The Psychophysiological Assessment of Female Sexual Function

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The success of sildenafil in treating male erectile dysfunction has brought increasing attention from researchers, drug companies, and funding sponsors to develop an effective pharmacological treatment for female sexual dysfunction. Demonstrating treatment efficacy necessitates a valid and reliable index of female sexual response. The first observable sign of sexual arousal in women is vaginal lubrication and a simultaneous increase in vaginal vasocongestion. The three primary psychophysiological assessment devices that rely on indirect measures of vasocongestion are the vaginal photoplethysmograph, devices that indirectly measure heat dissipation, and pulsed-wave Doppler ultrasonography. The most widely used and studied of these is the vaginal photoplethysmograph, which detects differences in transparency of engorged and unengorged vaginal tissue using a light reflectance method. Research has demonstrated the construct validity of this device and its response specificity to sexual stimuli. However, a recurrent issue with the use of this device is the lack of correspondence between genital measures of vasocongestion and subjective reports of "feeling sexually aroused." This contrasts with findings in men, which generally show high concordance between subjective and physiological measures. Evidence suggests that external stimulus information (e.g., relationship issues, sexual scenarios) may play a more important role in assessing feelings of sexual arousal than do internal physiological cues. Consistent with this is the fact that men are more accurate than women at detecting physiological changes in general (e.g., heart rate, blood pressure), but only when situational cues are absent. Clearly, this raises important conceptual issues in the definition of female sexual arousal.

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The psychophysiological assessment of female sexual function has a relatively short history in sexology (Rosen & Beck, 1988). It was not until 1975, when Sintchak and Geer introduced the vaginal photoplethysmograph, that the first practical and reliable measurement device for vaginal blood flow became available. The introduction of the vaginal photoplethysmograph spurred great research interest in the area of female sexual arousal throughout the late 70s and early 80s. A number of publications appeared that examined vaginal responses during various experimental manipulations and assessed the diagnostic implications of this new measurement device. Since then, advances in understanding female sexual response have slowed considerably. In fact, over the past decade and a half, only a handful of laboratories worldwide have focused exclusively on studying the female psychophysiological sexual response.

One likely reason for the prolonged paucity of research in this area is the lack of available funding for such research by major granting agencies. Funds allotted to the study of sexuality have been devoted almost exclusively to reproductive functioning, and not on the understanding of basic sexual physiology. This has had different implications for the advancement of knowledge of the sexual processes of males and females. In females, reproductive functioning centers around ovarian function and general gynecological health issues; the sexual response per se is hardly implicated. Because reproductive potential for a male, on the other hand, involves the ability to attain and maintain an erection until vaginal penetration and ejaculation have occurred, research dollars have gone toward advancing the understanding of male sexual response. As a result, much of what is assumed to represent the underlying mechanisms of female sexual responding is based on research conducted in males.

The lack of an inexpensive and appropriate animal model for studying female sexuality can also help to explain the delay in general knowledge regarding female sexual physiology. Although it may be argued that appropriate animal models are also absent for studying male sexuality, this seems to be even more

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problematic for females. In rats, for example, it is understandable how behavioral indices of initiation, maintenance, efficacy, ejaculation latency and intervals, and reinitiating mating after ejaculation might serve as models for sexual interest, arousal, orgasm, and refractory periods in human males. It is unclear, however, how lordosis responding (a spinal reflex in response to a male rat's attempt to mate), the most frequently studied sexual behavior in female mammals, might reflect stages of the human female sexual response. Moreover, other measures of sexual behavior in female mammals, such as ear wiggling and rejection behaviors, all reflect sexual interest or motivation (Meston, Gorzalka, & Wright, 1997); there is no appropriate animal model for female sexual arousal or orgasm. Female primate models allow for the measurement of, for example, uterine and vaginal contractions during sexual arousal and coitus, thus providing more insight into the human female sexual response than rat models. Primates, however, are extremely costly to study and cannot be used in the large numbers often necessary for conducting experiments (Levin, 1992).

After over a decade of stagnation, the enormous success of Pfizer's sildenafil (Viagra) for men has finally led to a reawakening of study into female sexuality. A number of pharmaceutical companies are currently in the race to develop the first Food and Drug Administration (FDA)-approved drug treatment for female sexual dysfunction. Like Viagra, many of the new drugs being tested are vasodilators. It is believed that vasodilators increase blood flow into the female genitals (as does Viagra in men) and, in turn, facilitate vaginal lubrication. Because the expected drug effects are largely (if not exclusively) physiological in nature, this recent surge of interest into female sexuality has triggered the need for a reliable physiological measure of female sexual responding. Moreover, given that these drugs are aimed exclusively at enhancing sexual function, testing the drugs' efficacy necessarily requires a clear understanding of exactly what female sexual function is.

In many ways, the field of study into female sexuality was not prepared for such a flurry of scientific inquiry. When vasodilator drug trials began in women, researchers could not even agree on what female sexual dysfunction was, or how exactly to measure it. What if a woman can get aroused and have an orgasm, but doesn't find doing so pleasurable? What if a woman has difficulty becoming sexually aroused, but isn't concerned or distressed by this? In June 1998, the first ever Consensus Conference on Female Sexual Dysfunction (sponsored by the Sexual Function Health Council of the American Foundation for Urologic Disease, with funds provided by a number of pharmaceutical companies) was held in an effort to define and classify female sexual disorders, to determine outcome variables for the treatment of sexual dysfunction, and to identify areas in need of future research (Bason et al., 2000).

This paper outlines some of these key issues surrounding the psychophysiological assessment of female sexual function. The paper begins with a brief summary of the classification of female sexual function and some of the problems associated with its current conceptualization. In order to provide a background for understanding the range of genital measures of arousal possible for women, the second section of this paper provides a brief review of the physiological changes that accompany female sexual arousal. A review of the three major types of psychophysiological assessment techniques currently available is then presented, followed by a discussion of the primary issues related to the measurement of female sexual response, and a summary of topics for future research in this area.

The Classification of Female Sexual Dysfunction

The diagnostic categories of sexual problems delineated in the *Diagnostic and Statistical Manual of Mental Disorders*, 4th edition (DSM-IV) (American Psychiatric Association, 1994) include sexual desire disorders (namely hypoactive sexual desire or sexual aversion disorder), sexual arousal disorders; orgasmic disorders; and sexual pain disorders (including dyspareunia and vaginismus). A recent survey by Laumann, Gagnon, Michael, and Michaels (1994), which was completed by more than 3,400 selected respondents, highlights the fact that these sexual disorders are common and affect women irrespective of age, socioeconomic status (SES), education, or religion. To note just a few examples, nearly 20% of women reported difficulties with lubrication, 30% reported being uninterested in sex, and more than 20% said that sex provided them with little pleasure.

The current DSM-IV classification system represents an improvement over earlier DSM editions in the attention now paid to psychological factors such as interpersonal distress. However, it remains open to criticism in that it lacks objective, empirically grounded criteria (Laan, 1998) and is ambiguous with regard to the degree of impairment necessary to qualify a problem as warranting clinical attention (Leiblum, 1998). For example, the DSM-IV defines hypoactive sexual desire as "Persistently or recurrently deficient or absent sexual fantasies and desire for sexual activity." The judgment of what constitutes "deficient" is made by the clinician, with consideration given to factors such as age and the context of the person's life (American Psychiatric Association, 1994, p. 498). As noted by Leiblum (1998), however, there is little objective evidence on exactly how such factors might be expected to impair desire. Moreover, overt measures of behavior such as intercourse or masturbation frequency are unreliable measurements because they may occur in the absence of desire, or may be suppressed because of religious, psychosocial, or other factors.

The DSM-IV classification of female sexual disorders draws heavily on Kaplan's (1979) triphasic model of sexual response in which sexual desire, arousal, and orgasm can be conceptualized as relatively distinct sexual phases. Yet in actual clinical practice, sexual desire, arousal, and orgasm difficulties coexist more often than not. For example, hypoactive sexual desire disorder frequently occurs secondary to other sexual disorders such as arousal disorder, anorgasmia, or dyspareunia (sexual pain). In such cases, desire in usually restored with the successful treatment of the other presenting sexual problem.

The confusion and controversy surrounding the classification and diagnosis of female sexual dysfunction are symptomatic of an underlying lack of knowledge regarding the etiology of female sexual dysfunction, a lack of normative data on what constitutes functional and dysfunctional sexual behavior, and the dearth of studies examining potential physical indices of female sexual problems. With the exception of certain of the sexual pain concerns, the contribution of physiological factors to the diagnosis female sexual dysfunction is rarely considered. Even female sexual arousal disorder, which is defined almost exclusively in physical terms (i.e., absence of the normal lubrication-swelling response), is diagnosed largely on the basis of subjective complaints of decreased arousal. Objective, physiological measures of sexual arousal (e.g., lubrication, vasocongestion) are not considered. Moreover, only in the case of postmenopausal or oophorectomized women are physiological factors (i.e., abnormal hormone levels) particularly suspect in the etiology. This is in contrast to the diagnosis of male erectile dysfunction, which is commonly considered physiological in origin. Testosterone deficiency, vasculogenic or neurogenic impairment, and venous leakage are just some of the common organic factors known to impede male erectile responding. With regard to assessment, psychophysiological recordings of nocturnal penile tumescence, cavernosography, and vasoactive injections into the corpora are common diagnostic tools for assessing male erectile dysfunction and for discriminating between psychogenic and biogenic etiological factors.

The absence of physiological diagnostic criteria for female sexual dysfunction is due, in part, to the fact that past clinical research has failed to identify reliable physiological sexual response correlates of sexual disorders in women. Wincze, Hoon, and Hoon (1976), and Palace and Gorzalka (1990, 1992) found lower levels of vaginal blood volume (VBV) responses to an erotic film among women with arousal and orgasmic difficulties compared with control women. Morokoff and Heiman (1980), however, failed to find differences in vaginal pulse amplitude (VPA) between women with and without sexual difficulties, and Wincze, Hoon, and Hoon (1978) found no significant differences in physiological (VBV) sexual responses in women who were assessed prior to and following sexual therapy.

The contradictory results of these studies have led some researchers to question whether VBV and VPA responsiveness may in fact play an important role in female sexual disorders. There are, however, a number of potentially important methodological limitations that may help to explain these inconsistencies. First, previous researchers have combined women with a variety of sexual difficulties—including low sexual desire, arousal difficulties, and anorgasmia—into one heterogeneous experimental group. Given that these disorders correspond to different stages of the female sexual response, there is no apparent a priori reason to assume that women with different sexual difficulties would show similar patterns of physiological sexual responding. Hence, insufficient specificity in the classification of sexual disorders might have obscured differences in physiological sexual responding between functional women and women with specific sexual complaints. Second, in previous studies researchers have used either VPA or VBV to assess physiological sexual responding. Given the generally low correlation between these two indexes of sexual responding (e.g., Meston & Gorzalka, 1995, 1996a, 1996b; Zingheim & Sandman, 1978), some of the inconsistencies noted between past studies may be accounted for by the use of different sexual response variables. And third, differences in erotic stimuli and data reduction and analyses between studies add to the difficulty of comparing results.

Recent research that has focused on discrete types of sexual difficulties lends new support for an etiological role of biological factors. Park and colleagues (1997) demonstrated that female sexual arousal is associated with neurotransmitter-mediated vascular smooth muscle relaxation, which stimulates vaginal lubrication, vaginal wall engorgement, and increased clitoral vasocongestion. Thus, women with atherosclerotic vascular disease may experience decreases in vaginal engorgement and lubrication, and diminished vaginal and clitoral sensations and orgasm. Meston and Gorzalka (1996a) noted differences in sexual responsiveness to sympathetic nervous system (SNS) activation between women with and without orgasm difficulties. Sexually functional women and women with low sexual desire showed a significant increase in VPA responses to an erotic film with preexposure to SNS activation relative to a control condition. Anorgasmic women, on the other hand, showed a significant decrease in VPA responses to an erotic film following increased SNS activation. Traditionally, female anorgasmia has been attributed to a lack of sufficient stimulation, sexual inexperience, or a variety of psychological factors. The findings from Meston and Gorzalka's (1996a) study suggest that, in addition, anorgasmia may involve a primarily physiological component.

The Female Physiological Sexual Response

The first observable sign of female sexual arousal is vaginal lubrication (Masters & Johnson, 1966). Within approximately 20 seconds of sexual stimulation, vaginal lubrication appears simultaneously with an increase in blood flow (vasocongestion) to the internal and external genitals. Although the process by which these two events occur in unison is not well understood, it is generally believed that some sort of hydrostatic mechanism causes increased pressure in the tissue walls which, in turn, results in gradual transudation (Masters & Johnson, 1966). Vaginal lubrication originates in the subepithelial vascular bed and is transported through the interepithelial spaces, referred to as intercellular channels (Hirsch, 1998). Additional lubrication during intercourse comes from secretion of the Bartholin's glands, although traditionally these glands have been linked to a more primal function of emitting an odiferous male-attractant fluid (Hirsch, 1998). Estrogen receptors throughout the vaginal epithelium, in stromal cells, and in the smooth muscle fibers in the muscularis are responsible for maintaining vaginal lubrication, as well as the thickness and rugae of the vaginal wall. Insufficient amounts of estrogen result in the thinning of vaginal walls and a drier and less acidic vaginal environment (Hirsch, 1998). Wagner and Levin (1978) have noted that fluctuations in the regulation of the sodium-potassium balance of the vaginal tissue also play an important mediational role in the production of vaginal lubrication.

During the initial phase of sexual arousal, increased blood flow into the genital region produces engorgement and consequent swelling of the erectile tissue of the vestibule and venus plexus which surround the lower portion of the vagina. The vaginal walls become dark purple as a result of this increase in genital engorgement. Research that used a xenon washout procedure indicates that average genital blood flow in an unaroused state ranges from 5.5 to 19.6 mL/min whereas during sexual stimulation, blood flow ranges from 21.5 to 45.0 mL/min (Wagner & Ottesen, 1980). Levin (1981) described the process of vasocongestion as resulting from increased heart stroke volume and dilation of smooth muscle cells in the major arteries that supply genital tissue. Precapillary arterial dilation accompanies the beginning stages of vasocongestion and gradually shifts to arterialized blood flow and increased venous output as arousal continues (Wagner & Ottesen, 1980). Further increases in genital blood flow result from the constriction of smooth muscle cells in the surrounding larger veins, and via the relaxation of smooth muscles that surround the vascular bed (Rosen & Beck, 1988).

During sexual arousal there is an increase in the concentration of lactic acid, glycerol, and higher-molecular-weight lipids in vaginal fluid (Huggins & Preti, 1976), and following orgasm the potassium levels approximate blood plasma levels (Levin & Wagner, 1976). The unaroused vaginal pH level is approximately 4.5; with sexual stimulation, pH levels increase to values in the 6.0 to 6.5 range (Berman, 1998). Kinsey, Pomeroy, Martin, and Gebhard (1953) enumerated 20 various genital and nongenital physiological changes that accompany sexual arousal. These include increases in heart rate, blood pressure, peripheral blood flow, and respiration rate; genital, nasal, and salivary secretions; neuromuscular tension; and central nervous system (CNS) changes.

As sexual arousal increases, the clitoris and the labia minora become engorged. The clitoris increases in size and diameter and retracts under the clitoral hood. Uterine elevation occurs, likely the result of contraction of parametrial muscle fibers that surround the vagina and uterus (Rosen & Beck, 1988). Formation of the orgasmic platform in the outer third of the vagina signals that complete vasocongestion has occurred. The vascular system of the vagina consists of a complex anastomotic network throughout its length. The blood supply originates within the uterine, internal iliac, and vaginal arteries. The vaginal artery is composed of numerous arteries on each side of the pelvis and is connected to both the anterior and posterior vaginal surfaces.

Research on the vascular mechanisms involved in female sexual responding has lagged considerably behind that in men. Much of what is thought to facilitate or inhibit female sexual responding from a vascular or nervous system perspective is based on analogies that have equated the male erectile and female vasocongestive responses. While it is possible that comparable physiological mechanisms exist between genders, one must stay aware of the fact that there are many integral differences between the genital structures of males and females. For example, there is no functional hydraulic system in the female vagina that is analogous to the male penis (Bancroft, 1989).

Physiological Assessment of Female Sexual Arousal

It was not until 1968—24 years after the first published study of the measurement of male erection (Ohlmeyer, Brilmayer, & Hullstrung, 1944)—that an account of the first promising effort to measure sexual arousal in women was published (Shapiro, Cohen, DiBianco, & Rosen, 1968). Shapiro and colleagues' method used two vaginal thermistors that were mounted on a cervical diaphragm. One of the thermistors was heated slightly by current flow in order to maintain a constant temperature differential between the two thermistors. Differences between the thermistor-assessed temperature of the vaginal wall and core body temperature corresponded to the degree of capillary engorgement of the vagina. Previous attempts to record physiological sexual changes had focused almost exclusively on extragenital measures such as heart rate, respiration rate, changes in blood pressure and body temperature, and sweat gland activity.

Shortly after the publication of Shapiro et al.'s 1968 paper, Zuckerman (1971) provided an extensive review of the literature on psychophysiological indices of sexual responding. Zuckerman postulated that extragenital measures of sexual responding were not especially useful in assessing sexual arousal given their lack of specificity. That is, extragenital measures are altered with exposure to anxiety, fear, excitement, and any number of other affect-laden events; hence, those measures tell us nothing specific about the state of sexual arousal. This observation, taken together with Masters and Johnson's milestone book *Human Sexual Response* (1966)—which described the two major indicators of sexual arousal as being myotonia and vasocongestion (particularly in the genitals)—directed researchers to use specific genital measures for assessing sexual response patterns.

Many of the early attempts to measure genital blood flow in women proved unsuccessful for a variety of methodological and practical reasons. In addition to the vaginal thermistors, Shapiro et al. (1968) created a device for measuring vaginal pH as an indicator of vaginal lubrication. As noted earlier, vaginal pH levels increase substantially as sexual arousal increases. This and later attempts to measure vaginal pH and lubrication (e.g., Wagner & Levin, 1978) proved technically unreliable and intrusive. Moreover, changes in pH levels have since been shown to be somewhat unreliable in that they vary depending where in the vagina measurements are taken (Wagner & Levin, 1984). Karacan, Rosenbloom, and Williams (1970) developed an innovative mechanical strain gauge to measure clitoral enlargement. In a small sample of women with congenital clitoral enlargement, the authors demonstrated the presence of clitoral erections during sleep which occur with much the same frequency as penile tumescence in men. However, the device was not applicable to the general female population. In an effort to measure uterine contractions, Bardwick and Behrman (1967) devised a transducer made of a thick polyethylene tube connected to a rubber balloon. The device was inserted through the cervix into the uterus and filled with water. Measures of uterine contractile amplitude, duration, and frequency were calculated by matching the water pressure to atmospheric pressure. This measurement technique proved unsuccessful largely due to the pain involved in positioning the device and the tendency for women to become anxious and extrude the device (Rosen & Beck, 1988).

Current assessment techniques for the measurement of physiological sexual arousal in women rely primarily on indirect assessments of vaginal blood flow (direct assessment of vasocongestion is too invasive a technique to be used with human subjects). The three primary means of assessing vaginal blood flow include vaginal photoplethysmography, indirect measures of heat dissipation, and pulsed wave Doppler ultrasonography.

The vaginal photoplethysmograph. The most frequently used method for monitoring vaginal blood flow is vaginal photoplethysmography. This technique was introduced by Sintchak and Geer (1975) and improved upon by Hoon, Wincze, and Hoon (1976). The vaginal photoplethysmograph is a clear acrylic, tampon-shaped device that contains either an incandescent light source, or an infrared light-emitting diode as a light source, and a photosensitive light detector. The light source illuminates the capillary bed of the vaginal wall, and the photo transistor detects the light that is reflected back from the vaginal wall and the blood circulating within it. The amount of back scattered light is in direct relation to the transparency of engorged and unengorged tissue and, hence, serves as an indirect measure of vasoengorgement. Simply stated, the greater the back-scattering signal, the more blood is assumed to be in the vessels (Levin, 1992). The vaginal probe was designed to be easily inserted by the subject. A positioning shield can be placed on the probe's cable in order to standardize the depth of insertion between uses (Laan, Everaerd & Evers, 1995).

There are two components of the signal that can be derived from the photplethysmograph. When the signal is coupled to a direct current (DC) amplifier, a measure of VBV is obtained. VBV is believed to reflect slow changes in the pooling of blood in the vaginal tissue (Hatch, 1979). The DC signal is used at low sensitivity, and the standard dependent variable is the change from levels of VBV at baseline. Because there is no discernible zero point with VBV, absolute measures of blood volume cannot be detected, hence the need to measure in units of blood volume change. When the signal is coupled to alternating current (AC), a VPA measure is obtained. VPA is believed to reflect phasic changes in vaginal engorgement with each heartbeat; higher amplitudes indicate higher levels of blood flow (Geer, Morokoff & Greenwood, 1974). The dependent variable typically used is the amplitude of the pulse signal, which is measured from the bottom to the top of the pulse wave. Analyses of VPA are usually conducted by either averaging across specific stimulus presentations, across the highest 20-30 seconds of arousal, or across selected time periods.

There has been substantial controversy among researchers concerning which of the genital measures, VBV or VPA, is the most sensitive and reliable. Weinman (1967) argued that VBV should be a more sensitive signal given that blood volume changes produced by the heart, as is the case with VPA, represent only a fraction of the total vaginal blood volume. Geer et al. (1974), however, found that whereas VPA increased in concert with the progression of an erotic film, VBV failed to do so. Consequently, the authors concluded that VPA was the more sensitive measure. Studies that have compared VBV and VPA measures have also concluded that VPA is a more sensitive measure of sexual arousal than is VBV (e.g., Geer et al., 1974; Heiman, 1977; Meston & Gorzalka, 1995, 1996a, 1996b). In a study of the construct validity of VPA and VBV during sexual, neutral, and nonsexual emotional states, Laan, Everaerd, and Evers (1995) concluded that VPA is the superior measure in terms of convergent and divergent validity. Their conclusion was based, in part, on the finding that VBV—but not VPA—was responsive to anxiety as well as sexual stimulus. They also noted that VBV showed a drift over time during baseline recordings, and is more sensitive to movement artifacts than VPA.

Advantages to using vaginal photoplethysmography as a technique for assessing female sexual arousal include (a) the ability of subjects to insert the probe in privacy, without the assistance of a researcher; (b) the ability to measure blood volume changes over relatively long periods of time without harm or discomfort to the subject; and (c) the relatively short period of time required for VBV and VPA levels to return to baseline, which allows for multiple, sequential stimulus recordings. Disadvantages of using this technique include the inability to measure sexual responses during orgasm due to the sensitivity of the probe to movement artifacts, and the lack of a sound theoretical basis for interpreting what exactly the signal means. As noted by Levin (1992), in some tissues an increase in VPA may represent a restriction of venous drainage rather than vasodilation per se. In addition, VBV and VPA signals provide no information as to whether the vasodilation is occurring in the arteries, arterioles, capillaries, venules, or veins (Levin, 1992).

Indirect measures of heat dissipation: The labial thermistor. Introduced by Henson, Rubin, Henson, and Williams (1977), this measurement technique consists of a thermistor that is attached to the labia with a conductor wire clip. Reference thermistors are placed on the subject's chest and on the wall of the experimental room, in order to control for fluctuations in body and atmospheric temperature (Rosen & Beck, 1988). Studies using this technique have noted increases in labial temperature ranging from 0.10° to 1.38° C with exposure to erotic stimuli (Henson et al., 1977; Slob, Koster, Radder & Werften-Bosch, 1990). Advantages of the labial thermistor include (a) the ability to measure temperature changes during orgasm due to the thermistor's relative immunity to movement artifacts, (b) the ability of subjects to affix the thermistor without experimenter assistance, and (c) the relatively simplistic transducer design which could potentially allow for at-home monitoring. The primary drawback of this device is the long period of time required for temperature to return to baseline following sexual stimulation (Rosen & Beck, 1988). This drawback necessarily precludes the use of the labial thermistor when multiple, sequential recordings are required. Despite reasonable validity and reliability, this device has not, as of yet, been widely used or accepted as a measure for the assessment of female sexual responding.

Indirect measures of heat dissipation: The vaginal thermistor. First introduced by Shapiro and colleagues (Shapiro et al., 1968; Cohen & Shapiro, 1970), the vaginal thermistor measures changes in vaginal temperature using a vaginal blood flow sensor clipped to a diaphragm ring. A similar but more elaborate thermoconductive probe was developed by Fugl-Meyer, Sjogren, and Johansson (1984). This later device consists of a battery-powered transducer mounted on a diaphragm ring. The signal output from the thermistors is sent to a receiver outside the body, allowing for a radiotelemetric means of measuring vaginal temperature. The advantages of this device include the ability to monitor sexual responses in a more natural setting; and the ability to monitor blood flow during any form or stage of sexual activity, including masturbation, intercourse, and orgasm (due to the absence of movement artifacts). Disadvantages to using the vaginal thermistor include (a) the cost and inconvenience associated with the need to fit subjects individually for the diaphragm ring, (b) potential confounds resulting from slight repositioning of the diaphragm during muscle contractions that may occur during high levels of arousal (Semmlow & Lubowsky, 1983; as cited in Rosen & Beck, 1988), and (c) a general lack of understanding regarding how vaginal temperature changes are to be interpreted (Levin, 1992). Although this device showed promise insofar as it broadened the range of sexual activities and settings possible for measuring sexual responses, few studies have been conducted using this device. Hence, to date, little is known regarding the reliability and validity of measures of vaginal temperature changes.

Indirect measures of heat dissipation: The heated oxygen electrode. In 1978, Wagner and Levin introduced a device that measures intravaginal transcutaneous oxygen partial pressure. This device consists of a heated oxygen electrode that fits inside a suction device, which is then attached to the vaginal wall. The electrode is heated by an electric current usually set to 43° C. The amount of electrical power that is needed to keep the disc at this set temperature is recorded. Heat loss occurs primarily via conduction through the tissue and tissue fluid to the blood. An increase in blood perfusion leads to an increase in heat loss and, subsequently, an increase in power output is required to keep the disc at the set temperature (Levin, 1992). This increase in power is an indirect measure of the changes in blood flow that occur under the device. The electrode also measures the amount of oxygen that diffuses across the skin, which provides an indirect measure of short term changes in blood flow.

Advantages of using the heated oxygen electrode include its relative freedom from movement artifacts because of its attachment to the vaginal surface (hence allowing for monitoring during orgasm) and the fact that it can be calibrated in terms of absolute blood flow, and the signal obtained is relatively well understood. Disadvantages of the device include (a) measurement sessions are limited to 1 to 1½ hours because of the potential damage to vaginal mucosa with extended recordings; (b) the expense of the instrumentation; and (c) the need for placement by the experimenter, which limits its practical applicability.

Pulsed wave Doppler ultrasonography. Recently, studies have been conducted using Doppler ultrasonography to measure blood velocity in the clitoral cavernosal artery and to record changes in blood flow associated with intravaginal pressure changes (Berman, 1998). Duplex ultrasonograpy allow for continuous, real-time imaging of anatomic and vasocongestive components of the female sexual response. The main advantages of this measurement technique include the ability to monitor during high levels of sexual arousal due to the relative absence of movement artifacts, and the ability to record blood volume in absolute units (centimeters per second). Disadvantages include the expense of instrumentation and the need for placement and continuous monitoring by a trained technician, which can be expected to inevitably alter the woman's comfort and privacy.

Issues in the Psychophysiological Assessment of Female Sexual Arousal

A recurrent issue in the psychophysiological measurement of female sexual arousal is the correspondence between genital blood flow measures and subjective reports of arousal. Studies that have employed both subjective and physiological indices of sexual arousal in women have generally reported low correlations between measures. This contrasts with findings reported in men, which usually indicate a high positive correspondence between penile tumescence and subjective reports of sexual arousal. A number of explanations have been proposed to account for this variability. Heiman (1976) suggested that the low concordance noted between measures of sexual arousal in women may reflect an inability on the part of women to detect subtle changes in vaginal blood flow. Hence, higher levels of physiological sexual arousal should result in an improved ability to detect the increase in genital blood flow. Indeed, some studies have noted that higher levels of physiological sexual arousal result in improved response concordance. To test this explanation, Laan, Everaerd, Velde, and Geer (1995) presented women with a series of 1-minute erotic film segments and measured the correlation between subject and genital blood flow measures across stimulus presentations. The authors found that the degree of correspondence between measures was independent of the strength of the genital measures.

The low concordance between measures of sexual arousal in women has also been attributed to the way in which subjective sexual arousal has traditionally been measured. Most studies have assessed subjective sexual arousal following erotic stimulus presentation using some type of self-report Likert scale with one or more emotional-sexual descriptors. This methodology has been criticized because it relies on retrospective recall of sexual feelings; it permits only a restricted range of responses, particularly compared with that afforded by psychophysiological measures; and because the method does not accurately reflect subjective feelings of arousal that may fluctuate throughout the erotic presentations depending on individual sexual preferences.

In response to such criticisms, a number of researchers have used continuous assessment measures of sexual responding. Wincze, Hoon, and Hoon (1977) were the first to employ this type of methodology. Their technique involved a lever, mounted to a table, which could effortlessly be moved by the subject throughout the entire stimulus presentation. The subjects could view the position of the lever, which enabled them to see the degree of subjective arousal they were indicating. However, the use of a continuous measure of subjective sexual responding did not promote higher correlations between subjective and genital measures. In a later study, Wincze, Venditti, Barlow, and Mavissakalian (1980) tested the possible distracting effects of using this type of device to monitor subjective responses. They concluded that there were no discernible differences in the degree to which continuous versus questionnaire assessment techniques influenced genital responses.

Laan, Everaerd, Bellen, and Hanewald (1994) investigated the possibility that low correlations between subjective and physiological measures of sexual responding in women may be the result of negative affect induced by using traditionally male-produced erotica. This would also explain the gender difference noted above, insofar as such films would not also induce a negative mood state in males. The authors compared responses in women who were shown a conventional "man-made" film to responses induced by a "woman-made" film that highlighted the sexual pleasure of the female actress. They hypothesized that the woman-made films would increase attentional focus on erotic cues and, consequently, result in an increased correspondence between measures. Their results showed that, indeed, the woman-made erotica increased subjective ratings of sexual arousal but did not influence correlations between measures. Consistent with this finding, Laan, Everaerd, Berlo, and Rijs (1995) reported that agreement between subjective and genital sexual responses in women was not enhanced with positive mood induction, nor reduced by negative affect.

Perhaps the most viable explanation for the generally low concordance between measures of sexual arousal in women is that women may be estimating the degree to which they are subjectively aroused according to standards other than genital blood flow changes. That is, for women, external stimulus information may play a more important role in assessing feelings of sexual arousal than internal, physiological cues. Several lines of research support this explanation. In a review of gender differences in visceral perception, Pennebaker and Roberts (1992) argued that women rely largely on stimulus information, and men on bodily cues, when defining their internal states. The authors cited a great deal of research indicating that men are consistently more accurate than women at detecting physiological changes in, for example, heart rate, blood pressure, stomach contractions, finger temperature, and blood glucose levels. Interestingly, when there are situational cues available in addition to physiological cues, men and women are equally skilled at detecting their physiological state.

Studies that have experimentally manipulated attentional cues also lend support for this explanation. For example, Korff and Geer (1983) instructed women to either (a) focus on specific genital changes, (b) focus on overall physiological changes (e.g., heart rate), or (c) focus on no specific attentional cues (control condition). The authors found that both forms of attentional instructions led to increased correlations between subjective and genital arousal compared with the control condition. These findings suggest that, when women use bodily changes to estimate their subjective state, as men perhaps do, agreement between responses is enhanced.

As suggested by Laan and Everaerd (1995), in addition to using external cues to a greater extent than do men, women may also attribute more meaning to a given situation. As evidence for this notion, they cited a study by Dekker (1988) that found subjective sexual arousal in men was defined primarily in terms of sexual excitement. In women, on the other hand, sexual arousal was defined not only in terms of sexual excitement, but also in terms of positive and negative emotions. Consistent with Laan and Everaerd's hypothesis, Hall (1984) and others have noted that women are better than men at attributing meaning to nonverbal and emotion-based facial cues.

The explanation that women attend more to contextual than physiological cues in estimating their subjective state of sexual arousal fits well within the framework of developmental psychology. As noted by Pennebaker and Roberts (1992), males and females undergo substantially different learning experiences in understanding their bodies' physiological cues. Sexual arousal for a male (i.e., erectile response) provides a much more direct and salient feedback system than does vasocongestion and lubrication for a female. These responses would differentially attract attention to genital cues for males compared to females, and may help to explain why males generally learn to masturbate at a much earlier age, and engage in masturbation more frequently, than do women (Meston, Trapnell, & Gorzalka, 1996). Gender differences in socialization with regard to bodily experiences might also help to explain the gender difference in use of internal and external cues to assess bodily signals. Masturbation and knowledge of, and reference to, genitalia have traditionally been much more accepted among men than women. Moreover, particularly in American culture, women have been socialized to perceive menstruation as being aversive, disruptive, and shameful—reasons not to attend to genital cues. On the other hand, puberty in males marks the onset of masculinity and sexual virility.

Future Directions

Vaginal photoplethysmography, the most common means for assessing vaginal blood flow, provides a sensitive, reliable, and valid indication of physiological sexual arousal in women. However, the psychophysiological assessment of female sexual responding in general is far from mature, and several important questions remain unanswered. First, it is unclear whether changes in genital blood flow in response to sexual stimuli can reliably differentiate women with and without sexual problems. As noted earlier, few studies have attempted to answer this question, and methodological limitations associated with those studies preclude drawing any definitive conclusions. Thus, the degree to which genital measures of blood flow may assist in the assessment of female sexual dysfunction is unknown. Second, because the vaginal photoplethysmograph is prone to movement artifacts at high levels of sexual arousal, most studies have measured sexual responding only during the initial stages of sexual arousal. Consequently, it is unknown whether different response patterns might emerge at higher levels of arousal and orgasm.

Third, and perhaps most perplexing, is the fact that changes in genital responding to sexual stimuli do not appear to significantly determine women's subjective perception of being sexually aroused. Moreover, increases in genital arousal occur somewhat automatically, within seconds of the onset of an erotic stimulus, and occur even in the absence of subjective reports of feeling sexually aroused (Laan et al., 1994). This finding necessarily begs the question of what exactly is sexual arousal in women, and whether physiological changes that occur in the absence of a subjective sexual experience should even be considered a sexual response. If so, genital changes that involuntarily occur during REM sleep (Fisher et al., 1983) or during rape would constitute sexual arousal. Clearly it does not make sense to define sexual arousal in such terms. Future research is needed to better understand the full range of criteria involved in women's subjective appraisal of whether or not they feel sexually "turned on."

The question of exactly what determines sexual arousal in women is especially relevant to the recent interest among pharmaceutical companies that seek a solution for female sexual dysfunction. As noted earlier, most pharmacological treatments currently being tested act as vasodilators, with the end goal to increase blood flow into the genitals. But even if they are successful at doing so, will this necessarily improve a woman's sexual experience? Chances are, if the drugs cause significant and substantial increases in vasocongestion, the woman will be able to detect such changes. But is this the final solution, or will contextual cues such as relationship satisfaction, affective state, and sexual scenarios play a larger role in the equation? For women whose problem is primarily a lack of lubrication (as is commonly the case among postmenopausal women), or who have arterial vascular problems, drugs that facilitate genital blood flow may provide the necessary cure. But most women with sexual problems do not fall into this category. Because, at present, the degree to which genital blood flow plays a role in disorders of drive or orgasm is unknown, it is impossible to predict the impact that vasodilators might have on these more commonly diagnosed sexual problems.

The pharmaceutical industry has provided a welcome impetus for further study into the sexuality of women. It has brought a marked awareness to the fact that we do not know very much about female sexual responding. It is now up to individual researchers to develop standardized criteria and procedures for evaluating female sexual function and dysfunction, and for better understanding the myriad key factors that contribute to sexual well-being among women.

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