assessment and treatment of individuals with pelvic floor muscle dysfunction, such as incontinence and pelvic pain.[16−18] sEMG is sensitive to the level of PFM dysfunction in individuals with lower urogenital tract dysfunction and pain disorders, including vulvodynia and vaginismus.[19−21]

Although Masters and Johnson[4] demonstrated how the PFMs contract both voluntarily and involuntarily during sexual arousal, few studies have evaluated sEMG responses to erotic stimuli. Both and Laan[22] pilot tested a vaginal sEMG (with an attached VPP) inserted by participants to measure involuntary and voluntary PFM activity in 30 sexually functional women. Involuntary PFM activity and genital response were measured during sexual and anxiety-evoking film clips, and voluntary PFM activity was measured after participants were asked to carry out pelvic floor "flick-and-hold" muscle contractions (brief contractions of 1 to 2 seconds and sustained contractions of 10 seconds). Although pelvic floor activity was predicted to increase in response to threatening and sexually threatening films, and not in response to erotic stimuli, results indicated that PFM activity increased for both threatening and erotic stimulus conditions.

Given that the study by Both and Laan[22] could not differentiate anxiety-eliciting from sexual stimuli, they concluded that their device showed a lack of sensitivity to involuntary PFM activity. Thus, Both et al[14] tested a modified version of the sEMG device in 36 sexually functional women, which had electrodes with greater surface area (from 17 × 7.5 mm to 26 × 3 mm) and an improved signal-to-noise ratio by building an amplifier directly into the probe. Consistent with their predictions, sEMG was highest in response to the anxiety film and lowest in response to the sexual and neutral films. Additionally, sEMG values in response to the sexually threatening films were intermediate between the anxiety and sexual films.[14] They concluded that sEMG is sensitive to changes in pelvic floor activity for both voluntary and involuntary pelvic floor contractions associated with anxiety. The results also suggested that the PFM may be highly reactive to threatening and sexually threatening stimuli, particularly when the participant self-reported anxiety and tension.

The sEMG values during the sexual stimuli showed a nonsignificant trend toward being lower than sEMG values to neutral stimuli.[14] Unfortunately, their design did not allow the researchers to determine which PFM groups were showing this relaxation response or whether it was the superficial or deep muscles that responded to the sexual stimuli.

It is well known that the deep and superficial layers of the PFM have different contraction and innervation patterns.[23,24] We are aware of 1 study that has evaluated the deep and superficial PFM layers as they relate to sexual function.[25] In the study by Gentilcore-Saulnier et al,[25] PFM activity was examined in 11 women with provoked vestibulodynia and 11 control subjects using sEMG. Participants completed an assessment using a vulvalgesiometer and sEMG recordings, as well as a digital intravaginal assessment, with both examining PFM activity in response to a painful pressure stimulus.[25] Deep PFM activity (measured inside the vagina) did not significantly differ between participants with and without provoked vestibulodynia; however, women with genital pain had higher resting tonic PFM activity with the superficial sEMG recordings (which were placed near the labia majora). This region also responded to painful pressure applied to the vulva, whereas the deep PFM did not.

Gentilcore-Saulnier et al[25] did not assess responses to erotic stimuli in their study, but their results highlight the importance of measuring both deep and superficial PFM activity, because different PFM layers may respond differently to stimulation, including sexual stimulation. For example, the deep PFMs are thought to enhance sexual response by relaxing, slightly widening, and elongating the vaginal canal to allow penetration to occur, followed by contraction during orgasm.[11,25,26] The superficial PFMs aid in the contraction and engorgement of the cavernosal tissue of the clitoris during arousal,[27,28] as well as in decreasing the size of the vaginal introitus to hold an object of penetration inside the vagina.[25,29] Further research is required, however, to examine the role of the superficial and deep PFM during the initial stages of sexual arousal in women.[25,30]

The primary aim of the current pilot study was to explore both deep and superficial PFM activity in response to sexual stimuli in a group of sexually healthy women. We examined whether deep vs superficial PFM activity are elicited by sexual stimuli and whether (deep and superficial) PFM activity responds just to sexual stimuli or also to anxiety-eliciting stimuli. Furthermore, 2 different types of superficial sites were collected and compared.

A secondary aim of this pilot study was to examine the concordance between sEMG activity (at both superficial and deep PFM locations) and self-reported sexual arousal. Concordance, or the degree of agreement between self-reported sexual arousal and physiological sexual response,[31] has not previously been examined using sEMG. In a meta-analysis of studies on concordance, Chivers et al[32] suggested that that the type of instrument used to measure physiological sexual arousal may influence concordance, given that thermography yielded higher concordance values than vaginal photoplethysmography. This pilot study was designed to test the feasibility of the procedure and to stimulate further research in the study of PFM activity during sexual arousal.

METHODS

Participants

Participants were 15 sexually healthy cisgender women (assigned female at birth and currently identified as women) who were paid ($40 Canadian) for taking part in the study. They were recruited online, from Craigslist, our laboratory's Facebook page and website, our hospital's research institute website, and from community advertisements soliciting sexually healthy premenopausal women. Inclusion criteria were adult cisgender women who were premenopausal (due to the effects of hormonal status on PFM activity) and sexually active (because women were asked to insert a vaginal probe) within the past month. Exclusion criteria included diagnosis of a sexual dysfunction, any genital pain or pelvic pain disorder, any bowel or bladder syndromes or urinary incontinence or pelvic organ prolapse (or treatment thereof), medically induced menopause, and total or partial hysterectomy, given that each of these conditions has been found to be associated with alterations in pelvic floor muscle activity. Furthermore, given the known impact of pregnancy on the pelvic floor,[33,34] we excluded women who had previously delivered (vaginally or by caesarean section) or who were currently pregnant.

Mean age of the participants was 26.9 years (range 21−42). Participants were of mixed sexual orientations, with 8 (53%) identifying as bisexual, 6 (40%) as heterosexual, and 1 as lesbian (7%). All participants were sexually active and had experienced sexual activity (eg, vaginal penetration) at least once per week.

Measures

Three validated questionnaires were completed at the start of the testing session in hardcopy format and were used to provide descriptive information about the sample. The Female Sexual Function Index (FSFI)[35] was administered to assess baseline levels of sexual response (desire, arousal, lubrication, orgasm, satisfaction, pain, and overall sexual function) and to rule out the presence of sexual difficulties. Scores can range from 2 to 36, with lower scores indicating greater sexual dysfunction. Individual subscale scores range from 0 to 6 (for arousal, lubrication, orgasm, and pain), 1.2 to 6 (for desire), and 0.8 to 6 (for satisfaction). Cronbach's alpha for the FSFI total score was acceptable at $\alpha = 0.75$.

The Derogatis Sexual Functioning Inventory (DSFI),[36] Sections III (Drive) and IV (Sexual Attitudes) were administered to describe the current level of sexual activity and degree of sexual liberalness vs conservatism among our sample. Scores on the Attitude domain can range from −60 (sexually conservative) to 60 (sexually liberal). Cronbach's alpha for the Attitudes domain was high at $\alpha = 0.84$.

Participants also completed 2 versions of the Sexual Arousability Inventory (SAI).[37] First, they completed a 28-item SAI that asked about level of sexual arousal experienced in response to a variety of different types of stimulation, and participants responded on a 7-point Likert scale from −1 (adversely affects arousal; unthinkable, repulsive, distracting) to 5 (always causes sexual arousal; extremely arousing) such that higher scores corresponded with higher levels of sexual arousal. Cronbach's alpha for this scale was excellent at $\alpha = 0.90$.

Second, they completed the SAI-E, which asked about the level of anxiety evoked in response to the same list of 28 erotic activities. The 7-point Likert scale ranged from −1 (relaxing, calming) to 5 (always causes anxiety; extremely anxiety evoking), with higher levels corresponding to more anxiety associated with sexual activity. The SAI-E is a valuable research tool for determining the association between sexual arousability and anxiety among research participants.[38−40] Cronbach's alpha for this scale was excellent at $\alpha = 0.91$. Scores on both the SAI and SAI-E can range from −28 to 140.

Stimuli

The neutral film was 5 minutes and depicted a travelogue documentary. The 4 erotic film excerpts had a length of approximately 7 minutes each. The erotic films depicted either mixed-sex or same-sex petting, cunnilingus or fellatio, and vaginal penetration (either penile or sex toy) and were chosen from the Erika Lust collection (a female director who produces erotic material considered to be more female-centric than mainstream erotic films). Female-centric erotic films evoke fewer feelings of guilt and aversion in women compared with male-centric films,[41] and these films have been used previously.[42] Participants were given the choice of viewing mixed-sex or same-sex films. The anxiety films consisted of an excerpt from the film *Cujo*, in which a woman and a child are threatened by a wild dog, or an excerpt from the film *Kiss the Girls*, where a woman is chased through a forest by a violent man. All participants watched 2 sexually explicit film clips and 2 anxiety-evoking film clips.

sEMG

sEMG activity was measured at both the deep and superficial layers of the PFM. Deep PFM activity was obtained using a single-user Thought Technology vaginal sEMG sensor (T6050) probe (Thought Technology Ltd, Montreal, Quebec, Canada), which has an insertion depth of approximately 2 inches, inserted by the participant after the researcher left the room. Superficial PFM activity was obtained in 2 locations: on the bulbocavernosus muscles and perianally. The sEMG measurements were obtained using uni-gel single-use sEMG electrodes (T3425) placed by the lead author over the right and left bulbocavernosus muscles (in 1 condition) and bilaterally to the anus (at 2 and 10 o'clock) (in the second condition). The sEMG electrodes were noninvasive and small in size (35 mm) and were further rounded down to a size of approximately 24 mm to improve comfort. An experienced pelvic floor physiotherapist provided hands-on training to accurately locate the muscles of interest and instruct on the proper placement of sensors before beginning data collection. Using the BioGraph Infiniti PC v5.0 software, the MyoTrac Infiniti Encoder (SA9800), manufactured by Thought Technology, was used to collect sEMG measurements. Participants were asked whether the sensors were comfortable before proceeding with the testing.

Self-Reported Sexual Arousal

Both discrete and continuous measures of self-reported sexual arousal were administered. The Film Scale was used to assess sexual arousal and affective reactions to the erotic, anxiety-evoking, and neutral films. This scale was adapted from Heiman and Rowland[43] and assessed 6 domains: sexual arousal (1 item), perceptions of physical arousal (4 items), autonomic arousal (5 items), anxiety (1 item), and positive and negative affect (10 items each). The scale has been found to be a valid and sensitive measure of emotional reactions to erotic stimuli.[43] Items were rated on a 7-point Likert scale from Not at All (1) to Intensely (7).

Continuous self-reported arousal was measured with an arousometer during the presentation of each of the film stimuli. The arousometer was constructed by a local engineer and modeled after the one described by Rellini et al.[44] This device consisted of a computer optic mouse mounted on a plastic track with 10 intervals and was affixed to the arm rest of the recliner so that the participant could easily move the mouse while simultaneously reclining and viewing stimuli. Participants were instructed to move the mouse up and down the track over the course of the films to indicate their level of sexual arousal, from 7 to -2, with 7 = Highest Level of Sexual Arousal, 0 = No Sexual Arousal, and -2 = Sexually Turned Off. Mean continuous self-reported arousal was obtained every 30 seconds throughout each of the different film segments.

Procedure

Interested participants contacted the researcher, who explained all procedures over the telephone and screened callers to determine eligibility. Participants were randomly assigned by a flip of a coin to 1 of the 2 sensor placement order groups (half the participants had bulbocavernosus sEMG testing first followed by perianal sEMG, and the other half had the opposite order of testing). They were then randomly assigned (flip of a coin) to 1 of the 2 film order groups (baseline, neutral, erotic; baseline, neutral, anxiety), where half the participants viewed the first order of films, and the other half had the opposite film order. In total, there were 4 possible film order/sensor placement groups to which a participant could be assigned.

On arrival to the laboratory, participants read and signed the consent form and had all details of the experiment explained to them. Participants were informed that they would be watching a series of neutral, erotic, and anxiety-evoking film clips. Following informed consent, they were asked to choose between watching same-sex or mixed-sex erotic films and then instructed to undress from the waist down and insert the intravaginal sEMG probe per the researcher's instructions. After inserting the probe and reclining in a comfortable position, the researcher returned to the testing room to place the surface electrodes either over the bulbocavernosus muscle, or perianally (depending on the condition order to which the participant was randomized).

The researcher left the testing room, and initiated data collection on the MyoTrac Infiniti EMG Encoder (Thought Technology) and recorded baseline sEMG activity for 30 seconds in an adjacent room. Participants then completed a pre-film discrete measure of sexual arousal and affect, and then the film sequence began: 1-minute baseline, 5 minutes neutral, and 7 minutes erotic or 7 minutes anxiety-evoking (depending on the film order to which the participant was randomized). During the films, participants were asked to use the arousometer to track their subjective sexual arousal while remaining as physically still as possible in the recliner.

Immediately after the last film, participants completed another discrete measure of sexual arousal and affect and then notified the researcher, who returned to the room to turn off the MyoTrac Infinity data collection unit. The researcher then removed the sensors measuring superficial PFM activity and placed new sensors at the other superficial site (ie, bulbocavernosus sensors were removed, and new ones were placed perianally; perianal sensors were removed, and new ones were placed over the bulbocavernosus muscles). The participant again completed the discrete measure of arousal and affect and then repeated the film sequence for the second testing session, which included a different set of neutral, erotic, and anxiety-evoking films, of the same duration as those presented during the first testing segment. The intravaginal probe was not removed between the 2 testing segments and collected vaginal sEMG data throughout the session. We only analyzed data from the first vaginal sEMG testing segment to allow for consistency with bulbocavernosus and perianal conditions, which were only measured once. All procedures were approved by the Clinical Research Ethics Board at the University of British Columbia and the associated hospital research ethics board.

Data Analysis

All data from the questionnaires were entered and analyzed in SPSS 19.0 (IBM, Armonk, NY), and analyses of sEMG data were carried out in R version 3.3.1.[45] The sEMG data were analyzed using mixed-effects linear regressions. Mixed-effects linear regressions were chosen because they allow for autocorrelation and can control for changes in variance over time. For each sEMG location (intravaginal, bulbocavernosus, or perianal), regressions were run with 30-second epochs of root mean squared sEMG data as the dependent variable, and time (in 30-second intervals) and film type as independent variables. To obtain the root mean squared sEMG data, the mean value of the sEMG during the 1 minute of relaxation was removed from the raw sEMG during the film conditions. This was done to remove any voltage offset. The data were then visually examined, and any obvious movement artefacts were removed. 30-second epochs of root mean squared data were calculated from these cleaned data. The root mean square transformation is commonly used in electromyographic data analysis and provides a useful measurement of signal amplitude.[46]

Film type included 4 possibilities: neutral before anxiety, neutral before erotic, anxiety, and erotic. A difference in response for the different film types was tested using the interaction term between time by film type. A significant interaction would indicate different slopes between time and sEMG for the different film types. If a significant interaction was detected, we followed up with pairwise tests of 3 specific hypotheses: (i) neutral before anxiety vs anxiety, (ii) neutral before erotic vs erotic, and (iii) anxiety vs erotic. *P* values for post hoc tests were corrected using Holm's method.[47]

The random effects models were fit with random intercepts and slopes by subject. To account for temporal autocorrelation within a subject during a particular film, we modeled the correlation structure using an autoregressive model of order 1, which models the residuals at time *t* as a function of the residuals at time *t*-1 at the level of individual time series of film type within subjects. Last, we included a variance structure to model heteroscedasticity of the residuals. This was included as a varPower structure, which accounts for changes in the variance over time within subjects.

The intravaginal data were analyzed from the first set of films only for each participant (even though intravaginal sEMG data were collected twice). Due to the small sample size, we intentionally did not test for differences between participants in the different counterbalanced groups; however, our use of a counterbalanced method was intended to minimize order effects.

For the film scale data, we used a paired samples *t*-test to compare self-reported responses between the neutral and either erotic or anxiety film conditions to confirm that the films elicited the appropriate affect. With respect to continuous sexual arousal, we used a repeated-measures analysis of variance to examine continuously reported sexual arousal from the 5-minute neutral film to the 7-minute point of the erotic film. In cases where there were significant movement artifacts that could not be smoothed, we deleted those 30-second epochs, which meant that in some cases fewer than 24 data points were measured.

Concordance was measured using within-subjects Pearson *r* correlations between contemporaneous data obtained with sEMG and the arousometer during both the erotic and anxiety film conditions. Because we had 2 data collection periods per erotic and anxiety film (1 with the superficial sensor at the bulbocavernosus and 1 with the superficial sensor perianally), we calculated concordance with the data from the first testing segment only. To determine statistical significance, alpha was set at .05.

Table 1. Descriptive characteristics for the FSFI, DSFI Drive and Attitude subscales, the SAI, and SAI-E

Domain measured	Mean	SD	Reference range
FSFI			
Desire	4.88	1.01	1.2–6
Arousal	5.44	0.60	0–6
Lubrication	5.62	0.38	0–6
Orgasm	5.09	1.16	0–6
Satisfaction	3.65	1.69	0.8–6
Pain	4.32	2.30	0–6
Total score	29.01	4.11	2.0–36.0
DSFI-Attitude	41.53	11.49	−60–60
SAI	109.73	15.12	−28–140
SAI-E	-3.40	14.17	−28–140

DSFI = Derogatis Sexual Functioning Inventory; FSFI = Female Sexual Function Index; SAI = Sexual Arousability Inventory; SAI-E = Sexual Arousability Inventory—Expanded; SD = standard deviation.

RESULTS

Sample

Table 1 presents the average from each of the FSFI subscales. Compared with available normative data, these numbers suggest that participants experienced no significant sexual function-related difficulties on any domain, and their overall level of sexual functioning was above the clinical cutoff of 26.5, in the range comparable to sexually healthy women.[35]

On the DSFI[36] Drive domain, participants reported an average sexual intercourse frequency of once per month, with 7% of the sample reporting that they were not currently having intercourse. The average masturbation frequency was 2 to 3 times per week, with all 15 participants reporting at least monthly masturbation. Kissing/petting had an average frequency of approximately 1 to 3 times per week, and 7% reported none of this activity recently. The average sexual fantasy frequency was 4 to 6 times per week, and all participants reported at least 1 sexual fantasy per month. Participants recalled first becoming interested in sexual activity at the mean age of 13.0 years (standard deviation 5.1), and the mean age of first sexual intercourse was 18.5 years (standard deviation 3.2). Scores on the DSFI Attitude domain suggested that this was a relatively liberal sample with regard to sexual attitudes and experiences.

Scores on the SAI[37] indicated a fairly high level of sexual arousability in response to various sexual activities. Scores on the SAI-E (Table 1) suggest no, or a very low, level of anxiety associated with various sexual activities.

Table 2. Results of t-test for erotic film condition during the bulbocavernosus sensor placement

Variable	t	df	P	Cohen's d	95% CI
Self-reported sexual arousal	6.64	14	<.001	1.72	(1.13, 3.17)
Perceptions of genital arousal	6.96	14	<.001	1.80	(1.08, 2.95)
Positive affect	5.93	14	<.001	1.53	(0.70, 2.10)
Perception of autonomic activity	7.31	14	<.001	1.89	(0.87, 2.33)
Negative affect	1.61	14	.130	0.42	(−0.11, 0.88)
Anxiety	−0.32	14	.751	−0.08	(−0.52, 0.37)

CI = confidence interval; df = degrees of freedom.

Self-Reported Sexual Arousal and Affect with Film Stimuli

Discrete Measures

Tables 2−5 present participants' self-reported sexual arousal and affect as measured by the film scale. In the erotic film condition (during the bulbocavernosus sensor placement), there was a significant increase with a large effect size in self-reported sexual arousal, perception of genital arousal, positive affect, and perception of autonomic activity. There was no statistically significant change with a small effect size in negative affect and in anxiety (Table 2).

In the erotic film condition (during the perianal sensor placement), there was a significant increase with a large effect size in self-reported sexual arousal, perception of genital arousal, positive affect, and perception of autonomic activity. There was no statistically significant change with a small effect size in negative affect and in anxiety (Table 3).

In the anxiety-evoking film condition (during bulbocavernosus sensor placement), there was a statistically significant decrease, with a large effect size in self-reported sexual arousal. There were no significant changes, with a small effect size observed for perception of genital arousal and positive affect. There was a statistically significant increase with a large effect size for autonomic arousal, negative affect, and anxiety (Table 4).

In the anxiety-evoking film condition (during perianal sensor placement), there was a significant decrease with a large effect size in self-reported sexual arousal. There were no significant changes and with small effect size in perception of genital arousal and positive affect. There was a significant an increase with a medium to large effect size in autonomic arousal, negative affect, and anxiety (Table 5).

Continuous Sexual Arousal

In the erotic film condition (during bulbocavernosus sensor placement), there was a significant increase in continuously reported sexual arousal, $F(23{,}299) = 40.82$, $P < .001$ (Figure 1). A similar significant increase in continuously reported sexual arousal was observed with perianal sensor placement, $F(23{,}322) = 26.40$, $P < .001$ (Figure 2). In the anxiety-evoking film condition, as expected, continuously reported sexual arousal significantly decreased during bulbocavernosus sensor placement, $F(18{,}234) = 3.75$, $P < .001$ (Figure 1), and there was no significant change in continuous arousal with perianal sensor placement, $F(16{,}208) = 0.55$, $P = .92$ (Figure 2).

Pelvic Floor sEMG Activity Responses to Film Stimuli

Table 6 presents the mixed-effects linear regression results for all 3 sEMG locations. One participant was excluded from the models because she had sEMG values orders of magnitude higher than any other participant, and these extreme outliers caused problems for model convergence. The coefficients listed in Table 6 indicate how the intercept and slope change under different conditions. Differences in the predicted relationships between time and sEMG for the different film types are shown in Figures 3−5.

Intravaginal sEMG (Deep PFM Activity)

For intravaginal sEMG, there was a significant interaction between time by film type (Likelihood ratio test statistic = 32.6,

Table 3. Results of t-test for erotic film condition during the perianal sensor placement

Variable	t	df	P	Cohen's d	95% CI
Self-reported sexual arousal	3.18	14	<.01	1.34	(0.50, 1.95)
Perceptions of genital arousal	5.76	14	<.001	1.47	(0.83, 2.70)
Positive affect	5.04	14	<.001	1.19	(0.63, 2.33)
Perception of autonomic activity	5.50	14	<.001	1.75	(0.85, 2.80)
Negative affect	1.70	14	.112	0.34	(−0.28, 1.16)
Anxiety	−1.74	14	.104	−0.25	(−1.06, 0.39)

CI = confidence interval; df = degrees of freedom.

Table 4. Results of t-test for self-reported responses during anxiety-evoking film condition during the bulbocavernosus sensor placement

Variable	t	df	P	Cohen's d	95% CI
Self-reported sexual arousal	−4.41	14	<.01	−1.07	(−2.10, −0.52)
Perceptions of genital arousal	−0.18	14	.858	−0.05	(−0.46, 0.38)
Positive affect	−1.30	14	.216	−0.33	(−0.77, 0.17)
Perception of autonomic activity	5.07	14	<.001	1.31	(0.54, 1.78)
Negative affect	2.92	14	<.05	0.75	(0.18, 1.39)
Anxiety	4.08	14	<.01	1.05	(0.50, 2.06)

CI = confidence interval; df = degrees of freedom.

$P < .0001$). Model results are shown in Table 6. Post hoc pairwise tests suggested a significant difference between neutral before anxiety and anxiety film types ($P < .0001$), between neutral before erotic and erotic film types ($P = .003$), and between anxiety and erotic film types ($P < .000$; Figure 3). The pairwise comparisons suggest a greater sEMG response to anxiety-evoking as compared with erotic film stimuli.

Bulbocavernosus sEMG (Superficial PFM Activity)

For bulbocavernosus sEMG there was no significant interaction between time and film type (Likelihood ratio test statistic − 0.44, $P = .93$), indicating no differences in sEMG responses to the various film stimuli. Table 6 and Figure 4 show the coefficients and predicted relationships.

Perianal sEMG (Superficial PFM Activity)

There was a significant interaction between time by film type during perianal sensor placement (Likelihood ratio test statistic = 11.86, $P = .008$) (Table 6). The differences in the predicted relationships between time by sEMG for the different film types are shown in Figure 5. As was found for intravaginal sEMG, post hoc pairwise tests suggested that there was a significant difference between neutral before anxiety and anxiety film types ($P = .02$), and between neutral before erotic and erotic film types ($P = .03$). In contrast, no difference was detected between the anxiety and erotic film types ($P = .60$).

Concordance Between sEMG and Continuous Sexual Arousal

A within-subjects Pearson correlation coefficient was used to explore the association between continuously reported sexual arousal and sEMG data. Mean concordance estimates between bulbocavernosus sEMG and self-reported sexual arousal during the erotic film were $r = 0.349$, 95% confidence interval (CI) (0.12, 0.57). Concordance using intravaginal sEMG recording was $r = 0.293$, 95% CI (−0.02, 0.60), and using perianal sEMG placement was $r = 0.236$, 95% CI (−0.04, 0.51). These mean concordance scores were compared in 3 paired-samples t tests, and none of the differences reached significance (t values ranged from .51 to .90, P values from .375 to .781).

We also examined concordance between sEMG activity and self-reported sexual arousal at each of these sensor locations as participants watched the anxiety-evoking film to look at the association between muscular tension and self-reported sexual arousal while exposed to anxious stimuli. All estimates were <.16 and did not differ significantly from each other (t values ranged from .07 to.92, P values from .402 to .944). Last, we compared the concordance scores between erotic and anxiety-evoking conditions for all equivalent sensor placements (eg, concordance with intravaginal probe response and self-reported arousal compared during erotic stimuli vs anxiety stimuli). The mean concordance was higher during the erotic stimuli than during the anxiety-evoking stimuli for each placement but only the bulbocavernosus placement difference reached statistical significance, $t(8) = 3.58$, $P = .007$, 95% CI (0.23, 1.07).

DISCUSSION

We explored both deep and superficial PFM activity to sexual stimuli using sEMG in a group of sexually healthy women. There was an overall increase in intravaginal sEMG in both the erotic and anxiety conditions compared with neutral conditions, with a

Table 5. Results of t-test for self-reported responses during anxiety-evoking film condition during the perianal sensor placement

Variable	t	df	P	Cohen's d	95% CI
Self-reported sexual arousal	−3.46	13	<.01	−0.92	(−1.83, −0.34)
Perceptions of genital arousal	0.62	13	.545	0.09	(−0.59, 0.84)
Positive affect	1.20	13	.251	0.16	(−0.50, 0.94)
Perception of autonomic activity	4.92	13	.001	1.05	(0.46, 2.20)
Negative affect	2.62	13	.05	0.57	(−0.03, 1.49)
Anxiety	3.78	13	.01	1.39	(0.60, 1.99)

CI = confidence interval; df = degrees of freedom.

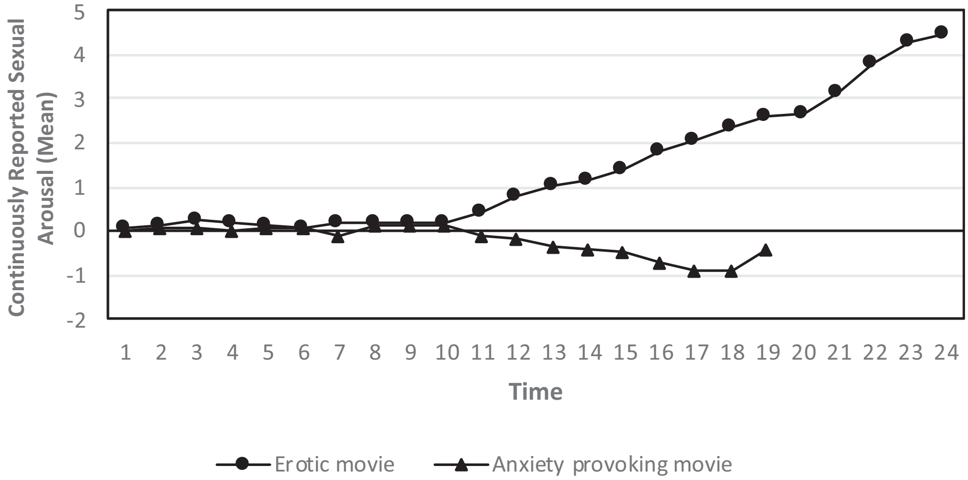

Figure 1. Effects of erotic film (closed circles) and anxiety film (closed triangles) compared with neutral film on self-reported sexual arousal (with bulbocavernosus sensor placement). Note: Each data point reflects the mean arousometer rating over a 30-second epoch. X-axis represents time with neutral film at points 1 to 10 and erotic film or anxiety responses at points 11 to 24. Y-axis reflects self-reported sexual arousal from −2 (sexually turned off) to 7 (highest level of subjective sexual arousal).

greater sEMG response to anxiety-evoking as compared with erotic film stimuli. There was also an increase in perianal sEMG for the erotic and the anxiety films relative to the neutral films. Bulbocavernosus sEMG responses did not differ among the neutral, erotic, or anxiety film conditions.

With respect to subjective sexual arousal, film excerpts evoked the predicted emotional states. In other words, the sexual film evoked significant changes in self-reported sexual arousal and perceptions of genital arousal, whereas the anxiety film did not. Furthermore, self-reported anxiety significantly increased with anxiety films but not erotic films, as predicted, and perception of genital arousal and positive affect increased during erotic films but not anxiety films, as predicted.

Regarding concordance, values ranged from 0.236 to 0.349 and did not significantly differ from one another. Moreover, when examining the 95% CIs, our observed concordance estimates overlap with the concordance value of 0.26 found in a meta-analysis of women using the VPP (0.26).[32] Concordance values when using intravaginal sEMG (0.293) and when using perianal sEMG (0.236) did not differ significantly from concordance using bulbocavernosus sEMG. Not surprisingly, the mean concordance between self-reported sexual arousal and sEMG responses during each of the anxiety-evoking film conditions was very low and did not differ across pelvic floor muscle locations.

Compared with neutral stimuli, sexually explicit stimuli evoked a significant increase in PFM sEMG activity in 2 of 3 electrode locations, specifically intravaginal and perianal sEMG, but not with bulbocavernosus electrode placement. These results are in contrast to the findings of Both et al,[14] which indicated a lower mean sEMG response during sexual films compared with

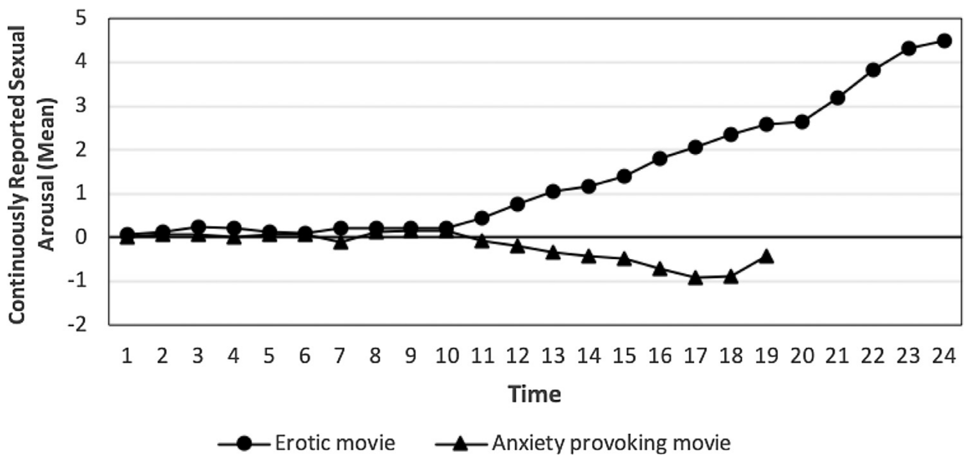

Figure 2. Effects of the erotic and anxiety-provoking film compared with neutral film on self-reported sexual arousal responses (with perianal sensor placement). Note: Each data point reflects the mean arousometer rating over a 30-second epoch. X-axis represents time with neutral film at points 1 to 10 and erotic or anxiety film responses at points 11 to 24. Y-axis reflects self-reported sexual arousal from −2 (sexually turned off) to 7 (highest level of subjective sexual arousal).

Table 6. Mixed-effects linear regression results for all 3 sEMG locations

	Intravaginal		Bulbocavernosus		Perianal	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Intercept	4.25	0.40	2.13	0.66	2.87	0.48
Time	−0.003	0.002	0.0008	0.002	0.0006	0.004
Film type						
Neutral before anxiety	Reference		Reference		Reference	
Neutral before erotic	0.076	0.34	−0.35	0.36	−0.12	0.45
Anxiety	−1.05	0.34	−0.17	0.34	−0.06	0.45
Erotic	−0.78	0.30	0.31	0.32	0.68	0.39
Time by film type						
Neutral before anxiety	Reference		Reference		Reference	
Neutral before erotic	0.0003	0.002	0.0015	0.002	0.0009	0.003
Anxiety	0.011	0.002	0.0011	0.002	0.007	0.003
Erotic	0.005	0.002	0.0009	0.002	0.0056	0.002

SE = standard error; sEMG = surface electromyography.

neutral films, which they interpreted as pelvic floor activity decreasing during exposure to erotic films. We cannot rule out the possibility, however, that the discrepancies between our study and the study by Both et al[14] may be due to differences in study methods, sEMG equipment (eg, different diameters of the sEMG sensors and vaginal probes used; sEMG electrode size), use of different film stimuli, or electrode and probe placement. For example, the lengthened sEMG probe used by Both et al[14] had an insertion depth of approximately 89 mm, whereas our probe measured approximately 50.8 mm from base to tip. It is possible that electrodes covering a larger part of the pelvic floor musculature may have picked up a stronger sEMG signal, resulting in higher sEMG values and measurement sensitivity.[14] We also cannot rule out the possibility that different amounts of sympathetic nervous system activation took place across the 2 studies, accounting for the observed differences, given the varying lengths of the erotic stimuli used. Future studies should aim to include a more objective measure of sympathetic nervous system activity to assess the extent to which such changes mediated the PFM activity.

The sEMG activity increased significantly in response to the anxiety film clips when using the intravaginal and perianal electrodes. In the study by Both et al,[14] sEMG values were also significantly higher in response to the anxiety-evoking film; as well, stronger reported feelings of threat and anger were related to a stronger sEMG response. Similarly, van der Velde et al[19] demonstrated an increased pelvic floor response during exposure to anxiety-evoking stimuli, suggesting that the pelvic floor musculature may engage a defense mechanism system in response to threatening situations.

There was no difference in sEMG response during anxiety and sexual stimuli at the bulbocavernosus locations. This is similar to what was found by Both and Laan,[22] who observed an increase in

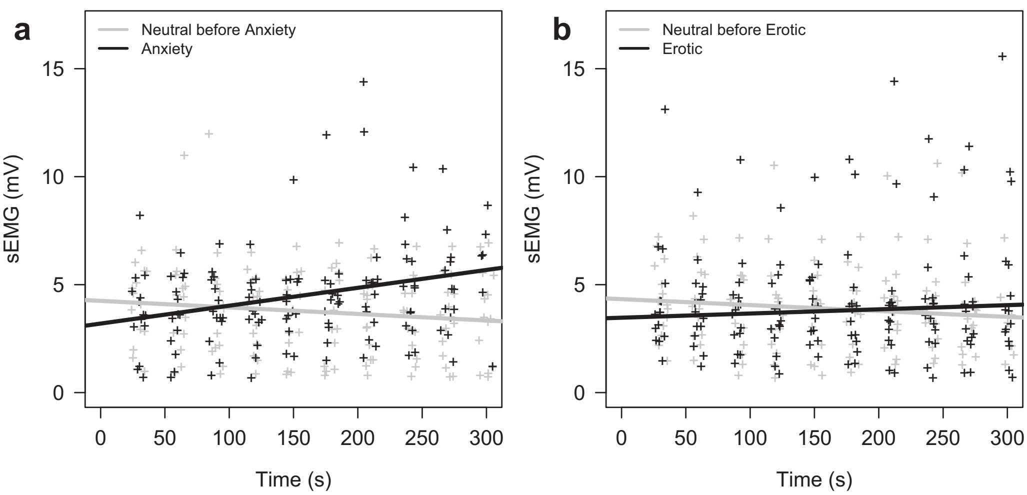

Figure 3. Relationship between intravaginal sEMG and time for (a) anxiety film types, and (b) erotic film types. Neutral film data are shown in gray. The lines indicate the predicted relationship from the mixed-effects regression model. Data points are offset a small random amount along the x-axis to minimize overlap of symbols.

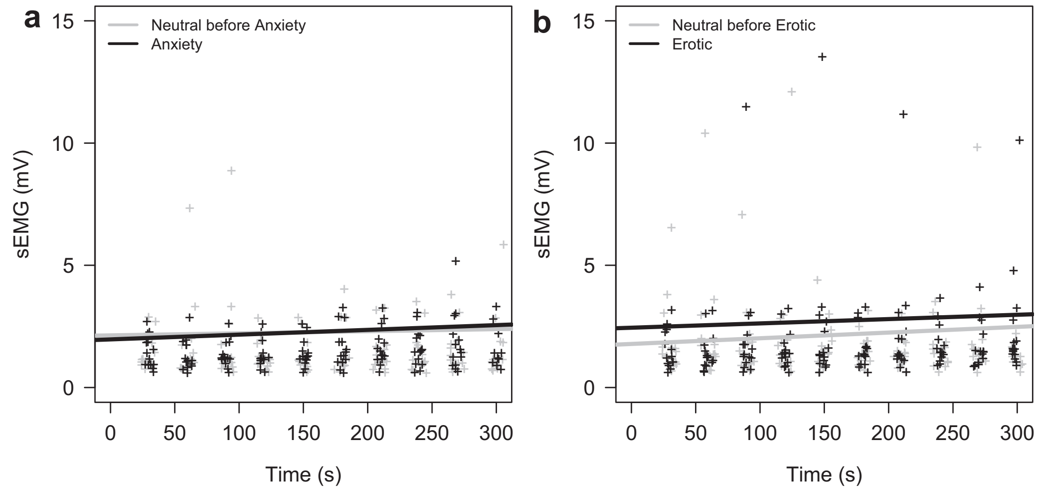

Figure 4. Relationship between bulbocavernosus sEMG and time for anxiety film types (a) and erotic film types (b). Neutral film data are shown in gray. The lines indicate the predicted relationship from the mixed-effects regression model. Data points are offset a small random amount along the x-axis to minimize overlap of symbols.

pelvic floor activity during exposure to both threatening and erotic film clips. Although these results contrast with those of van der Velde et al,[19] it is worthwhile noting that although the sEMG recorded no change from neutral to erotic films, the majority of participants in the study by van der Velde et al[19] study still reported experiencing contractions of their pelvic floor muscles during the erotic film. Our finding suggests therefore that sEMG using placement of sensors at the bulbocavernosus does not provide a specific measure of sexual arousal.

With regard to disparate responses across the deep vs superficial muscular locations, it is possible that the sEMG measurement at the bulbocavernosus muscle may have lacked sensitivity to pick up differential pelvic floor activity between the anxiety and erotic films. In other words, we suggest that the degree of bulbocavernosus muscle contraction induced by the erotic films did not reach a high enough amplitude to be detected by the sEMG electrodes. Lower-amplitude contractions in voluntary striated muscles recruit fewer muscle fibers, and sEMG electrodes may not have been sensitive enough to detect these lower levels of muscle contraction.[48] As such, sEMG electrodes may provide only a limited assessment of fine muscle activity.

The use of fine-wire electromyography for puborectalis and bulbocavernosus muscles might be worthy of consideration for future studies to assess smaller muscle contraction and to pick up less surrounding muscle activity.[48,49] In addition, increased time between stimulus presentations (to allow PFM tension to dissipate) may be an important factor, because lower levels of change may not be detectable if the participant did not have enough time between films to return to their base resting sEMG level. Although participants were instructed to complete the post-film and pre-film assessments of sexual arousal and affect as a return-to-baseline, the use of a neutral distraction task may have facilitated a fuller return to sEMG baseline.[14]

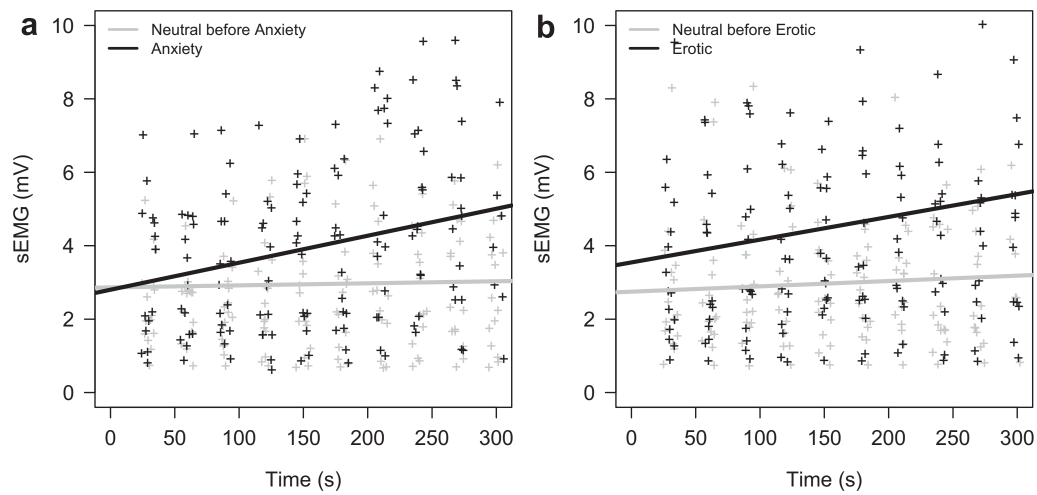

Figure 5. Relationship between perianal sEMG and time for anxiety film types (a) and erotic film types (b). Neutral film data are shown in gray. The lines indicate the predicted relationship from the mixed-effects regression model. Data points are offset a small random amount along the x-axis to minimize overlap of symbols.

It is important to consider several limitations of our research. We were unable to test directly for differences between participants in the different counterbalanced groups because of the small sample size. Given that this was a pilot, it will be important for future research to examine this question using a larger sample size. Furthermore, although we showed that deep PFM activity responds differently to erotic vs anxiety stimuli, we cannot conclude that the observed differences in sEMG responsivity was the sole result of increased PFM activity or whether surrounding muscle groups were also recruited. Researchers may want to examine whether participants are able to contract muscle groups other than the pelvic floor to test for the ability of the sEMG to differentiate between non-PFM groups.[14] Alternatively, researchers may want to use sEMG with additional channels placed on the buttocks, abdomen, and upper legs, for example, to determine whether these muscle groups remained relaxed during exposure to erotic and anxiety stimuli and to eliminate the possibility of interference from surrounding muscle groups.[14]

Additionally, it is important to note that the language of "women" and "female" within the context of our study may be restrictive and that testing vaginal response may not accurately represent the experiences of all women, particularly transgender and intersex individuals or those with diverse genitalia. Limitations of this study was the inclusion of only cisgender women. A further limitation was the fact that we did not assess for recreational drug use, which may have impacted pelvic floor muscle tone.

The results of this pilot study have promising clinical and research implications by encouraging a better comprehension of the mechanisms involved in physiological arousal and providing further insight into the role of the pelvic floor during sexual response. Understanding more about the role of the PFM as it responds to sexual stimuli may inform what types of endpoints to measure in therapeutic trials where treatments of low sexual arousal may be tested. After improvement of the sensitivity of the sEMG measurement, additional research will be required to determine whether sEMG can be used as a reliable and valid method of assessing sexual arousal in a clinical or research setting.

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