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The response of the corporal tissue and cavernosus muscles to urethral stimulation: an effect of penile buffeting of the vaginal introitus

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Running head: corporal tissue and cavernosus muscles' response to urethral stimulation.

Abbreviations list:

The electromyographic = (EMG)
corpora cavernosa = (CCs)
corpus spongiosum = (CS)
corpus spongiosum, bulbocavernosus = (BCM)
ischiocavernosus = (ICM

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ABSTRACT

Aims/Objectives. We investigated the hypothesis that urethral stimulation in humans induces sexual response in the form of activation of the corporal tissue and cavernosus muscles through a reflex mechanism.

Methods. Electromyographic activity of corpora cavernosa (CC), corpus spongiosum (CS), bulbocavernosus (BCM) and ischiocavernosus (ICM) muscles was recorded in 43 healthy volunteers (24 men, 19 women, age 37.7±8.2 years) during urethral stimulation. The tests were repeated after individual anesthetization of urethra, CC, CS, BCM, and ICM.

Results. During stimulation of the distal urethra, slow wave variables of CC and CS decreased while motor unit action potentials of BCM and ICM increased. Urethral stimulation after individual anesthetization of urethra, CC, CS, BCM, and ICM did not effect significant changes in these structures, but saline administration did.

Conclusion. Diminished electromyographic activity of CC and CS with increased activity of BCM and ICM during distal urethral stimulation presumably denote sinusoidal muscle relaxation of CC and CS and cavernosus muscles' contraction. Sinusoidal muscle relaxation and contraction of cavernosus muscles upon distal urethral stimulation are suggested to be mediated through a reflex which we call 'urethro-corporocavernosal reflex'. Sinusoidal and cavernosus muscles' response during coitus appears to effect degree of tumescence for both male and female partners.

Key words: corpora cavernosa**,** corpus spongiosum**,** ischiocavernosus/bulbocavernosus muscles, slow waves, electromyography.

INTRODUCTION

During sexual stimulation, genital organs are subjected to several changes which are comprised of gross physioanatomical changes such as the increase in length and girth of the penis in the male and the clitoris in the female. These changes were associated with penile and clitoral vasocongestion which are controlled by facilitatory parasympathetic and inhibitory sympathetic inputs (Giuliano et al, 2002). Also, internal anatomical changes occur as a result of cervical buffeting during the sexual act (Schultz et al, 1999; Munarriz et al, 2003; Yucel et al, 2004;; Shafik et al, 2004;2005 a,b). The erectile tissue exists not only in the clitoral or penile body, but also in the periurethral region (Yucel et al, 2004). Other areas of sexual activation include the anterior vaginal wall, Halban's fascia and the G-spot (Grafenberg, 1950; Ferguson, 1999).

It has been reported that urethral stimulation effect sexual activation in male and female rats (Gerstenberg et al, 1990); however neither the effect in humans nor the mechanism of action could not be traced in the literature. We hypothesized that urethral stimulation in humans induces sexual response in the form of activation of the corporal tissue [corpora cavernosa (CC) and corpus spongiosum (CS)] and of the cavernosus muscles [bulbo- / ischiocavernosus (BCM, ICM)] and that this occurs through a reflex mechanism. This hypothesis was investigated in the current study.

MATERIAL and METHODS

Subjects. The study was comprised of 43 healthy volunteers (24 men, 19 women, mean age 37.7±8.2 SD years, range 28-44). They had no genitourinary complaint in the past or at the time of enrollment. Eleven of the 19 women were multiparous and 8 nulliparous. They had normal menses and sexual life.

Physical examination, including neurologic and gynecologic assessment, was normal. An informed consent was given by the subjects after having been informed about the nature of the study and their role in it. The study was approved by the Cairo University Faculty of Medicine Review Board and Ethics Committee.

Methods. The bladder was emptied by micturition prior to performing the tests. Urethral stimulation was induced by an intraurethral surface electrode while the EMG activity of the

CC, CS as well as of the BCM and ICM were recorded by an electromyographic needle electrode.

The surface electrode was mounted on an indwelling graded urethral catheter (Hald & Bradley, 1982). The catheter was introduced into the urinary bladder (UB) per urethram and then pulled back gradually to lie in the urethra.

The EMG activity of the CC and CS was recorded by means of a concentric EMG needle electrode measuring 40 mm in length and 0.65 mm in diameter. Two needle electrodes were introduced into each of the corpus cavernosus (CC) and corpus spongiosum (CS): one in the upper and one in the lower third. In the female, two concentric needle electrodes were introduced into the vestibular bulb: one in the upper and one in the lower 1/3. Another 2 electrodes were inserted into the crus clitoris: one in the upper and one in the lower 1/3. A ground electrode was applied to the thigh and a strain-gauge respiratory transducer to the thoracic wall. After recording the electric activity, the upper electrode was transferred to the mid third of the CC and the recordings were repeated. The needle electrodes were then transferred to the contralateral CC and the electric activity was recorded.

The EMG activity of the ICM and BCM was recorded by means of a concentric EMG needle electrode measuring 40 mm in length and 0.65 mm in diameter. The ischiopublic ramus of the ICM with the overlying crus penis or clitoridis was palpated and the needle inserted into the ICM lying on its medial aspect. A second identical needle was placed in the BCM; the penile bulb in the male and the vestibular bulb in the female were palpated and the needle electrode introduced into the muscle overlying it.

A standard EMG apparatus (Type MES, Medelec, Woking, UK) was used to amplify and display the recorded potentials. Films of these potentials were taken on a light-sensitive paper (Linagraph type 1895, Kodak, London, UK) from which measurements of the duration of the motor unit action potentials were obtained. The EMG signals were in addition stored on an FM tape recorder (type 7758A, Hewlett-Packard, Waltham, MA) for further analysis as required. All filtered signals were collected and recorded using an online computer with a data acquisition and analysis software (Chart V 4.2, AD instruments, Castle Hill, Sydney, Australia). The acquisition rate was 10 Hz, and the EMG normal band width was 0.1 to 5.0 Hz.

Electrical stimulation of the urethra was effected by a train of 5 square wave pulses of 1 ms duration and separated by 1 ms, with a threshold varying from 35 to 74 mA (mean 54.6±10.4).

Full erection was induced by ingestion of 50 mg of sildenafil citrate, assisted by viewing of sexually stimulating video films, and the EMG activity of the cavernosus muscles and the corporal tissue was recorded.

Urethral, CC, CS, BCM, and ICM anesthetization. To examine whether the effect of urethral stimulation on the CC, CS, BCM, and ICM was a direct or reflex effect, the urethra was anesthetized by the administration of 5% lidocaine gel. The gel was introduced into the urethra through the gel container after the urethral orifice had been sterilized by alcohol. Twenty minutes after urethral anesthetization, the urethra was stimulated as aforementioned and the response of the CC, CS, BCM, and ICM was recorded. The test was repeated three hours later when the anesthetic effect had waned. After one day, the test was performed again using bland gel instead of lidocaine.

On separate days, each of the CC, CS, BCM, and ICM was individually anesthetized and the effect of urethral stimulation on these structures was registered. Two ml of 2% lidocaine were injected into each of the CC, CS, BCM, and ICM around the inserted needle electrode; the response of these structures to urethral stimulation was then recorded after 20 minutes and after 3 hours. This test was repeated using normal saline instead of lidocaine.

To ensure reproducibility of the results, the recordings were repeated at least twice in the individual subject and the mean value was calculated. The results were analyzed statistically using the Student's t test, and values were given as the mean ± SD. Differences assumed significance at $p<0.05$.

RESULTS

No adverse side effects were encountered during or after performing the tests and all the tests were completed and subjects evaluated.

Electromyography of the BCM, ICM, CC, and CS. The BCM and ICM did not exhibit basal EMG activity (fig. 1). Meanwhile, basal slow waves (SWs) were registered from the electrodes applied to the CC and CS (fig. 2). The waves were negatively deflected and had an invariable shape in all the recordings from the same site. They exhibited in each individual the same frequency, amplitude, and conduction velocity by the 2 electrodes;

these wave variables were constant in each subject. The SW variables showed significantly lower values for the CS if compared to those of the CC (fig. 2; table 1).

Bursts of fast activity spikes or action potentials (APs) superimposed or followed the SWs. They presented as negative deflections and their frequency was inconsistent in each subject (fig. 2).

Stimulation of the prostatic, membraneous and the proximal ¾ of the penile urethra in the males as well as the proximal ¾ of the female urethra effected no CC, CS, BCM, or ICM response. Upon stimulation of the distal ¼ of the entire urethra using the aforementioned parameters, the SW frequency, amplitude, and conduction velocity of the CC and CS decreased ($p<0.05$) (fig.3) and the motor unit action potentials (MUAPs) of the BCM and ICM increased ($p<0.05$, figs. 1). The wave response did not show significant change ($p>0.05$) upon increase of urethral stimulation intensity and was constant during the stimulation period. Upon stimulation cessation, the response of the corporal tissue and cavernosus muscles was sustained for 2-5 sec (mean 3.2±1.1) before returning to the pre-stimulation status. Upon urethral re-stimulation immediately after the response had returned to the basal value, the CC, CS, BCM, and ICM did not show a change from the basal activity; a response was achieved 3-6 minutes (mean 4.3±1.2) after the return of the EMG activity to the basal value. This refractory (responseless) period showed progressive increase with further increase in the number of re-stimulations, until after 5-7 periods of re-stimulation the response of the corporal tissue or cavernosus muscles ceased. The refractory period continued for 75-110 minutes (mean 91.7±13.4) before the response of the corporal tissue and cavernosus muscles to urethral stimulation occurred; the wave variables (frequency, amplitude, conduction velocity) of the response were similar to those of the original response.

When rigid penile erection was induced, the EMG of the CC and CS showed a significant reduction ($p<0.01$) which was significantly greater ($p<0.01$) than that induced by urethral stimulation. Meanwhile, cavernosal muscles' EMG exhibited a significant increase.

Effect of anesthetization of urethra, corporal tissue and cavernosus muscles. Urethral stimulation 20 minutes after urethral anesthetization did not produce significant changes ($p>0.05$) in the EMG of the CC, CS, BCM, and ICM. Repetition of the test 3 hours from anesthetization, when the anesthetic effect had waned, effected an EMG response similar to that before anesthetization ($p>0.05$). Urethral stimulation 20 minutes after individual anesthetization of the CC, CS, BCM, and ICM did not effect a significant EMG response in these structures. When, after 3 hours of anesthetization, the anesthetic effect had worn off, the EMG response of the CC, CS, BCM, and ICM was similar to that before anesthetization. When bland gel was administered into the urethra, and normal saline injected into the CC, CS, BCM, and ICM instead of lidocaine, and the test was repeated, the results were similar to those before gel or saline administration.

The aforementioned results were reproducible with no significant difference when the tests were repeated in the individual subject.

DISCUSSION

Tactile stimulation of the genital organs produces changes in the genital structures and leads to sexual arousal. These changes take the form of increased length and diameter in the male penis and the female clitoris. Other tissues respond to sexual arousal and these include the male and female urethra as well as the female vestibular bulbs of the clitoral crura and the anterior vaginal wall (Schultz et al, 1999; Munarriz et al, 2003; Yucel et al, 2004).

Although the urethra is an extragenital organ, it is considered as one of the sites of sexual arousal (Erlandson, 1977). The potential arousal properties of the urethra raise questions about the origin of these properties. Do they arise from urethral neural connections or are they characteristics of the urethral epithelium? The current study has demonstrated that urethral stimulation in the distal 1/4 of the urethra effected decreased EMG activity of the corporal tissue and increased cavernosus muscles' EMG. These findings presumably denote a decrease of the corporal tissue tone with a resulting penile or clitoral tumescence due to the filling of the cavernosus sinusoids with blood. Meanwhile, the increased BCM and ICM EMG activity seems to indicate an increase of their contractile activity. Both the corporal tissue relaxation and the cavernosus muscles' contraction would apparently induce penile or clitoral tumescence. Cavernosus muscles' contraction produces tumescence by constricting the cavernous tissue at the site of their insertion in the penis or clitoris. The stimulating effect was sufficient to induce tumescence but not full erection. It seems that this tumescent effect of urethral stimulation bears on both the male and female during the sexual act. Thus penile buffeting of the vaginal vestibule apparently stimulates not only the glans clitoris and glans penis, but also the urethral orifice of both sexes. It seems that the friction of the male and female urethral orifice during vestibular buffeting stimulates the nerve endings of the distal part of the urethra in either sex with a resulting emission of impulses which seem to be conducted to the spinal cord through the dorsal and the pudendal nerves. Efferent impulses appear to be transmitted from the spinal cord along the pudendal nerve to the corporal tissue and cavernosus muscles of the male and female.

Thus penile buffeting of the female urethral orifice with a resulting corporal tissue relaxation and cavernosus muscles contraction postulates a reflex relationship between the 2 actions: urethal stimulation on the one side and corporal tissue and cavernosus muscles' reaction on the other side. This relationship was reproducible and its reflex nature is evidenced by its disappearance upon individual anesthetization of either of the suggested two arms of the reflex arc, namely the urethra as one arm and the corporal tissue and cavernosus muscles as the other one. We call this reflex relationship: the 'urethro-corporocavernosus reflex'. This reflex appears to be evoked during penile buffeting of the vaginal vestibule leading to stimulation of the corporal tissue and cavernosus muscles of both the man and the woman. Anesthetization of the urethra or corporal tissue and cavernosus muscles seems to block their innervation so that nerve impulses cannot be transmitted from the urethra to the corporal tissue and cavernosus muscles. Lidocaine blocks the sensory fibers (C and A α-fibers) which are responsible for pain and reflex activity (Yokoyami et al, 2000; Silva et al, 2002).

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Table 1. The basal frequency, amplitude, and conduction velocity of the slow waves recorded from the corpus cavernosum and corpus spongiosum[+]

Slow waves						
	Frequency (cycle/min)		Amplitude (mV)		Conduction velocity (cm/s)	
	Mean	Range	Mean	Range	Mean	Range
Corpus cavernosum	4.4±1.2	3.2 – 5.9	0.61±0.07	0.48 – 0.78	5.8±1.1	3.9 – 6.7
Corpus spongiosum	3.1±0.9	2.2 – 4.2	0.48±0.05	0.33 – 0.64	3.3±0.5	2.4 – 4.8

\+ values were given as the mean ± SD

Table 2. The frequency, amplitude, and conduction velocity of the slow waves recorded from the corpus cavernosum and corpus spongiosum during urethral stimulation[+]

Slow waves						
	Frequency (cycle/min)		Amplitude (mV)		Conduction velocity (cm/s)	
	Mean	Range	Mean	Range	Mean	Range
Corpus cavernosum	2.2±0.7	1.4 – 3.2	0.19±0.03	0.14 – 0.28	2.3±0.5	1.2 – 3.4
Corpus spongiosum	1.1±0.4	0.8 – 1.7	0.12±0.02	0.09 – 0.18	1.2±0.2	0.74 – 1.9

\+ values were given as the mean ± SD

Table 3. The motor unit action potentials of the bulbocavernosus (BCM) and ischiocavernosus (ICM) muscles during urethral stimulation

	BCM (μV)		**ICM (μV)**	
	Mean	**Range**	**Mean**	**Range**
Basal	0	0	0	0
Urethral stimulation	118.6±12.6	89 – 138	96.4±9.3	72 – 109

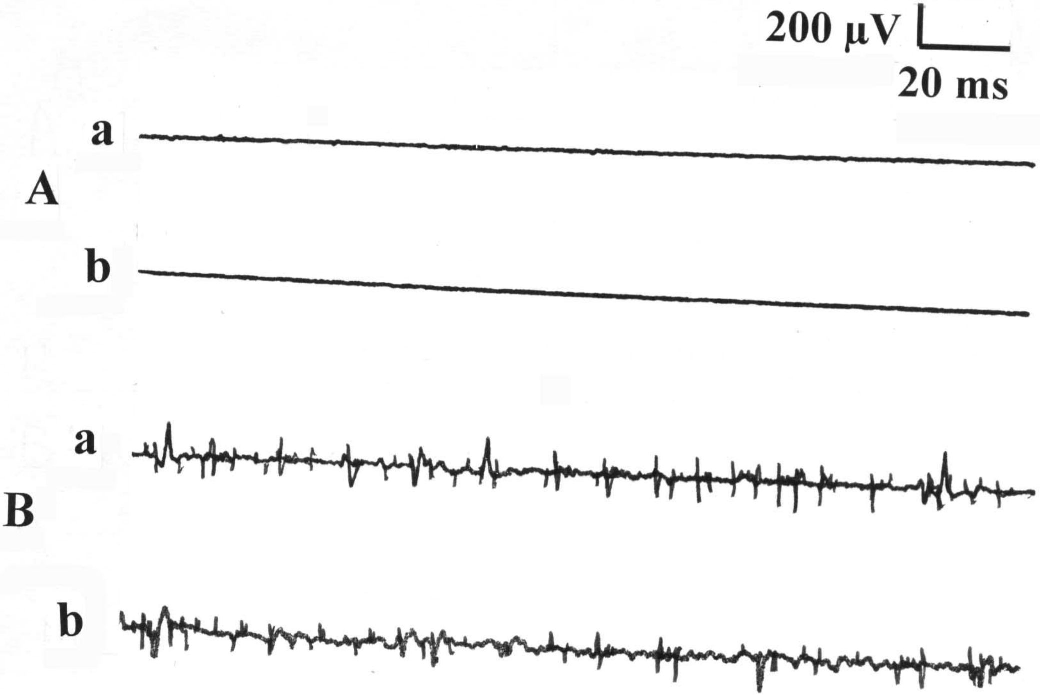
+ values were given as the mean ± SD

ILLUSTRATION

Fig. 1. The EMG activity of a) bulbocavernosus muscle, and b) ischiocavernosus muscle. (A) at rest, and (B) during urethral stimulation.

Fig. 2. The basal slow waves and action potentials recorded from the A) corpora cavernosa and B) corpus spongiosum.

Fig. 3. EMG of A) corpus cavernosum, and B) corpus spongiosum during urethral stimulation.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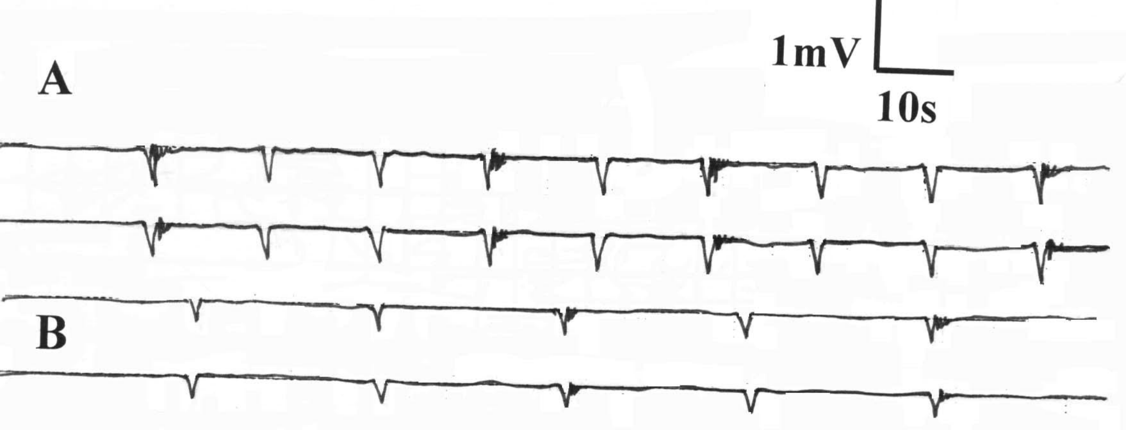
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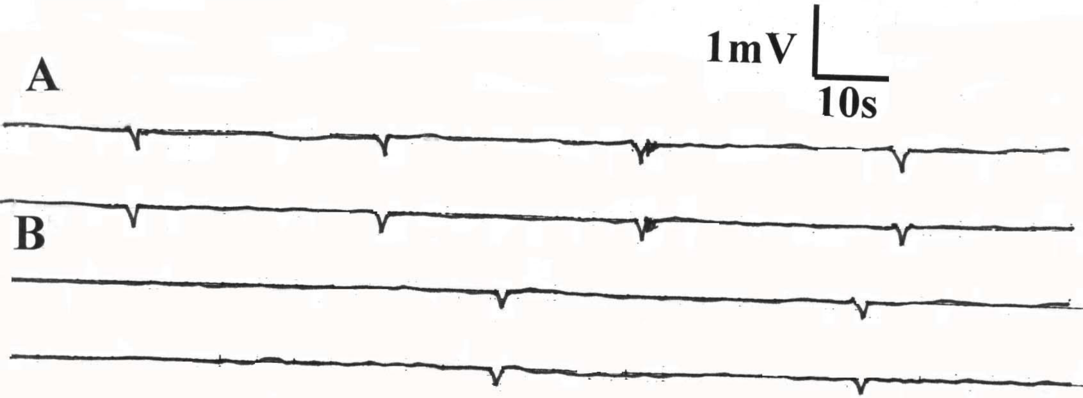
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