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Continent women have better urethral neuromuscular function than those with stress incontinence

Kimberly Kenton, Elizabeth Mueller, and Linda Brubaker

Division of Female Pelvic Medicine & Reconstructive Surgery, Departments of Obstetrics & Gynecology and Urology, Loyola University Stritch School of Medicine, 2160 South First Avenue, Maywood, IL 60153, USA

Kimberly Kenton: kkenton@lumc.edu

Abstract

Introduction and hypothesis—The objective of this study is to describe urethral neuromuscular function using concentric needle electromyography (EMG) in stress incontinent (SUI) and asymptomatic women.

Methods—Following Institutional Review Board approval, we recruited SUI and asymptomatic women without urinary incontinence. Participants underwent quantitative urethral EMG and urodynamic testing.

Results—Sixty-seven women (37 SUI, 30 continent) with mean±SD age of 44±12 years participated. Nearly all EMG parameters showed significant differences between continent and SUI women consistent with better motor unit recruitment in continent women. Continent women had larger-amplitude, longer-duration motor unit action potentials (MUP) with increased turns and better MUP recruitment during bladder filling ($P<.05$). Increasing age was inversely correlated with nearly all MUP parameters ($P<.05$), suggesting MUP to be consistent with neuropathy.

Conclusions—We found significant differences in multiple MUP parameters in urethral sphincter between continent and stress incontinent women, suggesting continent women have better urethral innervation. We also found significant neuropathic MUP changes with advancing age, regardless of continence status.

Keywords

Electromyography; EMG; Stress incontinence; Urethra; Urethral closure pressure

Introduction

Despite the high prevalence of stress urinary incontinence (SUI) in women, clinical algorithms for treatment remain simplistic based on rudimentary concepts of pathophysiology [1]. This lack of mechanistic understanding limits therapeutic options aimed at the underlying pathophysiology for an individual affected patient. Current treatments are primarily aimed at obstructing or repositioning the urethra to compensate for an intrinsic failure in the normal urethral closure mechanism. A recent study comparing continent and stress incontinent women indicated that urethral closure pressure alone successfully predicted nearly 50% of SUI cases [2]. The authors concluded that therapies to

improve urethral function may be beneficial; however, the etiology for urethral failure is still unknown.

Electromyography (EMG) has an important role in differentiating neuromuscular injury from primary muscle pathology, localizes injury, and provides important information about chronicity and prognosis of the injury. Pelvic floor EMG has been used to allocate therapy based on muscle denervation which is physiologically unable to respond to first-line SUI therapies such as pelvic muscle exercises. It is known that the levator muscles of women with SUI commonly exhibit denervation with reinnervation [3–5]. Similarly, electrophysiologic and histologic studies demonstrated that women with SUI have decreased urethral skeletal muscle volume and urethral neuromuscular changes consistent with denervation injury [6–8] and women who undergo successful continence surgery have better urethral motor unit recruitment than those with persistent SUI [9]. There is evidence that urethral neurovascular integrity is also important. Investigators have reported a decrease in urethral pressure after a pudendal nerve block in nulliparous female volunteers [8], while selective blockade of autonomic receptors to the periurethral smooth muscle contributed little to urethral pressure [10]. Yet, few data exist quantifying neuromuscular function in the urethra of women with SUI or comparing them to findings from asymptomatic continent women.

As with most biomedical tests, EMG relies on normative data for its interpretation and furthering our understanding of differences in neuromuscular function of women with SUI when compared to asymptomatic women without urinary incontinence may yield important insights into the pathology and potential sights for regenerative therapies. The aim of this study was to describe urethral neuromuscular function using concentric needle EMG in a wellcharacterized group of women with SUI and compare those measures of urethral function to a cohort of asymptomatic women without urinary tract symptoms.

Materials and methods

Following Institutional Review Board approval, we recruited two groups of women between 2006 and 2009. Stress incontinence patients seeking care at Loyola University's Urogynecology Center were recruited if they had at least one answer of "sometimes" or "always" on first six items on the Medical, Epidemiologic, and Social Aspects of Aging urinary incontinence questionnaire [11]. In addition, asymptomatic control women without urinary incontinence were recruited from the community using flyers and webbased advertisements and have been previously described [12]. We excluded women with a history of neuromuscular disease, prior continence surgery, or coagulaopathy; who had stage III or IV pelvic organ prolapse; who were less than 6 months from their most recent vaginal delivery; who were taking an anticoagulant medication; and who had an elevated post-void residual urine volume or urine dipstick positive for nitrites or leukocytes.

Consented research participants completed demographic information and the short form of the Pelvic Floor Distress Inventory (PFDI-20), a validated condition-specific bother questionnaire for pelvic floor disorders with three subscales: urinary, prolapse, and colorectal [13]. Participants also underwent standardized physical examination, including pelvic organ prolapse quantification [14]. After voiding, participants underwent catheterized post-void residual urine volume assessment and urine dipstick analysis.

All eligible participants underwent standardized quantitative EMG during filling cystometry using a Laborie Dorado urodynamic equipment and microtip catheters (Millar Instruments, Houston, TX).

Concentric needle EMG

We performed three methods of concentric needle EMG of the urethral sphincter on all participants. Anesthetic cream containing 2.5% lidocaine and 2.5% prilocaine (EMLA cream, Astra, Westborough, MA) was applied to the external urethral meatus 20 min prior to the study to optimize participant comfort. We used a Medtronic Keypoint.NET electromyography instrument (Medtronic Corporation, Minneapolis, MN) equipped with automated software to perform multiple motor unit action potential analysis (Multi-MUP) and interference pattern (IP) analysis at baseline, and a Nicolet Viking IVp electromyography instrument (Nicolet Instrument Corporation, Madison, Wisconsin) was used to process EMG signals during filling cystometry. We used standard filter settings (10 Hz to 10 kHz) and an amplifier gain of 50 μ V per division. A disposable 30-gauge, 1-inch concentric needle electrode was inserted into the striated urethral sphincter muscle using three different insertion sites: 12 o'clock (5 mm above the external urethral meatus), 3 o'clock, and 9 o'clock. Needle electrode was positioned at each insertion site using auditory and oscilloscope guidance.

Multi-MUP analysis

At baseline with the bladder empty, the Multi-MUP software on the Medtronic Keypoint.NET electrodiagnostic instrument automatically obtained amplitude (measure from positive to negative peak), duration (measure of MUP length from initial spike to terminal portion), phases (number of times MUP crosses baseline plus 1), turns (change in direction of MUP where amplitude changes by 100 μ V), and percent polyphasia (percentage of all MUP that are polyphasic) from three different insertion sites. Any MUPs with an unstable baseline were discarded as previous investigators demonstrated that unstable baseline precludes accurate analysis [15].

Interference pattern analysis

With an empty bladder, we instructed participants to gradually "squeeze as if they were trying to hold in urine" to recruit more MUP and create an IP. The IP analysis was done at each insertion point during resting muscle activity and as the participant increased urethral sphincter muscle activity with a voluntary squeeze. At each site, a 500-ms epoch of EMG activity was automatically obtained and analyzed. The following EMG parameters were obtained: turns (change in direction of MUP where amplitude changes by 100 μ V), amplitude, turn/amplitude ratio (measure of the number of MUP activated during muscle contraction), number of short segments (portion of EMG signal with sharp activity characterized by short rise times), percent activity (percent of time during an epoch that sharp activity occurs), and envelope (peak to trough amplitude exceeded by only 1% of the amplitudes during the epoch).

Quantitative MUP analysis

The needle electrode was re-positioned at the 9 o'clock position using auditory and oscilloscope guidance for the Multi-MUP and IP analyses. Maximum voluntary activity software on the Nicolet Viking IVp electromyography instrument (Nicolet Instrument Corporation, Madison, Wisconsin) was used to analyze the activity of the striated urethral sphincter during bladder filling. This automated motor unit analysis software program quantifies several EMG parameters using IP analysis. Maximum voluntary activity software measures the mean rectified voltage (MRV) or the mean amplitude calculated over the entire tracing after the waveform is rectified. A recording of MUP activation was made with subject at rest with an empty bladder and during filling cystometry to 300 ml bladder volume.

Data analysis

Data were maintained in a Health Insurance Portability and Accountability Act compliant database. SPSS Version 16 (Chicago, IL) was used for data management and analysis. Histograms were created to determine if MUP from Multi-MUP and IP analyses were normally distributed. Urethral EMG parameter data from the subjects were pooled to calculate mean, standard deviations (SD), and 95% confidence intervals for each parameter. We used independent Student's *t* test to compare means of independent groups and Chi-square test of association to compare nominal data. Pearson's correlations were used to assess the relationship between MUP parameter and age. We used a significance level of 0.05, and all tests were two-sided.

Results

Sixty-seven women (37 stress incontinent and 30 continent) with a mean $\pm$ SD age of 44 $\pm$ 12 years participated in the study. Table 1 displays demographic characteristics and pelvic floor symptoms of the groups. Continent women were on average a decade younger, more likely to be vaginally parous, and more likely to be African American than stress incontinent women.

Multi-MUP parameters

Thirty-seven percent of MUP analyzed in continent women were polyphasic, in contrast to only 27% in stress incontinent women ($P=.03$). All MUP parameters differed significantly between continent and stress incontinent women. Continent women had larger-amplitude, longer-duration MUPs with increased turns (Table 2).

Interference pattern parameters

Several MUP parameters showed significant differences between continent and SUI women consistent with better MUP recruitment in continent women. MUP in continent women had more turns, larger turns/amplitude ratio, increased activity, and increased number of short segments. Stress incontinent women had lower levels of MUP recruitment as measured by decreasing number of turns per second, lower turns/amplitude ratio, decreasing percent activity, and decreased number of short segments during the IP analysis. Similarly, continent women had a larger change in MUP MRV during bladder filling than SUI women.

Demographic characteristics that differed between groups (age, race, continence status, vaginal parity) were placed in multivariate linear regression models to determine which were associated with various MUP parameters. Using backwards linear regression, age was the only parameter significantly associated with IP turns ($P<.0005$), turns/amplitude analysis ($P<.0005$), percent activity ($P<.0005$), and NSS ($P<.0005$). In contrast, using backward linear regression, continence status was the only variable associated with change in MRV during bladder filling ($P=.001$).

Table 3 shows the relationship between age and each of the MUP parameters. Increasing age was inversely correlated with nearly all MUP parameters in Multi-MUP and IP analyses, suggesting MUP to be consistent with neuropathy.

Discussion

We found significant differences in multiple MUP parameters in the striated urethral sphincter between continent and stress incontinent women. Our findings are consistent with the belief that continent women have better innervation of the urethral sphincter than stress incontinent women. Stress incontinent women had lower levels of MUP recruitment

findings consistent with those found in neuromuscular disorders. The number of turns per second is influenced by the number of MUP and their firing rate. In neuropathic states, fewer MUP exist; therefore, the voltage generated by each surviving MUP is greater, which results in fewer turns per amplitude. During IP analysis, the summation from overlap of MUP influences the number of turns and amplitude. In patients with neuromuscular disorders, an increase in duration results in more summation and cancelation of small spikes and may give rise to low numbers of turns per second [16]. Weidner et al. demonstrated similar changes in the levator ani and external anal sphincter of women with stress incontinence and prolapse [3]. Women with prolapse and stress incontinence had decreased number of turns and decreased ability to recruit high threshold MUP in the levator ani and external anal sphincter when compared to nulliparous controls.

Continent women showed similar trends in MUP parameters in the Multi-MUP analysis. Continent women had larger-amplitude, longer-duration, polyphasic MUP, whose changes are consistent with reinnervation after denervation injury. When a motor unit is injured, peripheral sprouting from neighboring axons results in longer-duration, higher-amplitude, polyphasic MUP. Although these EMG findings are frequently interpreted as “abnormal,” they actually represent reinnervation. Since the majority of continent women in our study were parous, it is possible that these women sustained a mild neural injury and had superior subsequent reinnervation with better urethral sphincter function. In addition, continent women showed a greater increase in mean rectified voltage (amplitude) with bladder filling suggesting that women with stress incontinence have decreased activation of MUP with filling. We did not find a difference in the absolute MRV at baseline or 300 ml. This is consistent with the clinical scenario encountered in women with stress urinary incontinence. Women with stress incontinence often leak with increases in bladder volume and abdominal pressure, but do not leak at rest, suggesting that women with stress incontinence are unable to recruit urethral MUP during times of stress.

Weidner et al. recently reported important differences in urethral EMG parameters between nulligravid and primigravid women [17]. Primigravidas had MUPs with fewer turns, lower amplitudes, and less activity compared to nulligravidas, indicating that they were less able to successfully recruit MUP. While parity may result in some reinnervation changes associated with neuropathy, it does not explain differences in our groups. Parity was not associated with any MUP parameters in multivariate analysis, suggesting that it did not play an important role in stress incontinence symptoms in our cohort. Similarly, Podnar et al. only found minor EMG changes in the external anal sphincter after vaginal delivery, and these changes did not seem to indicate a loss of external anal sphincter function [18].

In contrast, advancing age was consistently associated MUP changes reflective of poor urethral neuromuscular function, and in some cases, age was more strongly associated with urethral MUP parameters suggestive of denervation than continence status. In fact, our findings, while limited by demographic differences between cohorts, suggest that age is more important in changes in urethral innervation than continence status. Older women demonstrated decreased MUP recruitment as measured by decreasing numbers of turns and lower turns/amplitude ratio. This relationship between age and urethral function is consistent with urodynamic measures of urethral function, histologic studies, and clinical rates of stress incontinence [6, 19–21]. Urodynamic studies consistently report decreases in urethral closure pressures in continent women with advancing age [19, 20]. Similarly, histologic studies on female cadavers demonstrated a decrease in nerve and muscle fiber density in the striated urethral sphincter with advancing age and estimated that approximately 2% of striated urethral sphincter muscle fibers are lost per year. They suggest that loss of muscle fibers with aging is consistent with the hypothesis that muscle loss is a result of neural injury but conclude that the way nerve injury would affect urethral function remains unclear. Our

urethral EMG data, which show MUP changes consistent with neuropathy not myopathy, support that the histologic findings of decreased muscle are likely secondary to neuromuscular decline rather than primary muscle pathology [21, 22].

The important association between MUP parameters suggestive of urethral neuromuscular dysfunction and age is consistent with clinical data, which show increasing rates of stress urinary incontinence with aging. In a large study of Norwegian women, Rortveit et al. found no difference in the prevalence of urinary incontinence in women over age 65, who were nulliparous, had delivered by Cesarean, or delivered vaginally, although vaginal parity was a risk factor at earlier ages [23, 24]. Other investigators demonstrated similarly high stress incontinence prevalence in postmenopausal nuns and twins regardless of vaginal parity [25].

MUP parameter differences were more significant in IP analysis than Multi-MUP analysis. Other investigators have reported similar findings in the EAS [26, 27], suggesting that MUP changes associated with reinnervation may be more prominent in MUP activated at higher levels of muscle force generation. Therefore, IP analysis may be a better method to detect small changes in MUP parameters.

The differences in baseline demographic characteristics of our continent and stress incontinent groups limit our ability to make definitive conclusions regarding the precise impact of age, race, and parity on quantitative urethral EMG parameters from these data. Although the SUI women were nearly a decade older, the dramatic differences in their EMG findings are unlikely due to this difference alone. These data will provide information to power future studies matching groups on age, race, and vaginal parity. Our data are strengthened by inclusion of a racially diverse cohort of women and careful characterization of these women with respect to urethral neuromuscular function and urinary symptoms.

We present important urethral neuromuscular function data on a large cohort of continent and stress incontinent women fully characterized with quantitative urethral EMG. We found significant differences in multiple MUP parameters in the striated urethral sphincter between continent and stress incontinent women, suggesting that continent women have better innervation of the urethral sphincter than stress incontinent women. We also found significant neuropathic MUP changes with advancing age, regardless of continence status. This supports histologic and clinical data that aging results in urethral neuromuscular decline with increasing prevalence of urinary incontinence symptoms. Therapies directed at neural preservation or regeneration may improve outcomes of stress incontinence treatments or prevent age-related neuromuscular decline.

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Table 1

Demographics and pelvic floor symptoms

	Continent (N=30) Mean±SD	Stress incontinent (N=37) Mean±SD	P value^a
Age (years)	39±14	48±9	.002
Body mass index	28±9	29±7	.76
Hispanic or Latino ethnicity	14%	19%	.54
Race			
Caucasian	43%	82%	.01
African American	50%	12%	
Other	7%	6%	
Vaginally parous (%)	59%	94%	.001
Pelvic floor distress inventory scores			
Urinary distress inventory	3.7±8.2	49±20	<.0005
Prolapse distress inventory	0.9±2.8	22±21	
Colorectal distress inventory	2.4±5.4	19±17	
Medical epidemiologic social aspects of aging scores			
Stress subscale	6.4±14.2	71.3±16	<.0005
Urge subscale	3.2±7.4	39±23	

^aIndependent samples *t* test

Table 2

Motor unit action potential parameters in continent and stress incontinent women

	Continent (N=30) Mean±SD	Stress incontinent (N=37) Mean±SD	P value ^a
Multi-MUP parameters			
Amplitude (μV)	377±174	324±79	.06
Duration (ms)	9.8±3.4	7.8±2.5	.007
Phases (N)	5.0±1.5	4.0±1.2	.02
Turns (N)	5.6±2.4	3.7±1.3	.004
Interference pattern parameters			
Turns (N)	199±108	118±71	.001
Amplitude (μV)	637±366	571±313	.50
Turns/amplitude	.72±.35	.48±.28	.004
Activity (%)	8.2±5.7	4.5±3.3	.002
Number short segments (N)	11±77	60±46	.002
Envelope (μV)	547±225	466±227	.15
Mean rectified voltage during cystometry			
Baseline (0 ml)	17.2±14.8	15.7±9.7	.61
Change 300 ml–baseline	10.9±12.5	3.3±5.6	.002

^aIndependent samples *t* test

Table 3

Correlation of age with motor unit action potential parameters

	ρ	P value ^a
Multi-MUP parameters		
Amplitude (μ V)	-.30	.02
Duration (ms)	-.44	<.0005
Phases (N)	-.50	.001
Turns (N)	-.46	.003
Interference pattern parameters		
Turns (N)	-.61	<.0005
Amplitude (μ V)	-.28	.03
Turns/amplitude	-.61	<.0005
Activity (%)	-.55	<.0005
Number short segments (N)	-.58	<.0005
Envelope (μ V)	-.43	<.0005
Mean rectified voltage during cystometry		
Baseline (0 ml)	-.26	.02
300 ml	-.41	.001
Change 300 ml–baseline	-.25	.06

^aIndependent samples t test