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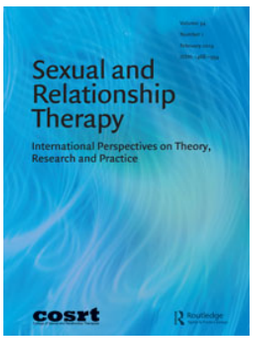

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Female genito-pelvic reflexes: an overview

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ABSTRACT

The female reproductive system includes an active and responsive genital tract that shows involuntary activity triggered by sexual arousal, genital stimulation and/or orgasm. This pelvic and perineal somatic and autonomic reflex muscle activity ("genito-pelvic reflexes") may be an important constituent of the female sexual response. The aim of this study was to review the literature critically on female genito-pelvic reflexes. Only a small number of studies (15) have been published on this issue. More neurophysiological research is needed to search for the implications of these genito-pelvic reflexes for female sexual (dys)function.

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Introduction

Female genital responses rely on an active and responsive genital tract that shows involuntary activity triggered by – or associated with – sexual arousal, genital stimulation and/or orgasm (Levin, 2003; Ringrose, 1966). This pelvic and perineal reflexive muscle activity ("genito-pelvic reflexes") may be an important constituent of female sexual (dys)functioning. A reflex is defined as an automatic stereotyped response to a specific stimulus, mediated by the central nervous system. It requires an intact reflex arc, i.e. a receptor, an afferent and efferent limb, an integrative centre and an effector (Guyton & Hall, 2011). However, this definition neither restricts reflexes to the spinal cord nor to skeletal (striated) muscles, which is highly relevant for sexual reflexes. In mammals other than humans, sexual genital responsiveness is under heavy brainstem and diencephalic control (Pfaus, 2009; Veening, Coolen, & Gerrits, 2014). In humans it is likely that, even when more expanded cortical and voluntary control is present (Beauregard, Levesque, & Bourgouin, 2001; Georgiadis & Kringelbach, 2012), automated or primordial neural control systems give rise to reflexive-like pelvic muscle activity (Huynh, Willemsen, Lovick, & Holstege, 2013).

In line with their embryonic origin, the perineum and pelvic floor are innervated by somatic nerves originating in the sacral spinal cord. This includes all the striated pelvic

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floor muscles, the genital skin, the anal canal, and the vulva including clitoris, labia and vaginal introitus.

The main somatic nerve of the perineum is the pudendal nerve, which has somatosensory and somatomotor tributaries, and which divides into three main branches (inferior rectal, perineal, dorsal penile/clitoral) at the level of the levator ani muscle. The muscles that embryonically derive from the cloacal sphincter (external anal and urethral sphincter, superficial transverse perineal muscle, bulbocavernosus muscle and ischiocavernosus muscle) are all innervated by pudendal nerve fibres originating in a specialized sacral motor neuronal pool called Onuf's nucleus (Iwata, Inoue, & Mannen, 1993; Onuf, 1899). As Onuf motoneurons innervate striated muscles but also are known to be relatively unaffected by somatic motoneuron diseases like amyotrophic lateral sclerosis (Mannen, Iwata, Toyokura, & Nagashima, 1977), they have been proposed to be of a mixed somatic/autonomic type (Kihira, Yoshida, Yoshimasu, Wakayama, & Yase, 1997). Interestingly, the pudendal nerve seems less involved in the innervation of the levator ani muscle. A separate nerve, the "levator ani nerve" (Wallner, Maas, Dabhoiwala, Lamers, & De Ruiter, 2010), arising from the ventral ramus of the third and fourth sacral nerves, is held to innervate the pelvic diaphragm. In at least 50% of cadavers studied, the pudendal nerve also contributed to innervation of the levator ani muscle, especially in regards to the medial portions (puborectal and pubococcygeal muscles) (Rock JA, 2003).

Pelvic viscera, including cavernous tissues, contain smooth muscle that is innervated by the autonomic nervous system. Sympathetic innervation derives from pregang.lionic motoneurons in the last three thoracic and the first two lumbar spinal cord segments. Post-ganglionic sympathetic fibres may reach the pelvic viscera either via the paired hypogastric nerve which originates from pre-aortic sympathetic ganglia or via branches originating from the sacral continuation of the sympathetic chain ganglia (Everaert et al., 2010). Thus, the former nerves descend into the pelvis while the latter reach the pelvis viscera from posteriorly. The parasympathetic pelvic splanchnic nerves arise from preganglionic motoneurons in the sacral segments to reach the pararectal pelvic parasympathetic ganglia (Everaert et al., 2010). The role of the parasympathetic vagal nerve in pelvic innervation is controversial. At the level of the pararectal parasympathetic ganglia, the sympathetic and parasympathetic nerve systems become entangled – and probably also interact – to form an inferior hypogastric plexus on both sides of the rectum. Visceral sensory information uses the neuroarchitecture laid out by the autonomic nerves to enter the spinal cord at corresponding levels. Most of vaginal sensory fibres travel in the parasympathetic pelvic splanchnic nerve (Everaert et al., 2010) or along with the sympathetic fibres arising from sacral sympathetic ganglia. However, the fact that paraplegic women may still perceive deep vaginocervical stimulation and may reach orgasm by virtue of this stimulation strongly suggests that a part of deep vaginal and cervical sensory information travels with the sympathetic hypogastric nerve (Sipski, Alexander, Gomez-Marin, Grossbard, & Rosen, 1996) or possibly even the parasympathetic vagal nerve (Komisaruk et al., 2004).

About a decade ago, Levin reviewed six genital reflexes and described their sexual functionality (Levin, 2003, 2007). However, until now, the literature on the subject of genitopelvic reflexes and their sexual implications is very scarce. One of the reasons for this is that measuring reflexes in the human pelvic region is very complicated. In general, electromyography and pressure measurements are used to obtain partly indirect information

about genito-pelvic reflexes. Pelvic- and perineal muscles provide poor access for techniques such as surface (non-selective) or intramuscular needle electromyography (selective), techniques that are known to measure reliable estimates of skeletal muscle force (Woods & Bigland-Ritchie, 1983). In the case of autonomic reflexes that involve visceral smooth muscles the situation is even more complex, because the physiological properties of smooth muscle do not allow reliable inference of muscle force or activity (Kuriyama, Kitamura, Itoh, & Inoue, 1998). Therefore, indirect measures (e.g. measuring intravaginal pressure with a solid-state pressure transducer in combination with a balloon-like device) in this research field are used. The aim of the present study is to give an overview of all available studies on female genito-pelvic reflexes and their proposed sexual implications.

Methods

PubMED was used to identify relevant genito-pelvic reflex studies published between January 1979 and May 2013. Search terms were: female genito-pelvic reflexes, vaginal reflexes, female sexual reflexes and female pelvic floor reflexes. All the studies published in English that dealt specifically with genito-pelvic reflexes and their sexual implications were included, regardless of their methodological quality. In addition, reference lists of identified studies were searched.

Results

Table 1 lists the result of the literature review. Fifteen studies were found, which described 15 reflexes: cervix-bulbocavernosus reflex (Ringrose, 1966), vagino-bulbocavernosus reflex (Ringrose, 1966), cervix-adductor muscle reflex (Ringrose, 1966), vagino-adductor muscle reflex (Ringrose, 1966), clitoro-pelvic reflex (Gillan & Brindley, 1979), vagino-cavernosus reflex (Shafik, 1993), vagino-levator reflex (Shafik, 1995b), vagino-puborectalis reflex (Shafik, 1995a), vagino-clitoral reflex (Lavoisier, Aloui, Schmidt, & Watrelot, 1995), vagino-vesicourethral reflex (Shafik & El-Sibai, 2001), vagino-anorectal reflex (Shafik, El-Sibai, & Ayyad, 2001; Shafik, Shafik, & El-Sibai, 2005), clitoro-uterine reflex (Shafik, El-Sibai, Mostafa, Shafik, & Ahmed, 2005), vagino-tubal reflex (Shafik, El Sebai, Shafik, & Shafik, 2005), cavernoso-anal reflex (Shafik, Shafik, Shafik, & El Sibai, 2006), the ano-cavernosal excitatory reflex (Shafik, Shafik, El-Sibai, & Shafik, 2006), and deep and superficial voluntary and reflexive contractions (Broens, Spoelstra, & Weijmar Schultz, 2014). Per study, the number of subjects and the mean age of the cohort, the afferent and efferent arms of the reflex, the mode of stimulation to elicit the reflex and the measurement techniques are detailed, together with the sexual function as proposed in the study.

Discussion

The aim of the present study was to review research into human female genito-pelvic reflexes, as a way to draw attention to this potentially important physiological phenomenon that has been largely ignored in the literature.

In the male neurobiological (animal) literature it is well established that genital function (e.g. erection, ejaculation) is organized at the spinal cord level in the form of spinal reflexes or pattern generators, which, in turn, stand under inhibitory control by brainstem

Table 1. Studies on genito-pelvic reflexes and their proposed sexual function.

Author (year)	Reflex	Subjects (N)	Mean age (years)	Afferent	Efferent	Stimulation	Measurement	Proposed sexual function
Ringrose (1966)	Cervix-BCM reflex	137	NR	Cervix	BCM	Mechanical (moving touch)	Visual observation	NR
Ringrose (1966)	Vagino-BCM reflex	137	NR	Vagina	BCM	Mechanical (moving touch)	Visual observation	NR
Ringrose (1966)	Cervix-adductor reflex	137	NR	Cervix	Medial thigh muscles (adductor group)	Mechanical (moving touch)	Visual observation	NR
Ringrose (1966)	Vagino-adductor reflex	137	NR	Vagina	Medial thigh muscles (adductor group)	Mechanical (moving touch)	Visual observation	NR
Gillan and Brindley (1979)	Clitoro-pelvic reflex	NR	NR	Clitoris	Pelvic floor	Mechanical (vibratory)	EMG	NR
Shafik (1993)	Vagino-cavernosus reflex	17	36.6	Vagina	BCM en ICM	Mechanical (pressure)	EMG	Enhance clitoral erection; enhance penile erection; milk semen
Shafik (1995b)	Vagino-levator reflex	17	36.6	Vagina	Levator ani muscle	Mechanical (pressure)	EMG	Vaginal widening; vaginal elongation (ballooning); uterus elevation (tenting)
Shafik (1995a)	Vagino-puborectalis reflex	14	34.8	Vagina	Puborectalis muscle	Mechanical (pressure)	EMG	Enhance penile erection; enhance male sexual pleasure
Lavoisier et al. (1995)	Vagino-clitoral reflex	10	Range 20–28 years	Vagina	clitoris	Mechanical (stationary and dynamic pressure)	Doppler (blood flow)	NR
Shafik and El-Sibai (2001)	Vagino-vesicourethral reflex	26	36.7	Vagina	Bladder and urethra	Mechanical (pressure)	Interaurethral and intravesical pressure	Prevent urinary leakage during sexual intercourse
Shafik et al. (2001)	Vagino-anorectal reflex	24	39.2	Vagina	anorectum	Mechanical (pressure)	Anal en rectal pressure	Prevent leakage of faeces and flatus during sexual intercourse
Shafik et al. (2005)	Vagino-anorectal reflex	23	33.7	Vagina	EAS, IAS, rectal muscles	Mechanical (pressure)	EMG and pressure (anal canal and rectum)	Prevent leakage of faeces and flatus during sexual intercourse
Shafik et al. (2005)	Clitoro-uterine reflex	23	36.7	Clitoris	Uterus	Electrical Mechanical	Electrical recordings EMG	NR
Shafik et al. (2005)	Vagino-tubal reflex	16	32.2	Vagina	Tuba uterina	Mechnical (pressure)	Tubal pressure	Assists sperm transportation

(*continued*)

Table 1. (*Continued*)

Author (year)	Reflex	Subjects (N)	Mean age (years)	Afferent	Efferent	Stimulation	Measurement	Proposed sexual function
Shafik et al. (2006)	Cavernosa-anal reflex	7	38,3	BCM and ICM	EAS and IAS	Electrical	EMG	Prevent leakage of faeces and flatus during sexual intercourse
Shafik et al. (2006)	Ano-cavernosal excitatory reflex	8	36.8	EAS	ICM	Electrical	EMG	Prevent leakage of faeces and flatus during sexual intercourse
Broens et al. (2014)*	Deep and superficial voluntary and reflexive contractions	16	23.0	Vagina	BCM PRM	Mechanical (pressure)	High resolution solid state circumferential catheters	Possibly involved in the sexual response and genito-pelvic pain/penetration disorder

Note: BCM = bulbo-cavernosus muscle, ICM = ischo-cavernosus muscle, PRM = puborectalis muscle, EAS = external anal sphincter, IAS = internal anal sphincter, NR = not reported.
*Study defined no new reflexes, but implies sexual functionality

centres which are themselves controlled by supraspinal centres (most notably the hypothalamus, but also cortical regions) (Georgiadis & Kringelbach, 2012; Pfaus, 2009). In analogy to men, some of the genito-pelvic responses found in women could rely upon spinal circuits for genital reflexes. For instance, the male pelvic floor, especially the muscles acting on the urethra, shows rhythmic activity during ejaculation. In a similar vein, high frequency fluctuations in rectal pressure indicative of fast pelvic floor contractions have been found during orgasm in women. The characteristics of these contractions are strongly suggestive of subcortical control of pelvic motoneurons (Georgiadis et al., 2006; Van Netten, Georgiadis, Nieuwenburg, & Kortekaas, 2008). Possibly, female pelvic muscle contractions during climax rely on similar spinal control systems as those known to exist in men (Veening et al., 2014). Genital responses that occur in spinal cord injured (SCI) women are suggestive that at least some of these reflexes are organized as spinal cord reflexes. SCI women are known to have lubrication and clitoral engorgement upon vulvar touch, while pelvic rhythmic contractions may be intact as well (Lombardi, Del Popolo, Macchiarella, Mencarini, & Celso, 2010). However, as indicated earlier, the reflexes discussed in this review may be applicable to multiple levels of the central nervous system, and not only the spinal cord. Moreover, instead of working hierarchically on reflex centres, the spinally intact supraspinal areas may also exert more or less direct control over somatic and autonomic motoneurons important for genital function. Therefore, it is unknown what exactly is the contribution of female genito-pelvic reflexes to sexual function, or how these reflexes would contribute to sexual dysfunction. Nevertheless, it has been speculated that exaggerated reflex activity in the pelvic area contributes to (the maintenance and worsening of) pelvic pain conditions like anal fissures (Meegdenburg, Trzpis, Heineman, & Broens, 2016). Thus, more knowledge about female genito-pelvic reflexes seems warranted.

The research methods used in most of the studies that we reviewed (peripheral stimulation and measurement) are insufficient to reveal the neurophysiological characteristics of a given reflex-like response. That is, it does not reveal the integral parts of a reflex, namely the receptors, afferent and efferent nerves and synapse centre. One can of course derive that mechanical stimulation (e.g. pressure or moving touch) excites mechanoreceptors, but apart perhaps from the clitoris (Shih, Cold, & Yang, 2013), the receptor constellation in the human vaginal tract is largely unknown. In a similar vein, vaginal afferent information may be conveyed by sacral parasympathetic nerves, by thoracolumbar sympathetic nerves, by sacral sympathetic nerves and may be even by the vagal nerve (Everaert et al., 2010). In addition, it is unclear whether different pathways would affect muscular responses via the same reflex centre.

Another limitation relates to the responses, which are measured from striated or smooth muscle. Striated muscle measurements clearly dominate in the studies reviewed, which makes sense given the much more difficult accessibility of smooth muscle to EMG, leaving only the possibility for indirect measurement. As indicated earlier, muscles that derive from the embryonic cloaca (BCM, ICM, anal and urethral sphincters and possibly also the puborectalis) are controlled by motoneurons in a special sacral nucleus termed Onuf's nucleus (Iwata et al., 1993; Onuf, 1899). Onuf motoneurons can be considered as an intermediate type between somatic and autonomic (Kihira et al., 1997). Thus, whether responses of striated cloacal muscles must be considered autonomic or somatic is not entirely clear, while it leaves open the possibility that reflex responses of these muscles are

controlled by a reflex centre distinct from responses of other striated pelvic muscles. Besides striated muscle activity, smooth muscle activity is important for sexual functioning such as clitoral and vaginal vasocongestion, vulvar and vaginal lubrication, and uterine motility (Levin, 1980). Vaginal smooth muscles show continuous electrical activity, with spontaneous vaginal motility (Gillan & Brindley, 1979). This activity, controlled by the autonomic nervous system, is increased at clitoral vibration and during menstruation (Meegdenburg et al., 2016). Assumed functions of these contractions are clearing the vagina from ex-and secretion products, and possibly activating vaginal blood supply at sexual quiescence (Salonia et al., 2010).

It is striking that most of the studies that were identified have been produced by the same research group. These studies have a uniform approach; electrical or pressure recording of muscular activity, induced by pressure (inflated balloon) or electrical stimulation. After, anaesthetisation tests were repeated. In their studies, Shafik's group consistently evaluated response reproducibility, the absence of responses during anaesthetization and the response latency. However, based on the demographics of the subjects in his studies, some of the studies seem to reflect the same subject cohort. The impression arises that different responses published in different papers (for example, the vagino-cavernosus and vagino-levator reflexes) were actually part of the same experiment. It would be important to know whether multiple reflexes were studied in the same subjects, or whether multiple reflexes were tested in different subjects. Until now, unfortunately, these studies have not been replicated by other research groups.

Levin pointed out that a short duration of the reflexes (seconds) could severely limit their functionality during coitus unless they were activated repeatedly (Levin, 2003, 2015). The duration of the reflexes in the studies of Shafik ranged from 2 to 8 seconds. Gillan and Brindley stated that in contrast with the phasic vagino-BCM reflex, the clitoro-pelvic reflex was a well-sustained tonic contraction (ranging from 2.0 to 3.5 minutes) (Gillan & Brindley, 1979). The latest is in line with a study of Broens et al. in which high resolution solid-state circumferential catheters were used to measure intravaginal pressures during voluntary contractions and provoked reflexive contractions in women without a sexual dysfunction. In their study, voluntary contractions were characterized by low (decreasing) and fluctuating pressures of short duration (less than 1.5 minutes). In contrast, reflexive contractions were characterized by much higher (increasing) pressures of a relatively much longer duration (even longer than 6 minutes) (Broens et al., 2014).

At present, the literature on genito-pelvic reflexes is very limited. The majority of studies on genito-pelvic reflexes have methodological shortcomings. These shortcomings could relate to; not reporting the reproducibility of the reflex, not performing anaesthetization to check the reflex in the absence of an afferent arm, not performing manual examination of pelvic floor muscle strength and tone in order to confirm the absence of pelvic floor hypo- or hyperactivity and not reporting the duration of the reflexive contractions. With the exception of the study of Ringrose (N = 137), subject cohorts were relatively small, while almost all the studies described in this overview were performed in sexually functioning women without sexual complaints. And in most studies it is not reported whether participants were sexually aroused during the measurements.

Genital pelvic reflexes are suggested to be involved in clitoral and penile erection, milking semen from the male urethra during sexual intercourse, the tenting effect and sperm–ovum transport. In several studies, it is suggested that female genito-pelvic reflexes might

play a role in preventing the leakage of faeces, flatus and urine during sexual intercourse**.** It is our opinion that the distinct impact of reflexive pelvic floor muscle contractions on the onset of female sexual dysfunctions may be underestimated. Research into the role of these reflexes for female sexual function is obvious but still in its infancy. Further investigation of reflexive pelvic floor muscles is required to identify its role in female sexual function. To realize this an open and positive social climate regarding sexuality and social recognition of sex research constitutes a prerequisite and undoubtedly the biggest challenge.

Conclusions

The number of studies on female genito-pelvic reflexes is very limited. However, any substantial evidence for these sexual implications is lacking. In the future, more neurophysiological research as well case-control studies are needed to confirm the sexual implications of these genito-pelvic reflexes.

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