Pelvic Floor Muscle Performance, Hip Mobility, and Hip Strength in Women With and Without Self-Reported Stress Urinary Incontinence

Erin Hartigan, PT, DPT, PhD, ATC, OCS[1]
J. Adrienne McAuley, PT, DPT, MEd, OCS, FAAOMPT[1]
Mike Lawrence, BS, MS[1]
Carly Keafer, PT, DPT[2]
Abbey Ball, PT, DPT, ATC[3]
Anna Michaud, BS[4]
Mary DeSilva, ScD, MS, MSFS[1]

ABSTRACT

Objective: To describe pelvic floor muscle (PFM) function, hip mobility, and hip strength profiles and compare measures between women with and without self-reported stress urinary incontinence (SUI).
Study Design: Descriptive.
Background: Women with SUI present with PFM and hip impairments; yet comparative data in asymptomatic women are lacking.
Methods and Measures: Adult women with (n = 21) or without (n = 20) SUI, with regular menses, were recruited. PFM performance, passive hip range-of-motion angles, and hip maximum isometric voluntary contractions (Nm/kg) (Biodex) were measured. Values were compared between groups and legs (dominant [Dom] and nondominant [Non-dom]) (significance: $P < .05$).
Results: Women with SUI were older ($P < .001$), had higher parity, more tender points (Dom, $P = .020$), greater prone hip internal rotation (IR) angles (Non-dom, $P = .025$), lesser flexibility per Ober test (Non-dom, $P = .013$; Dom, $P = .050$), lower seated hip external rotation (ER) force (Non-dom, $P = .008$; Dom, $P = .033$), and lower hip abduction force (Non-dom and Dom, $P < .001$) than women without SUI. Leg differences for the SUI group were prone hip IR angles ($P = .033$), seated hip IR force ($P = .015$), and prone hip ER force ($P < .001$). Leg differences in women without SUI were PFM power ($P = .005$), prone hip angles (IR, $P = .038$; ER, $P = .004$), and prone hip ER force ($P < .001$).
Conclusions: The lack of significant differences in PFM function between the 2 groups was unexpected. Greater hip strength and mobility along with unique between-leg differences may suggest a coping mechanism in asymptomatic women with similar PFM function as women with SUI. Investigating relationships among PFM and hip profiles and severity of SUI appears warranted.
Key Words: joint range of motion, lower urinary tract symptoms, muscle strength, regional interdependence

We have included a Video Abstract that highlights interesting findings in our article (see the Video Abstract, Supplemental Digital Content 1, available at: http://links.lww.com/JWHPT/A23).

[1]*Westbrook College of Health Professions, University of New England, Portland, Maine.*

[2]*Advance Orthopedic and Sports Therapy, Tewksbury, Massachusetts.*

[3]*Select Physical Therapy, Auburn, Maine.*

[4]*Maine Health Cardiology, Scarborough, Maine.*

The authors declare no conflicts of interest.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (http://journals.lww.com/jwhpt/pages/default.aspx).

DOI: 10.1097/JWH.0000000000000141

INTRODUCTION

Stress urinary incontinence (SUI) is involuntary urinary leakage that occurs during increased intra-abdominal pressure as a result of coughing, sneezing, or physical exertion.[1,2] While urinary incontinence (UI) is commonly experienced by older women, SUI is the predominant type of UI among premenopausal women.[3] Risk factors for SUI include elevated body mass index (BMI),[4,5] pregnancy/postpartum,[6] higher parity,[7] and vaginal delivery.[6,8–11] SUI is reported in young women (15-39 years old), with similar rates among athletes and nonathletes (39% and 41%, respectively).[12] Those affected by SUI report that the condition negatively affects their quality of life,[13] and the annual surgical and nonsurgical management of SUI exceeds $12 billion in the United States.[14] This equates to a significant financial burden for women, as an estimated 70% of conservative management costs are out-of-pocket expenses.[14]

The link between UI and pelvic floor muscle (PFM) function is well documented.[2,15,16] The PFMs are composed of the levator ani muscles, the urogenital diaphragm, and urethral sphincter muscle. The levator ani muscles contribute to continence by reducing downward movement of the bladder neck,[17–19] while the sphincter is responsible for urethral close pressure.[17,19,20] PFM performance is clinically assessed by measuring power, endurance, recruitment, vertical displacement, ability to relax, spontaneous contraction with cough, tenderness to palpation, and ability to lengthen when asked to bear down.[21] PFM impairments in those with SUI include limited endurance,[22] fewer quick repetitions in a 10-second period,[23] less vertical displacement,[24] decreased power, and delayed recruitment of PFM compared with women without SUI.[25] While PFM training is the recommended first-line treatment for women with SUI and has shown good short-term benefits, not all women experience complete resolution of symptoms.[16] Moreover, the long-term benefit of PFM training has been questioned, as women who adhere to exercise do not have better outcomes than those who do not.[26]

Identification of modifiable musculoskeletal factors in women with SUI has cost-saving potential and likelihood to improve quality of life. Strengthening hip musculature improves PFM power in nulliparous women[27] and also reduces leakage in those with SUI.[28,29] This is likely due to the anatomical relationship, as the obturator internus muscle, one of the short hip external rotators,[30] has fascial attachments to the PFM.[27] Only hip abduction strength has been demonstrated to be statistically weaker in women with SUI compared with healthy controls.[23] Hip external rotation (ER) strength when tested in a seated position (ie, hips flexed) was not different between women with and without SUI.[23] More recently, the obturator internus muscle was found to generate more muscle activation with the hip extended compared with flexed.[31] This new information warrants investigating whether women with SUI would have different hip ER strength than asymptomatic women if tested in a prone position.

Normative data on hip and PFM function in women who deny leaking urine are limited. Explicitly asking individuals whether they leak urine is recommended as best practice for identifying complaints of SUI, as women may not self-disclose the symptoms due to embarrassment.[32,33] Furthermore, women may incorrectly assume that leaking is normal during high-impact activities.[34] Women with SUI often report low back pain (LBP)[35,36] and exhibit PFM weakness.[37] PFM performance has been shown to worsen with age[24,38] and parity.[38] Documentation of PFM performance, hip mobility, and hip strength measures that may differ between asymptomatic women and women with SUI in addition to potential confounding measures is needed to guide the examination and interpretation of musculoskeletal components associated with leakage.

The purpose of this exploratory study was to compare PFM performance, hip strength, and hip flexibility measurements between women with and without self-reported SUI. The goal was to establish a better understanding of the clinical presentation and relevant differences between groups to allow for informed screening, examination, and impairment-driven intervention within physical therapy practice. Differences in potential contributing factors such as age, BMI, parity, and history of LBP were also considered in addition to PFM performance and hip function (eg, hip range of motion, flexibility, and strength) in those with and without SUI.

METHODS AND MEASURES

Participant Recruitment

This study was part of a larger study that explored PFM function, hip function, and gait biomechanics in women with and without SUI. We report PFM function, hip motion, and hip strength here. Data on gait biomechanics will be presented in a separate article. A sample of convenience was used for recruitment. Participants were recruited through flyers posted within the university community and at local physical therapy clinics as well as university-wide e-mails, and in-person efforts by research personnel.

The inclusion criteria included adult women with regular menses for 3 consecutive months prior to enrollment in the study, who spoke and understood English, and had a BMI less than 30.0 kg/m^2. There was no upper age limit as long as the criterion of regular menses (ie, every 21-35 days)[39] was met. Exclusion criteria were: male sex; younger than 18 years; current pregnancy; history of back, leg, or pelvic surgery that would impact movement or force production with the exception of cesarean section or minimally invasive surgical procedures like an appendectomy; and presence of pain on the day of the data collection. To verify eligibility criteria of no pelvic pain, the National Institutes of Health Chronic Prostatitis Symptom Index (female version) questionnaire was used to confirm "0" scores for all questions.[40,41] The additional criterion for women without SUI was self-reported absence of urinary leakage. The additional criterion for the SUI group was verified by participant selection on question 6 of the International Consultation on Incontinence Questionnaire Short Form (ICIQ-SF), which states, "leaks when you cough or sneeze" or "leaks when you are physically active/exercising."[42–44] While urodynamic testing is considered the gold standard of diagnosing SUI, it is expensive and outside the scope of physical therapy practice. The ICIQ-SF has been found to correlate with urodynamic findings and was therefore used in this study to identify SUI.[45]

The researcher (EH) who confirmed eligibility and assigned the participant to the SUI or without SUI group per participant responses on the ICIQ-SF did not collect the PFM performance, goniometric, and strength data. One researcher (JAM), a licensed physical therapist with 23 years of experience and advanced practice qualifications in women's health, collected the goniometric and strength data, and performed the PFM examination, detailed further. This data collector (JAM) was blinded to group assignment. The research study was approved by the University of New England's Institutional Review Board (# 040816-006). Upon enrollment, participants completed a brief survey including age, parity, history of LBP, and severity of SUI symptoms.

Data Collection Procedures and Measures

Goniometric Measures

One researcher (JAM) performed all passive hip range-of-motion assessments and Ober tests using standard procedures as described by Norkin and White.[46] Bilateral hip internal and external rotation range-of-motion angles were measured in sitting (ie, hip flexion) and prone (ie, neutral hip position). The Ober test was performed bilaterally, with measures above horizontal (ie, hip abduction) reported as negative values. Given documented high intra-rater reliability of goniometric range-of-motion measurements, only one repetition of testing was performed by the same researcher for each participant.[47]

Pelvic Floor Muscle Examination

The PFM examination was performed in accordance with the recommendations of the American Physical Therapy Association's Section on Women's Health,[21] including PERFECT scheme measures described by Laycock and Jerwood.[48] There is conflicting evidence on the interrater and intrarater reliability of the Laycock method for internal examination.[48] Therefore, a single researcher (JAM) performed all of the PFM measurements. Measures collected via the internal PFM examination[48] were bilateral assessments of power (0-5), cocontraction of PFM with transverse abdominis (present/absent), and tone (low, normal, and high). Vertical displacement with contraction (present/absent), endurance (number of seconds able to maintain power), repetition (number of contractions that sustain the participant's measured endurance and power scores), fast contractions (number of quick contractions in 10-second period), and ability to relax (normal, delayed, and absent) were assessed using a midline assessment. Perineal descent with bearing down and spontaneous contraction with cough were scored as absent or present by external observation of the perineal body and introitus, respectively. Palpation (tender/not tender) was assessed at 2 internal locations bilaterally (obturator internus and levator ani), 5 external locations bilaterally, and the perineal body (midline)[49] (Tables 1 and 2). Once the PFM examination was complete, the participant dressed, and the research assistant walked with her to the Motion Analysis Lab for strength testing using a dynamometer.

Dynamometer Data

Joint torques were measured during maximum voluntary isometric contractions (MVICs) of the hip muscles for both legs with the start leg randomized. An isokinetic dynamometer (Biodex S4, Shirley,

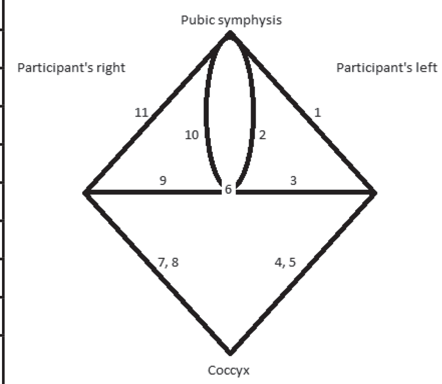
Table 1. Pelvic Floor Muscle Examination Recording Template

	Dominant	Nondominant
Power (MMT 0-5)		
Cocontraction/transverse abdominis	0 absent, 1 present	0 absent, 1 present
Tone (0 low; 1 normal; 2 high)		
Tenderness (8 predetermined locations)	Frequency count of tender points/8	Frequency count of tender points/8
Vertical displacement	0 absent, 1 present	
Endurance, s		
Repetition		
Fast contractions (number in 10 s)		
Ability to relax	0 absent, 1 delayed, 2 normal	
Perineal descent with bearing down	0 absent, 1 present	
Spontaneous contraction with cough	0 absent, 1 present	

Abbreviations: MMT, manual muscle testing; s, seconds.

Table 2. Pelvic Floor Muscle Palpation Locations

	Left	Right
External palpation		
Ischiocavernosus	(1)	(11)
Bulbocavernosus	(2)	(10)
Superficial transversus	(3)	(9)
Levator ani	(4, 5)	(7, 8)
Perineum	(6)	
Internal palpation		
Levator ani		
Obturator internus		
Total	Frequency count of tender points/8	Frequency count of tender points/8



New York) was used to measure the torque produced by the hip internal and external rotators in sitting and prone, and hip abductors in side-lying. Participants performed 3 trials for each muscle group in each position, with 3 minutes of rest between repeat MVIC trials. Isokinetic dynamometer testing with the Biodex is reported to have high test-retest reliability measurements.[50]

Data Analysis

Frequency counts and percentages were calculated for categorical variables (ie, parity, history of LBP, cocontraction of the transverse abdominis, vertical displacement, tender points, spontaneous PFM contraction with cough, and perineal descent with bearing down) and ordinal data (ie, tone and ability to relax). Means and standard deviations were calculated for continuous variables (ie, age, BMI, PFM power, endurance, repetitions, fast contractions, and hip angles and forces). When variables were assessed bilaterally, data were reported for each leg (ie, dominant [Dom] and nondominant [Non-dom]).

Bivariate analysis was used to assess differences in age, parity, history of LBP, and BMI (all potentially confounding variables) between groups although these variables were not controlled for in the analyses.

Statistical Analysis

Although this was an exploratory analysis and not hypothesis driven, nonparametric statistical testing was conducted to describe and make inferences about the data. Data were analyzed using SAS version 9.4 (The SAS Institute, Cary, North Carolina) and IBM SPSS Statistics version 21.0 (IBM Corp, Armonk, New York). Tests used for group comparisons (ie, with SUI and without SUI) were χ^2 tests for categorical, Wilcoxon-Mann Whitney tests for ordinal, and analyses of variance for continuous variables. Tests used for paired comparisons (ie, Dom and Non-dom legs) were χ^2 tests for categorical, McNemar's tests for dichotomous, Wilcoxon signed rank tests for ordinal, and paired *t* tests for continuous variables. For all analyses, a value of $P \leq .05$ defined statistical significance.

RESULTS

Group Differences

A demographic profile of the study sample including characteristics that may influence SUI and PFM function is presented in Table 3; Table 4 presents PFM examination findings; and Table 5 presents the hip mobility and strength profiles. The SUI group was statistically older ($P < .001$), had higher parity (Table 3), more tender points (Dom leg only, $P = .020$) (Table 4), greater hip internal rotation (IR) angles in prone (Non-dom leg only, $P = .025$), was less flexible per Ober test (ie, less relative hip adduction angles) (Non-dom leg, $P = .013$; Dom leg $P = .050$), and had lower seated hip ER force (Non-dom leg, $P = .008$; Dom leg, $P = .033$) and hip abduction force (Non-dom and Dom legs, $P < .001$) than the without SUI group (Table 5). History of LBP and BMI did not differ between groups (Table 3: $P \geq .153$). No significant group differences were found for the following variables: PFM performance (power, cocontraction, tender points on the nondominant limb, tone, endurance, repetitions, fast contractions, vertical displacement, ability to relax, spontaneous contraction with cough, or perineal descent [Table 4; $P \geq .165$]); hip angles (seated and prone hip ER angles, seated IR angles, or prone hip IR in the Dom leg [Table 5; $P \geq .051$]); or hip force (seated and prone hip IR MVIC and prone ER MVIC [Table 5; $P \geq .084$]).

Leg Differences

For the SUI group, the Dom limb had greater prone hip IR angles ($P = .033$), seated hip IR force ($P = .015$), and prone hip ER force ($P < .001$)

Table 3. Demographic Information: Mean (SD) or Frequency Count (%)

	With SUI (n = 21)	Without SUI (n = 20)	*P* Value
Age, y	32.7 (±7.6)	25.6 (±4.0)	<.001[a]
BMI, kg/m^2	23.1 (±2.6)	21.9 (±2.8)	.153
Parous (number reporting yes)	9 (43%)	0 (0%)	
Parity (number of children)			
0	12 (57%)	20 (100%)	
1	4 (19%)		
2	2 (9.5%)		
3	2 (9.5%)		
4	1 (5%)		
History of LBP (number reporting yes)	10 (52.4%)	7 (65%)	.418

Abbreviations: BMI, body mass index; kg, kilograms; LBP, low back pain; m, meters; SD, standard deviation; SUI, stress urinary incontinence; y, years.
[a]Statistically significant at $P \leq .05$.

compared with the Non-dom limb. No significant between-leg differences were found for the following variables for women with SUI: PFM performance (power, cocontraction, tender points, tone [Table 4; $P \geq .688$]); hip angles (seated hip IR and ER, prone hip ER, side-lying Ober [Table 5; $P \geq .091$]); or hip force (seated hip ER, prone hip IR, and side-lying abduction [ABD] [Table 5; $P \geq .327$]).

For the without SUI group, the Dom limb had greater PFM power ($P = .005$), prone hip IR angles ($P = .038$), and prone hip ER force ($P < .001$) and lesser prone hip ER angles ($P = .004$) than the Non-dom limb. No significant between-leg differences were found for the following variables for women without SUI: PFM examination (cocontraction, tender points, tone [Table 4; $P \geq .625$]); hip angles (seated hip IR and ER, side-lying Ober [Table 5; $P \geq .505$]); or hip force (seated hip IR and ER, prone hip IR, and side-lying ABD [Table 5; $P \geq .158$]).

DISCUSSION

This study provides comparative data for PFM function, hip mobility, and hip strength in women with and without SUI. Differences found between groups and legs provide insight into the clinical presentations of PFM function (Table 4) and objective hip data (Table 5). Unexpectedly, women with SUI did not present with compromised PFM performance compared with women without SUI. Women with SUI presented with more PFM tender points, different hip mobility (ie, greater hip IR angles [prone], less flexible per Ober test), and less hip strength (ie, hip ER [seated] and hip abduction) than the asymptomatic group. Notably, some side-to-side differences were consistent across groups (ie, the Dom leg presented with greater prone hip IR angles and greater prone hip ER strength), whereas other leg asymmetries were unique (ie, Dom leg: women without SUI had greater PFM power and lesser prone ER angles; women with SUI had stronger seated hip IR strength). It is the unique profile that may better inform screening and intervention for women with SUI. In addition, clinicians should take note that the position used to examine hip mobility and hip strength matters.

The group differences in age and parity (Table 3) that we found are consistent with the literature, as others have reported that these variables influence SUI.[3,7] BMI and history of LBP have also been shown to influence SUI[4,5,35,36]; however, our groups did not differ in either BMI or history of LBP. These conflicting findings are likely due to our exclusion criteria. For example, BMI was set to assure marker stability and reliability for the gait analysis portion of our data collection, which is not included in this article. Recruitment materials also noted that women who were currently experiencing pain were not eligible, likely discouraging women with frequent pain from volunteering.

The lack of group differences for PFM function was unexpected. The only statistical difference between groups was that women with SUI reported a greater number of PFM tender points on the side of their Dom leg. Otherwise, the clinical presentation was quite similar between groups. Tenderness has been reported in women with chronic pelvic pain,[51] but has not been reported as a typical finding in women with SUI. The number of women in each group with high tone was similar and only 2 women with SUI had low tone. Conflicting evidence exists regarding PFM tone in women with UI.[52,53] Our findings are more consistent with Unger and colleagues' findings,[53] who reported that the majority of women

Table 4. Pelvic Floor Muscle Examination Findings: Mean (SD) or Frequency Count (%)

		With SUI (n = 21)			Without SUI (n = 20)			
		Dominant	Nondominant	*P* Values: Limb Differences	Dominant	Nondominant	*P* Values: Limb Differences	*P* Values: Group Differences
Power (scale 0-5)	Converted (0-12)	7.9 (2.7)	7.7 (2.5)	.702	8.8 (2.7)	7.7 (2.8)	.005[a]	D: .294 ND: .938
5	12	1	1		3	2		
4+	11							
4	10	9	7		8	3		
4−	9							
3+	8				4	7		
3	7	8	10		4	5		
3−	6					1		
2+	5							
2	4	1	2					
2−	3							
1	2	2	1			1		
0	1				1	1		
Cocontraction (TrA) (present)		12/21 57.1%	13/21 61.9%	1.00	11/20 55%	13/20 65%	.625	D: .891 ND: .839
Tender points (number of yes if tender on any location)		16/21 (76%)	15/21 (71%)	1.00	8/20 (40%)	10/20 (50%)	.625	D: .020[a] ND: .165
	0	5	6		12	10		
	1	6	8		3	3		
	2	10	5		5	7		
	3	0	2		0	0		
Tone				.688			1.00	D: .782 ND: .862
Low	−1	2/21 9.5%	0/21 0%		1/20 5%	1/20 5%		
Normal	0	13/21 61.9%	15/21 71.4%		13/20 65%	12/20 60%		
High	+1	6/21 28.6%	6/21 28.6%		6/20 30%	7/20 35%		
Endurance (number of seconds to maintain power within maximum of 10 s)		7.5 (2.9)			7.6 (2.8)			.977
Repetitions		3.9 (2.8)			4.7 (2.5)			.319
Fast contractions (number in 10 s)		5.4 (2.2)			6.1 (3.3)			.476
Vertical displacement (present)		15/21 71.4%			17/20 85%			.300
Ability to relax (frequency)								.482
Normal	0	3/21 14.3%			6/20 30%			
Delayed	−1	17/21 81%			12/20 60%			

(*continues*)

Table 4. Pelvic Floor Muscle Examination Findings: Mean (SD) or Frequency Count (%) (*Continued*)

		With SUI (n = 21)	Without SUI (n = 20)	*P* Values: Group Differences
Absent	−2	1/21 4.8%	2/20 10%	
Spontaneous contraction *with* cough (present)		1/21 4.8%	3/20 15%	.275
Perineal descent *with* bearing down (present)		12/21 57.1%	12/20 60%	.855

Abbreviations: D, dominant limb; ND, nondominant limb; SD, standard deviation; SUI, stress urinary incontinence; TrA, transverse abdominis;
[a]Statistically significant at $P \leq .05$.

with SUI presented with increased PFM tone, yet others[52] have reported that women with SUI have normal to low muscle tone with no differences found between continent and incontinent women.

Lack of PFM performance differences between the groups is largely due to those without SUI presenting with low performance measures. The majority of participants could not hold a PFM contraction for 10 seconds and the majority of participants' limbs of both groups had PFM power of 3+/5 or lower. Coordination aspects of muscle performance were also compromised in both groups, as the majority of participants had delayed relaxation after a PFM contraction and lacked spontaneous PFM contraction with cough. Given the lack of statistical differences in PFM performance, perhaps the asymptomatic women have yet-to-be-described coping strategies to prevent SUI in the presence of similar PFM performance to those who leak.

PFM strengthening has been the traditional approach to treating women with SUI.[15,54] Our

Table 5. Hip Angles and Hip Strength Findings: Mean (SD)

	With SUI (n = 21)			Without SUI (n = 20)			
	Dominant	Nondominant	Paired *t* Test	Dominant	Nondominant	Paired *t* Test	Independent *t* Test
Hip angles,°							
Seated IR	40.5 (±7.5)	38.3 (±6.7)	.091	36.4 (±7.6)	36.0 (±6.1)	.868	D: .088 ND: .251
Seated ER	34.2 (±6.7)	35.8 (±6.4)	.247	35.7 (±5.2)	36.8 (±6.3)	.505	D: .441 ND: .691
Prone IR	51.2 (±8.9)	47.3 (±6.7)	.033[a]	45.5 (±9.2)	41.6 (±9.1)	.038[a]	D: .051 ND: .025[a]
Prone ER	38.5 (±9.5)	41.5 (±8.7)	.146	41.0 (±7.2)	46.9 (±9.2)	.004[a]	D: .356 ND: .064
Side-lying Ober (negative = ABD angles)	−6.1 (±4.6)	−5.4 (±4.3)	.319	−2.4 (±5.3)	−2.2 (±5.1)	.901	D: .050[a] ND: .013[a]
Hip strength, Nm/kg							
Seated IR	0.96 (±0.33)	0.86 (±0.28)	.015[a]	1.03 (±0.31)	0.95 (±0.26)	.158	D: .475 ND: .300
Seated ER	0.63 (±0.15)	0.61 (±0.14)	.327	0.73 (±0.13)	0.72 (±0.11)	.863	D: .033[a] ND: .008[a]
Prone IR	0.56 (±0.19)	0.57 (±0.19)	.527	0.66 (±0.18)	0.67 (±0.17)	.625	D: .084 ND: .080
Prone ER	0.57 (±0.11)	0.54 (±0.10)	<.001[a]	0.62 (±0.15)	0.60 (±0.15)	<.001[a]	D: .173 ND: .107
Side-lying abduction	1.05 (±0.26)	1.09 (±0.26)	.345	1.48 (±0.28)	1.44 (±0.28)	.436	D: <.001[a] ND: <.001[a]

Abbreviations: ABD, abduction; D, dominant limb; ER, external rotation; ND, nondominant limb; IR, internal rotation; SD, standard deviation; SUI, stress urinary incontinence.
[a]Statistically significant at $P \leq .05$.

findings substantiate that treatment interventions likely need to be tailored to the specific impairments identified during a PFM and hip examination. PFM testing was obtained in supine hook-lying; thus, we are unsure of PFM performance in other positions or tasks. In addition, some women reported leaking during specific stressors such as coughing/sneezing, jumping, or exercising. Thus, the stressor or ineffective contributions of the PFM and hip muscles that result in leaking may be task-dependent. Perhaps interventions to prevent leakage during a cough should be different from training to prevent leakage when landing from a jump.

Certain women performed well on PFM tests, yet experienced SUI. Conversely, other women presented with low values on PFM tests and denied episodes of leakage. The discrepant hip profiles may help to better understand the regional influences that affect continence. Reported reduction of symptoms in women with SUI who completed a hip strength training program[28] corroborates our findings that hip impairments may coexist in women with SUI. Perhaps the less flexible iliotibial band (ITB) per Ober testing, greater prone hip IR angles (ie, Non-dom leg only), greater number of tender points (ie, dom leg only), and lesser seated hip ER force and side-lying hip abduction force bilaterally in women with SUI predispose them to symptoms. Group differences during strength testing (ie, force values normalize to body weight) were large in magnitude for side-lying (ie, 40.9% and 32.1% greater force in the without SUI group for the Dom and Non-dom limbs, respectively) and seated hip ER (ie, 15.9% and 18.0% greater force in the without SUI group for the Dom and Non-dom limbs, respectively) and are likely clinically meaningful. The magnitude of angular differences between groups for the prone hip IR angles for the Non-dom limbs (ie, 5.7°) and Ober test (ie, Dom: 3.2°; Non-dom: 3.7°) also exceeds the standard error of the measurement for the prone hip IR and Ober tests (ie, 3.4°[55] and 1.3°,[56] respectively); yet the clinical significance of the angular differences between groups is less clear. Of note, impaired hip mobility and hip strength were position-dependent in those with SUI. For example, group differences in hip ER force were evident in the seated position and not in the prone position; yet hip IR angles differed in the Non-dom limb in prone and not when seated.

Muscle fiber direction and activation may provide some explanation for these group differences.[16,30,31] Weaker hip ER in sitting in the SUI group may reveal less force production by the short hip external rotators. According to Neumann,[30] the primary hip external rotators are the gluteus maximus and short external rotators (ie, piriformis, obturator internus, gemelli superior, gemelli inferior, and quadratus femoris). In sagittal plane neutral (ie, prone), the secondary hip external rotators (ie, posterior fibers of the gluteus medius and minimus, obturator externus, sartorius, and long head of the biceps femoris) may assist with force production, whereas contributions from the secondary muscles may be less in a seated position (ie, hip flexion).[30] Furthermore, the change in the length-tension relationship of the gluteal muscles in sitting may reduce their contribution to force output.[30]

The fiber orientation of the short hip external rotators creates optimal alignment for hip compression and thus stability. Evidence that the obturator internus muscle is the first muscle to activate during isometric hip abduction and ER contractions (ie, prior to gluteus maximus and piriformis) suggests its role to fine tune the position of the hip in preparation for activation of the larger muscles.[31] In addition, the obturator internus muscle demonstrated slightly greater activation during hip ER strength testing in 60° of hip flexion compared with 0° of hip flexion.[31] Although muscle activation does not infer force production, perhaps aberrant activation of the obturator internus muscle relates to the hip abduction and ER weakness in women with SUI.

The deep hip external rotators are sometimes referred to as the "rotator cuff" of the hip.[30] The obturator internus muscle's role in stabilizing the hip joint may allow for more efficient abduction and/or ER force production.[57] In this capacity, the obturator internus should act to both center the femoral head in the acetabulum and be recruited prior to the larger hip muscles that generate osteokinematic motion.[31] If the obturator internus is not optimally performing as a hip stabilizer, then this may result in inefficiencies and muscle imbalances in the larger hip muscles, thus the weaker hip ER and ABD forces. The apparent weakness in gluteus medius muscles may lead to over-recruitment of the tensor fascia latae and resultant tightness per Ober testing.

Weaker hip abductor strength in women with SUI has been reported by others,[23] yet the decreased hip flexibility per Ober testing appears to be a novel finding. Relationships between weak hip abductors and ITB syndrome have been found in female runners.[58] Perhaps weak hip abductors and tight ITB also coexist in women with SUI. Further exploration of the gluteus maximus and the tensor fascia latae muscles appears warranted to better understand this clinical presentation.

Women with SUI did not have a greater number of statistically significant between-leg differences compared with women without SUI as both groups presented with 3 "asymmetrical" hip variables. Both groups presented with statistically greater prone IR angles and prone ER forces in the Dom leg; therefore, these findings may indicate limb dominance unrelated to SUI. Since the majority of women presented with relatively poor PFM performance, testing whether asymmetrical hip performance influences PFM function appears warranted.

Perhaps a clinical presentation of the unique between-leg differences in the women with SUI combined with low PFM scores and the aforementioned hip impairments increases the likelihood of leaking in women. Conversely, the combination of side-to-side power and hip profiles noted in women without SUI may contribute to a successful coping strategy, as these asymptomatic women had similar PFM function compared with women with SUI. Perhaps women without SUI present with greater prone ER angles in the Non-dom leg to accommodate for the lesser hip IR angles in prone. Furthermore, the reduced prone hip IR angle in the Non-dom leg (eg, relatively shorter hip external rotators) may be to accommodate for the lesser PFM power on this side (ie, asymmetrical PFM power values were found in the asymptomatic group only). Of note, the Non-dom leg in asymptomatic women presented with less PFM force generation and greater prone hip ER angles, perhaps indicating a shift in the length/ strength curve.

The levator ani muscle is one of the larger of the PFM and has a fascial connection to the obturator internus muscle. If the obturator internus does not have adequate passive tension (ie, SUI group presented with an average of 5° more hip IR passive range of motion when tested in prone), then the effort of a levator ani contraction may be less effective. The length-tension alteration of the obturator internus may not be providing a stable enough attachment point from which the levator ani can adequately generate forces. Hip strengthening, even in asymptomatic women, has been shown to result in greater PFM contraction.[27] Perhaps an altered length-tension of the hip rotators and the tethering of the levator ani to the obturator internus may be the reason that some women with SUI do not achieve full success through PFM training alone, while others with SUI respond favorably to hip exercises.[28]

The clinical implications of our findings are threefold. First, pelvic health physical therapists should include a thorough examination of the hip as part of their standard practice and address relevant impairments as has been demonstrated via case report.[59] Second, patients who present with the aforementioned hip impairments (ie, greater IR angles prone, less flexible Ober test, or weakness during hip abduction or seated ER) should have a thorough screening of SUI symptoms. Third, if hip impairments do not improve as expected, one should consider further examination of the PFM. Improving outcomes per Ober testing and hip strength testing may also reduce likelihood of incurring patellofemoral pain or an anterior cruciate ligament tear.[58,60]

This exploratory study provides a comprehensive description of PFM and hip findings as well as comparisons of these data between women with and without self-reported SUI. SUI is activity-related; therefore, a limitation in this study is that data on activity levels initially were not collected. Perhaps asymptomatic women were not leaking because they were not physically challenging their urodynamic system. Future studies should include data about level of physical activity (ie, Rapid Assessment of Physical Activity questionnaire)[61] when investigating women with and without SUI. We did not perform a priori power analyses for all comparisons described, nor can we account for the potential confounding influence of age and parity. We did not collect data on bladder habits; therefore, it is unknown whether participants urinate through generating intra-abdominal pressure instead of relaxing the PFM to allow for an effective detrusor (bladder muscle) contraction.[62] Straining to urinate can compromise the static and dynamic support structures that prevent leakage.[63]

This cross-sectional exploration can only show overall average differences, and no conclusion can be made about cause and effect. A statistical approach using variables that differ between the groups may be useful to test whether PFM and or hip impairments predict the presence or absence of SUI. Further research is also warranted to investigate why some women with less-than-expected PFM function are asymptomatic. Further exploration of group as well as side-to-side differences in hip measures may elucidate neuromuscular strategies employed by each group.

CONCLUSIONS

Pelvic floor muscle performance did not differ between the groups of women with and without SUI. Findings demonstrate the importance of holistic care (eg, assessing and addressing hip mobility and strength) as well as individualized treatment (eg, symptoms do not guarantee PFM training is warranted). Overall, findings help inform and establish patient profiles for women with SUI.

Women presented with diminished PFM function as measured per the internal PFM examination, yet not all reported SUI. These findings are important for non-PFM practitioners in that they may encounter patients with diminished hip strength and mobility, which may help to guide their clinical decision-making. We recommend that clinicians test hip rotation strength in sitting, as this position may highlight strength deficits that may be missed when tested in prone. Conversely, hip IR angles should be tested in prone, as leg differences (both groups) and group differences (greater hip IR in Non-dom leg of women with SUI) were found in prone and not seated.

ACKNOWLEDGMENTS

We would like to acknowledge the University of New England's Office of Sponsored Programs for funding this project with a mini grant award; Doctor of Physical Therapy (DPT) alumni Willis Brucker, Adam King, Brooks Tryon, and current DPT students Stephanie Ostrowski and Gwenyth Breslen, who assisted with data collections and data processing; as well as our academic and clinical community for spreading the word about our study, thus facilitating recruitment efforts.

REFERENCES

1. Abrams P, Cardozo L, Fall M, et al. The standardisation of terminology of lower urinary tract function: report from the Standardisation Sub-committee of the International Continence Society. *Neurourol Urodyn*. 2002;21(2):167–178.
2. Haylen BT, de Ridder D, Freeman RM, et al. An International Urogynecological Association (IUGA)/International Continence Society (ICS) joint report on the terminology for female pelvic floor dysfunction. *Neurourol Urodyn*. 2010;29(1):4–20.
3. Hunskaar S, Lose G, Sykes D, Voss S. The prevalence of urinary incontinence in women in four European countries. *BJU Int*. 2004;93(3):324–330.
4. Subak LL, Whitcomb E, Shen H, Saxton J, Vittinghoff E, Brown JS. Weight loss: a novel and effective treatment for urinary incontinence. *J Urol*. 2005;174(1):190–195.
5. Thom DH, Brown JS, Schembri M, Ragins AI, Subak LL, Van Den Eeden SK. Incidence of and risk factors for change in urinary incontinence status in a prospective cohort of middle-aged and older women: the reproductive risk of incontinence study in Kaiser. *J Urol*. 2010;184(4):1394–1401.
6. Thom DH, Rortveit G. Prevalence of postpartum urinary incontinence: a systematic review. *Acta Obstet Gynecol Scand*. 2010;89(12):1511–1522.
7. Wesnes SL, Rortveit G, Bo K, Hunskaar S. Urinary incontinence during pregnancy. *Obstet Gynecol*. 2007;109(4):922–928.
8. Baydock SA, Flood C, Schulz JA, et al. Prevalence and risk factors for urinary and fecal incontinence four months after vaginal delivery. *J Obstet Gynaecol Can*. 2009;31(1):36–41.
9. Ekstrom A, Altman D, Wiklund I, Larsson C, Andolf E. Planned cesarean section versus planned vaginal delivery: comparison of lower urinary tract symptoms. *Int Urogynecol J Pelvic Floor Dysfunct*. 2008;19(4):459–465.
10. Rortveit G, Daltveit AK, Hannestad YS, Hunskaar S, Norwegian ES. Urinary incontinence after vaginal delivery or cesarean section. *N Engl J Med*. 2003;348(10):900–907.
11. Serati M, Salvatore S, Khullar V, et al. Prospective study to assess risk factors for pelvic floor dysfunction after delivery. *Acta Obstet Gynecol Scand*. 2008;87(3):313–318.
12. Bo K, Borgen JS. Prevalence of stress and urge urinary incontinence in elite athletes and controls. *Med Sci Sports Exerc*. 2001;33(11):1797–1802.
13. Tennstedt SL, Fitzgerald MP, Nager CW, et al. Quality of life in women with stress urinary incontinence. *Int Urogynecol J Pelvic Floor Dysfunct*. 2007;18(5):543–549.
14. Chong EC, Khan AA, Anger JT. The financial burden of stress urinary incontinence among women in the United States. *Curr Urol Rep*. 2011;12(5): 358–362.
15. Bo K.Pelvic floor muscle training in treatment of female stress urinary incontinence, pelvic organ prolapse and sexual dysfunction. *World J Urol*. 2012;30(4):437–443.
16. Neumann PB, Grimmer KA, Deenadayalan Y. Pelvic floor muscle training and adjunctive therapies for the treatment of stress urinary incontinence in women: a systematic review. *BMC Womens Health*. 2006;6:11.
17. Ashton-Miller JA, Howard D, DeLancey JO. The functional anatomy of the female pelvic floor and stress continence control system. *Scand J Urol Nephrol Suppl*. 2001;207:1–7; discussion 106–125.
18. Hung HC, Hsiao SM, Chih SY, Lin HH, Tsauo JY. Effect of pelvic-floor muscle strengthening on bladder neck mobility: a clinical trial. *Phys Ther*. 2011;91(7):1030–1038.
19. McLean L, Varette K, Gentilcore-Saulnier E, Harvey MA, Baker K, Sauerbrei E. Pelvic floor muscle training in women with stress urinary incontinence causes hypertrophy of the urethral sphincters and reduces bladder neck mobility during coughing. *Neurourol Urodyn*. 2013;32(8):1096–1102.
20. DeLancey JO, Trowbridge ER, Miller JM, et al. Stress urinary incontinence: relative importance of urethral support and urethral closure pressure. *J Urol*. 2008;179(6):2286–2290; discussion 2290.
21. American Physical Therapy Association Section on Women's Health. *Pelvic Health Physical Therapy Level 1 Lab Manual*. Washington, DC:Section on Women's Health; 2014.
22. Burti JS, Hacad CR, Zambon JP, Polessi EA, Almeida FG. Is there any difference in pelvic floor muscles performance between continent and incontinent women? *Neurourol Urodyn*. 2015;34(6):544–548.
23. Underwood D, Calteaux T, Cranston A, Novotny S, Hollman J. Hip and pelvic floor muscle strength in women with and without stress urinary insentience: a case control study. *J Womens Health Phys Ther*. 2012;36(1):55–61.
24. Leitner M, Moser H, Taeymans J, Kuhn A, Radlinger L. Pelvic floor muscle displacement during voluntary and involuntary activation in continent and incontinent women: a systematic review. *Int Urogynecol J*. 2015;26(11): 1587–1598.
25. Luginbuehl H, Baeyens JP, Taeymans J, Maeder IM, Kuhn A, Radlinger L. Pelvic floor muscle activation and strength components influencing female urinary continence and stress incontinence: a systematic review. *Neurourol Urodyn*. 2015;34(6):498–506.
26. Beyar N, Groutz A. Pelvic floor muscle training for female stress urinary incontinence: five years outcomes. *Neurourol Urodyn*. 2017;36(1):132–135.
27. Tuttle L, DeLozier E, Harter K, Johnson S, Plotts C, Swartz J. The role of obturator internus muscle in pelvic floor function. *J Womens Health Phys Ther*. 2016;40(1):15–19.
28. Jordre B, Schweinle W. Comparing resisted hip rotation with pelvic floor muscle training in women with stress urinary incontinence: a pilot study. *J Womens Health Phys Ther*. 2014;38(2):81–89.
29. Marques A, Stothers L, Macnab A. The status of pelvic floor muscle training for women. *Can Urol Assoc J*. 2010;4(6):419–424.
30. Neumann DA. Kinesiology of the hip: a focus on muscular actions. *J Orthop Sports Phys Ther*. 2010;40(2):82–94.
31. Hodges PW, McLean L, Hodder J. Insight into the function of the obturator internus muscle in humans: observations with development and validation of an electromyography recording technique. *J Electromyogr Kinesiol*. 2014;24(4):489–496.
32. Gasquet I, Tcherny-Lessenot S, Gaudebout P, Bosio Le Goux B, Klein P, Haab F. Influence of the severity of stress urinary incontinence on quality of life, health care seeking, and treatment: a national cross-sectional survey. *Eur Urol*. 2006;50(4):818–825.
33. Shaw C, Das Gupta R, Williams KS, Assassa RP, McGrother C. A survey of help-seeking and treatment provision in women with stress urinary incontinence. *BJU Int*. 2006;97(4):752–757.
34. Carls C. The prevalence of stress urinary incontinence in high school and college-age female athletes in the midwest: implications for education and prevention. *Urol Nurs*. 2007;27(1):21–24, 39.
35. Bush HM, Pagorek S, Kuperstein J, Guo J, Ballert KN, Crofford LJ. The association of chronic back pain and stress urinary incontinence: a cross-sectional study. *J Womens Health Phys Ther*. 2013;37(1):11–18.
36. Eliasson K, Elfving B, Nordgren B, Mattsson E. Urinary incontinence in women with low back pain. *Man Ther*. 2008;13(3):206–212.
37. Morkved S, Salvesen KA, Bo K, Eik-Nes S. Pelvic floor muscle strength and thickness in continent and incontinent nulliparous pregnant women. *Int Urogynecol J Pelvic Floor Dysfunct*. 2004;15(6):384–389; discussion 390.
38. Pereira LC, Botelho S, Marques J, et al. Electromyographic pelvic floor activity: Is there impact during the female life cycle? *Neurourol Urodyn*. 2016;35(2):230–234.
39. Davis E, Sparzak PB. *Abnormal Uterine Bleeding (Dysfunctional Uterine Bleeding)*. Treasure Island, FL: StatPearls Publishing LLC; 2018. https://www.ncbi.nlm.nih.gov/books/NBK532913/. Updated November 14, 2018. Accessed September 20, 2018.
40. Litwin MS, McNaughton-Collins M, Fowler FJJr, et al. The National Institutes of Health chronic prostatitis symptom index: development and validation of a new outcome measure. Chronic Prostatitis Collaborative Research Network. *J Urol*. 1999;162(2):369–375.
41. Marszalek M, Wehrberger C, Temml C, Ponholzer A, Berger I, Madersbacher S. Chronic pelvic pain and lower urinary tract symptoms in both sexes: analysis of 2749 participants of an urban health screening project. *Eur Urol*. 2009;55(2):499–507.
42. Avery K, Donovan J, Peters TJ, Shaw C, Gotoh M, Abrams P. ICIQ: a brief and robust measure for evaluating the symptoms and impact of urinary incontinence. *Neurourol Urodyn*. 2004;23(4):322–330.
43. Espuna-Pons M, Dilla T, Castro D, Carbonell C, Casariego J, Puig-Clota M. Analysis of the value of the ICIQ-UI SF questionnaire and stress test in the differential diagnosis of the type of urinary incontinence. *Neurourol Urodyn*. 2007;26(6):836–841.
44. Seckiner I, Yesilli C, Mungan NA, Aykanat A, Akduman B. Correlations between the ICIQ-SF score and urodynamic findings. *Neurourol Urodyn*. 2007; 26(4):492–494.
45. Hajebrahimi S, Nourizadeh D, Hamedani R, Pezeshki MZ. Validity and reliability of the International Consultation on Incontinence Questionnaire-Urinary Incontinence Short Form and its correlation with urodynamic findings. *Urol J*. 2012;9(4):685–690.
46. Hartigan EH, White DJ. The hip In: Norkin CC, White DJ, eds. *Measurement of Joint Motion: A Guide to Goniometry*. 5th ed. Philadelphia, PA: FA Davis; 2017.
47. Gajdosik RL, Bohannon RW. Clinical measurement of range of motion. Review of goniometry emphasizing reliability and validity. *Phys Ther*. 1987;67(12):1867–1872.
48. Laycock J, Jerwood D. Pelvic floor muscle assessment: the PERFECT scheme. *Physiotherapy*. 2001;87(12):631–642.

49. Steege JF, Metzger DA, Levy BS. *Chronic Pelvic Pain: An Integrated Approach*. Philadelphia, PA: WB Saunders; 1998.
50. Feiring DC, Ellenbecker TS, Derscheid GL. Test-retest reliability of the Biodex isokinetic dynamometer. *J Orthop Sports Phys Ther*. 1990;11(7):298–300.
51. Neville CE, Fitzgerald CM, Mallinson T, Badillo S, Hynes C, Tu F. A preliminary report of musculoskeletal dysfunction in female chronic pelvic pain: a blinded study of examination findings. *J Bodyw Mov Ther*. 2012;16(1):50–56.
52. Devreese A, Staes F, De Weerdt W, et al. Clinical evaluation of pelvic floor muscle function in continent and incontinent women. *Neurourol Urodyn*. 2004;23(3):190–197.
53. Unger C, McKinney J, Weinstein M, Pulliam S. Pelvic floor muscle evaluation findings in patients with urinary incontinence. *J Womens Health Phys Ther*. 2014;38(2):90–94.
54. Bo K. Pelvic floor muscle training is effective in treatment of female stress urinary incontinence, but how does it work? *Int Urogynecol J Pelvic Floor Dysfunct*. 2004;15(2):76–84.
55. Pua YH, Wrigley TV, Cowan SM, Bennell KL. Intrarater test-retest reliability of hip range of motion and hip muscle strength measurements in persons with hip osteoarthritis. *Arch Phys Med Rehabil*. 2008;89(6):1146–1154.
56. Herrington L, Rivett N, Munro S. The relationship between patella position and length of the iliotibial band as assessed using Ober's test. *Man Ther*. 2006;11:182–186.
57. Retchford TH, Crossley KM, Grimaldi A, Kemp JL, Cowan SM. Can local muscles augment stability in the hip? A narrative literature review. *J Musculoskelet Neuronal Interact*. 2013;13(1):1–12.
58. Foch E, Reinbolt JA, Zhang S, Fitzhugh EC, Milner CE. Associations between iliotibial band injury status and running biomechanics in women. *Gait Posture*. 2015;41(2):706–710.
59. Kurz J, Borello-France D. Movement system impairment-guided approach to the physical therapist treatment of a patient with postpartum pelvic organ prolapse and mixed urinary incontinence: case report. *Phys Ther*. 2017;97(4):464–477.
60. Quatman-Yates CC, Myer GD, Ford KR, Hewett TE. A longitudinal evaluation of maturational effects on lower extremity strength in female adolescent athletes. *Pediatr Phys Ther*. 2013;25(3):271–276.
61. University of Washington Health Promotion Research Center. How Physically Active Are You. https://depts.washington.edu/hprc/wp-content/uploads/rapa_03_06.pdf. Accessed August 5, 2016.
62. Castillo MS, Dinglasan JT, Shelly B, Allen KL. The renal and urologic systems In: Goodman C, Fuller K, eds. *Pathology: Implications for the Physical Therapist*.4th ed. St Louis, MO: Elsevier; 2014:985.
63. Bradley CS, Smith KE, Kreder KJ. Urodynamic evaluation of the bladder and pelvic floor. *Gastroenterol Clin North Am*. 2008;37(3):539–552.