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Is Balance Different in Women With and Without Stress Urinary Incontinence?

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Aims: This study investigated whether there are differences in center of pressure (COP) displacement, trunk motion, and trunk muscle activity in women with and without stress urinary incontinence (SUI) during static balance tasks when the bladder is empty and moderately full. **Methods:** Subjects stood on a force plate during six static balance conditions: eyes open, eyes closed, standing on foam with eyes open, standing on foam with eyes closed, tandem stance, and standing on a short base. Electromyographic activity (EMG) of the pelvic floor (PF), abdominal, and erector spinae muscles were recorded using surface electrodes. Motion of the lumbar spine, pelvis, and hips was measured with four inclinometers. Trials were performed with the bladder empty, and when the subject reported a sensation of moderate bladder fullness after drinking 250–1,000 ml of water. **Results:** Women with SUI had greater COP displacement (range and root mean square), and increased trunk muscle EMG during static balance tests compared to continent women. When tasks were performed with the bladder moderately full, COP displacement and abdominal muscle EMG were increased in both groups. **Conclusions:** This study demonstrates that women with SUI have decreased balance ability compared to continent women. Increased activity of the PF and trunk muscles in women with SUI may impair balance as a result of a reduced contribution of trunk movement to postural correction or compromised proprioceptive acuity. As compromised balance has been linked to falls risk, further research into balance deficits and falls prevalence in this population is warranted. *Neurourol. Urodynam. 27:71–78, 2008.* © 2007 Wiley-Liss, Inc.

Key words: bladder; electromyography; postural control

INTRODUCTION

Recent evidence suggests that women with stress urinary incontinence (SUI) have increased trunk muscle activity in association with challenges to postural control.[1] It has been argued that this may have negative consequences for continence as the associated increase in intra-abdominal pressure would be expected to challenge the stress continence mechanism. However, it is also possible that altered trunk muscle control may challenge other aspects of function, such as balance.

Mobility of the spine is important to compensate for, and attenuate disturbances to posture.[2–6] In fact, even during quiet standing the trunk muscles are phasically active to generate small movements to compensate for postural perturbations associated with respiration.[4] However, when control of the trunk muscles is altered, spinal mobility and the contribution of the trunk muscles to posture may be impaired, and balance may be compromised.[7–10]

As bladder filling is associated with increased trunk muscle activity,[11–13] it is possible that balance may be further challenged by bladder fullness. Women with SUI have increased abdominal muscle activity in response to postural perturbations when the bladder is moderately full.[1,14] Thus, a further increase in trunk muscle activity with bladder filling may compromise the quality of postural adjustments and lead to additional balance impairments.

The first aim of this study was to determine whether there is a difference in center of pressure (COP) displacement and movement of the lumbar spine, hips, and sacrum in women with and without SUI during static balance tasks. Second, we aimed to determine whether trunk muscle activity is different between women with and without SUI during these tasks. A third aim was to evaluate the effect of bladder fullness on balance in these populations.

MATERIALS AND METHODS

Subjects

Sixteen women with SUI and 13 continent women with similar age (49.8 (12.0) years and 53.1 (12.7) years, respectively ($P = 0.47$)), body mass index (25.8 (4.5) kg/m^2 and 25.0 (3.0) kg/m^2 ($P = 0.56$)), habitual activity level (43.7 (7.2) and 43.5 (6.8) ($P = 0.93$)),[15] and parity (1.9 (1.1) and 2.3 (1.6) ($P = 0.47$)) participated in this study. Participants with SUI reported incontinence during activities such as jumping, lifting, coughing, sneezing and running. The average severity of SUI was reported as 4 (standard deviation (SD) 1.7) on a 12-point

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Chris Winters led the review process.
Abbreviations used: SUI, stress urinary incontinence; COP, center of pressure; AP, anteroposterior; ML, mediolateral; EMG, electromyography; PF, pelvic floor; OI, obliquus internus abdominis; OE, obliquus externus abdominis; ES, erector spinae; RA, rectus abdominis; $dCOP_{AP}$, range of COP displacement in the AP direction; $dCOP_{ML}$, range of COP displacement in the ML direction; RMS, root mean square; $vCOP_{AP}$, mean velocity of COP displacement in the AP direction; $vCOP_{ML}$, mean velocity of COP displacement in the ML direction; ANOVA, analysis of variance; SD, standard deviation.
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scale[16,17] with scores ranging from 2 (drops or splashes of urine leakage at least a few times a month) to 8 (splashes of urine leakage daily). Subjects were excluded if they had any of the following: urge incontinence; respiratory disorders; previous spinal, pelvic floor (PF) or abdominal surgery; pregnancy within the preceding 2 years; or treatment for incontinence in the past year. Women with neurological disorders, vestibular problems, lower limb injuries, dizziness, and a history of falls were also excluded from participation to eliminate the effect of these potentially confounding factors on balance. The study was approved by the Institutional Medical Research Ethics Committee and conducted in accordance with the Declaration of Helsinki. Participants provided informed consent prior to participation. Subjects also participated in other studies.[1,14]

Force Plate and Kinematic Recordings

Ground reaction forces were recorded with a single force plate (Kistler, Amherst, NY). Angular motion of the lumbar spine, sacrum, and hips was recorded with four uniaxial inclinometers (CXTA02, Crossbow Technology, San Jose, CA; and AccuStar Electronic Clinometer, Schaevitz Sensors, Fairfield, NJ). Inclinometers were attached to the skin over the (1) right thigh midway between the greater trochanter and fibular head to record motion in the anteroposterior (AP) direction, (2) second sacral vertebrae to record motion in the AP direction, (3) second sacral vertebrae to record motion in the mediolateral (ML) direction, and (4) spinous processes of the twelfth thoracic and first lumbar vertebrae to record motion in the AP direction (Fig. 1). The Crossbow and AccuStar inclinometers have a resolution of $+/-0.05$ and 0.001°, respectively. Force plate and inclinometer data were sampled at 100 Hz using a Power1401 and Spike 2 software (CED, Cambridge, UK), and data were analyzed with Matlab 6.5 (Mathworks, Natick, MA).

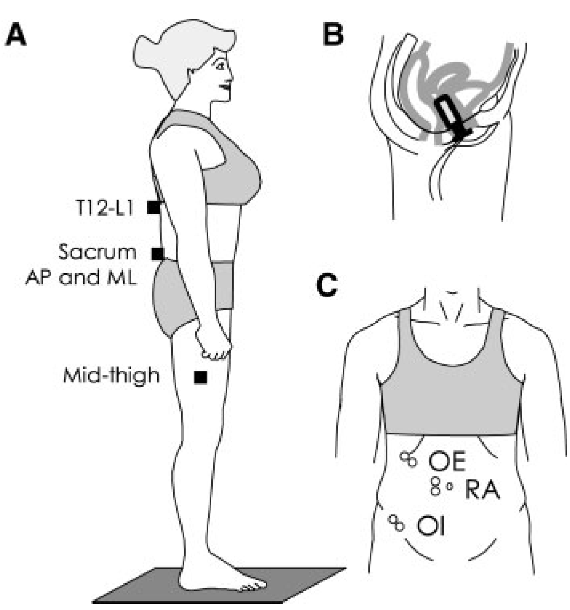

Fig. 1. Experimental set up. **A**: Inclinometer placements to record angular motion. **B**: Location of the pelvic floor electrode. **C**: Surface EMG electrode placement for obliquus internus abdominis (OI), obliquus externus abdominis (OE), and rectus abdominis (RA).

Electromyography

Electromyographic activity (EMG) of the trunk muscles was recorded with surface electrodes. Following skin preparation, pairs of Ag/AgCl surface electrodes (6 mm diameter, 30 mm inter-electrode distance) were placed on the right side of the body over obliquus internus abdominis (OI; 2 cm medial and inferior to the anterior superior iliac spine), obliquus externus abdominis (OE; eighth rib and just inferior in the mid-axillary line at an angle of 45° to the vertical),[18] erector spinae (ES; ~5 cm lateral to the L3 spinous process) and rectus abdominis (RA; ~4 cm lateral to the umbilicus). The ground electrode was placed over the right ilium.

A Periform Intra-Vaginal Probe electrode (NEEN HealthCare, Dereham, England) was used to record EMG activity of the PF muscles. This electrode has been used in previous studies,[19,20] and has been shown to record PF EMG without recording crosstalk from adjacent muscles during contractions of hip and trunk muscles of the intensity expected during static balance tasks.[1,19] EMG data were amplified 2,000 times, band-pass filtered between 30 and 1,000 Hz and sampled at 2,000 Hz using a Power1401 and Spike 2 software (CED). Data were exported for analysis with Matlab 6.5 (Mathworks).

Procedure

Subjects stood with bare feet on the force plate with the feet hip-width apart for all tasks except for tandem stance. Once comfort was achieved, foot position was measured to ensure accurate reproduction of the position between trials. Subjects were asked to stand still while focusing the eyes on a point ~3 m away at eye level. Six static balance tasks were performed: standing with eyes open, standing with eyes closed wearing a blindfold, standing on high-density foam (3.75 lb/cu; 15 cm thickness) with eyes open and closed, standing on a short base (9 cm wide) positioned midway along the sole of the foot, and standing in a modified tandem stance position with the feet separated by 2.5 cm in both ML and AP directions. These tasks are frequently employed to evaluate balance and form the main component of many commonly used balance tests.[5,21–23] Data were recorded for 70 sec which is necessary to include the slow components of balance, and to optimize stability and reliability of measures.[24]

Balance tasks were performed with the bladder empty and when subjects reported a sensation of moderate bladder fullness. Subjects emptied their bladder at the start of the experimental session. After completion of the first series of measurements, they drank water and repeatedly rated their perceived bladder fullness on a four-point scale[25] until they reached a level of moderate bladder fullness, or moderate desire to void. At this point (~20 min after water consumption) the measures were repeated. The average amount of water consumed was 610 ml (range 250–1,000 ml). Consumption of water was not different between continent (625 (SD 235) ml) and incontinent (595 (SD 180) ml) women ($P = 0.69$).

Data Analysis

Motion of the COP was calculated from the four vertical forces and eight horizontal shear forces recorded from the force plate using standard formulae. The following COP measures were calculated: range of COP displacement in the AP ($dCOP_{AP}$) and ML direction ($dCOP_{ML}$); root mean square (RMS) of $dCOP_{AP}$ and $dCOP_{ML}$; and mean velocity of COP displacement in the AP ($vCOP_{AP}$) and ML direction ($vCOP_{ML}$).

Range of displacement provided a measure of total COP excursion, and RMS was a measure of the average displacement from the mean.

Data from the inclinometers positioned at the level of the second sacral vertebrae were used to measure the AP and ML range of angular displacement at the sacrum. The amplitude of AP angular motion of the hip and lumbar spine was calculated as the difference between angular displacement of the inclinometers on either side of the joint (i.e., hip motion—difference between motion at the sacral and thigh markers; lumbar motion—difference between motion at the sacral and thoracolumbar markers). The RMS amplitude of the motion of hip, lumbar spine, and sacrum was also calculated.

EMG amplitude was calculated as the RMS EMG averaged over 500 msec at three points near the beginning, middle, and end of the trial. As it is recognized that individuals with different pathologies may be unable or unwilling to perform maximum contractions for EMG normalisation,[26] raw EMG data were analyzed to investigate differences in absolute muscle activity between groups. Many women with[27–29] and without[29,30] SUI are unable to perform a maximal contraction of their PF muscles, and women with SUI may be unwilling to perform a maximal abdominal muscle contraction as it would increase IAP[31] and challenge continence. Thus, as it is unlikely that a true maximal contraction can be obtained, normalization to maximum voluntary contraction is unlikely to be valid. Similarly, normalization of EMG to activity during submaximal contractions or standardized maneuver is unlikely to be accurate[26] as women with SUI may activate their muscles differently than continent women during such tasks. Therefore, activity recorded in a standard task would result in normalization to different values, and thus be meaningless.

We did not expect any systematic differences in factors that would influence the use of raw EMG data to compare between groups of women. Participants were matched for age, body mass index, physical activity level, and parity to minimize differences in changes in vaginal mucosa[32,33] and thickness of subcutaneous tissue overlying muscle.

Statistical Analysis

Balance measures were compared between continent and incontinent women using repeated measures analysis of variance (ANOVA) with two repeated measures (bladder fullness (2 levels) and balance task (6 levels)) and one independent factor (group (2 levels)). Separate analyses were performed for each of the COP and angular motion measurements. A repeated measures ANOVA was used to compare EMG amplitude between continent and incontinent women during quiet standing with the bladder empty and moderately full using one repeated measure (bladder fullness (2 levels)) and one independent factor (group (2 levels)). Each muscle was analyzed separately. Post-hoc testing was performed with Duncan's multiple range tests. Statistical significance was set at $P < 0.05$.

RESULTS

Is There a Difference in Balance Between Continent and Incontinent Women?

When COP and angular motion measurements were compared between groups during the six static balance tasks, $dCOP_{AP}$ range ($P = 0.047$), RMS of $dCOP_{AP}$ ($P = 0.035$), and RMS of $dCOP_{ML}$ ($P = 0.045$) were greater in women with SUI compared to continent women (Fig. 2). There was no difference in $dCOP_{ML}$ range, $vCOP_{ML}$, $vCOP_{AP}$, range and RMS of AP angular displacement of the hip, lumbar spine, or sacrum, or ML angular displacement of the sacrum between groups (Tables I and II).

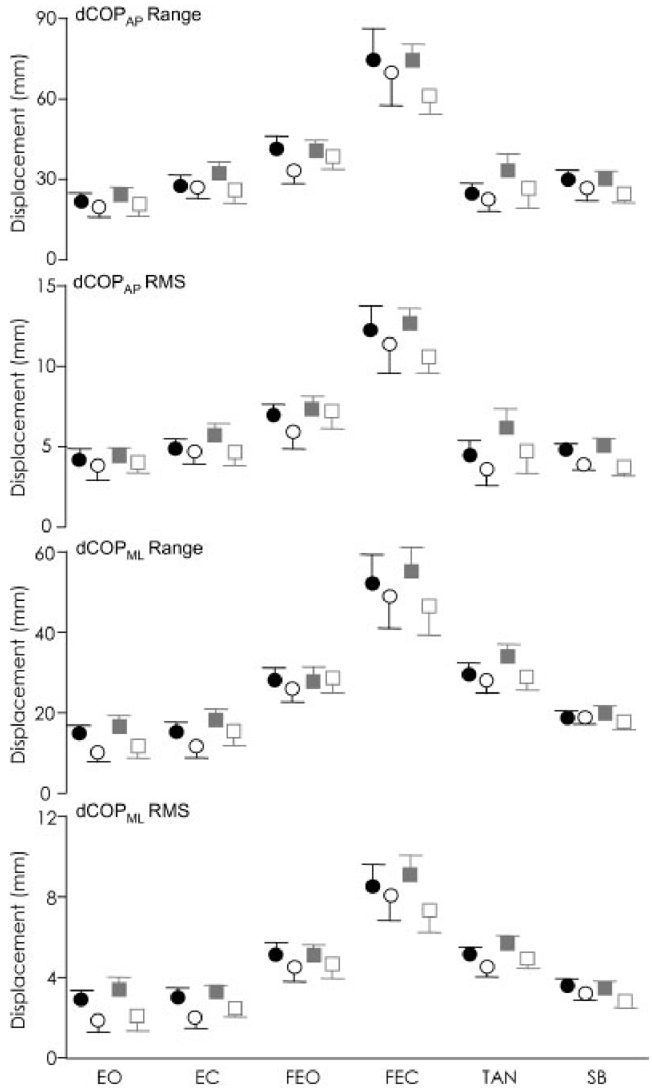

Fig. 2. Range and root mean square (RMS) of center of pressure displacement in the anteroposterior ($dCOP_{AP}$) and mediolateral direction ($dCOP_{ML}$) for incontinent (solid) and continent (open) women with the bladder empty (circles) and moderately full (squares) when standing with eyes open (EO) and closed (EC), on foam with eyes open (FEO) and closed (FEC), in modified tandem stance (TAN) and on a short base (SB).

Is Balance Affected by Task or Bladder Fullness?

There were differences in COP (Table III) and angular motion (Table IV) measurements between balance tasks. Compared to standing with eyes open, most COP and angular motion measures were increased when subjects stood with eyes open on foam, eyes closed on foam, on a short base, and in tandem stance, and AP COP measures were increased with eyes closed. There was no significant interaction between group and balance task for any of the angular motion (all: $P > 0.18$) or COP (all: $P > 0.45$) measures. However, one of the

TABLE I. Main Effects and Interactions (*P*-Values) for Group*, Balance Task and Bladder Fullness for Force Plate Parameters**

	Group	Task	Bladder	Group-task	Group-bladder	Task-bladder	Group-task-bladder
Range $dCOP_{AP}$	0.047	<0.001	0.29	0.82	0.11	0.061	0.45
RMS $dCOP_{AP}$	0.035	<0.001	0.002	0.76	0.32	0.043	0.36
Range $dCOP_{ML}$	0.11	<0.001	0.054	0.45	0.42	0.61	0.45
RMS $dCOP_{ML}$	0.044	<0.001	0.11	0.83	0.40	0.17	0.26
$vCOP_{AP}$	0.85	<0.001	0.69	0.64	0.20	0.36	0.74
$vCOP_{ML}$	0.97	<0.001	0.30	0.98	0.80	0.018	0.31

$dCOP_{AP}$, range of COP displacement in the anteroposterior direction; $dCOP_{ML}$, range of COP displacement in the mediolateral direction; RMS, root mean square; $vCOP_{AP}$, mean velocity of COP displacement in the anteroposterior direction; $vCOP_{ML}$, mean velocity of COP displacement in the mediolateral direction.
*Women with and without stress urinary incontinence.
**Eyes open, eyes closed, foam with eyes open, foam with eyes closed, short base, modified tandem stance.

16 subjects with SUI was unable to complete the tandem stance task, whereas, the 13 continent women were able to complete all tasks.

There was a significant main effect of bladder fullness for RMS of $dCOP_{AP}$, and a significant interaction between bladder fullness and balance task for RMS of $dCOP_{AP}$, $vCOP_{ML}$, RMS of ML sacral movement and range of lumbar spine AP angular motion (Tables I and II). When the bladder was full, subjects had increased $vCOP_{ML}$ ($P < 0.001$) and RMS of $dCOP_{AP}$ ($P < 0.001$) when standing in tandem, and increased RMS of $dCOP_{AP}$ ($P = 0.019$) when standing on foam with eyes open compared to when the bladder was empty. When subjects stood on foam with eyes closed, range of lumbar spine AP angular motion ($P < 0.001$) and RMS of ML sacral movement ($P = 0.014$) decreased when the bladder was moderately full compared to empty. Although not significant, there was a trend for increased range of $dCOP_{ML}$ when the bladder was moderately full (Table I). The other COP and angular motion measurements were unaffected by bladder fullness (Tables I and II).

The interactions between bladder fullness and group, and bladder fullness, group and task were not significant for any of the COP or angular motion measures (Tables I and II). This indicates that both groups were affected by bladder fullness in a similar manner. However, when the bladder was full, 2 (out of 16) women with SUI were unable to complete the tandem stance task, but all (13) continent women completed the task successfully.

Is There a Difference in Trunk Muscle EMG Between Continent and Incontinent Women?

There were differences in EMG between women with and without incontinence (Fig. 3). Women with SUI had greater PF ($P = 0.004$) and ES ($P = 0.03$) EMG compared to continent women, and a trend for greater OE ($P = 0.06$) and RA ($P = 0.08$) EMG. There was no significant difference in OI ($P = 0.22$) EMG between groups.

When the bladder was moderately full, PF EMG decreased ($P = 0.04$), whereas, OI ($P = 0.03$) and RA ($P = 0.005$) EMG increased (Fig. 3). EMG of ES ($P = 0.12$) and OE ($P = 0.29$) was not affected by bladder fullness. There was a trend for a significant interaction between bladder fullness and group for PF EMG ($P = 0.06$) such that when the bladder was moderately full, incontinent women had a tendency for a greater decrease in PF EMG than continent women. The interactions between bladder fullness and group were not significant for the other trunk muscles (all: $P > 0.12$).

DISCUSSION

This study demonstrates that women with SUI have greater COP displacement (range and RMS) than continent women, which suggests that balance ability is impaired in this population. The increased EMG activity of the PF and trunk muscles during quiet stance is consistent with that reported during tasks that challenge the postural control of the trunk.[1] This increased activity may contribute to the decreased balance ability in women with SUI.

Possible Mechanisms for Impaired Balance in Women With Stress Urinary Incontinence

Increased trunk muscle EMG has been shown to decrease balance.[34,35] As muscle contraction increases trunk stiffness, this may reduce the contribution of trunk movement to postural correction,[35] and lead to increased COP displacement in women with SUI. Despite increased muscle activity, angular

TABLE II. Main Effects and Interactions (*P*-Values) for Group*, Balance Task and Bladder Fullness for Angular Motion Measures**

	Group	Task	Bladder	Group-task	Group-bladder	Task-bladder	Group-task-bladder
AP sacrum range	0.25	<0.001	0.73	0.68	0.74	0.18	0.66
RMS AP sacrum	0.30	<0.001	0.83	0.43	0.25	0.59	0.76
ML sacrum range	0.21	<0.001	0.57	0.54	0.74	0.081	0.96
RMS ML sacrum	0.083	<0.001	0.43	0.91	0.52	0.025	0.88
AP lumbar range	0.18	<0.001	0.52	0.18	0.43	0.048	0.090
RMS AP lumbar	0.23	<0.001	0.43	0.39	0.44	0.13	0.21
AP hip range	0.43	<0.001	0.82	0.67	0.84	0.098	0.33
RMS AP hip	0.46	<0.001	0.56	0.58	0.82	0.52	0.88

RMS, root mean square; AP, anteroposterior; ML, mediolateral.
*Women with and without stress urinary incontinence.
**Eyes open, eyes closed, foam with eyes open, foam with eyes closed, short base, modified tandem stance.

TABLE III. Results (P-Values) for Post-Hoc Analysis of Force Plate Parameters for the Different Balance Tasks Compared to the Eyes Open Condition for Women With and Without Incontinence

		Eyes closed	Eyes open foam	Eyes closed foam	Short base	Tandem stance
Range $dCOP_{AP}$		0.003↑	<0.001↑	<0.001↑	0.015↑	0.004↑
RMS $dCOP_{AP}$*	BE	0.048↑	<0.001↑	<0.001↑	0.78	0.23
	BF	0.015↑	<0.001↑	<0.001↑	0.002↑	0.55
Range $dCOP_{ML}$		0.27	<0.001↑	<0.001↑	<0.001↑	<0.001↑
RMS $dCOP_{ML}$		0.62	<0.001↑	<0.001↑	<0.001↑	0.020↑
$vCOP_{AP}$		0.069↑	0.025↑	<0.001↑	<0.001↑	0.036↑
$vCOP_{ML}$*	BE	0.25	<0.001↑	<0.001↑	<0.001↑	0.75
	BF	0.27	0.007↑	<0.001↑	<0.001↑	0.20

$dCOP_{AP}$, range of COP displacement in the anteroposterior direction; BE, bladder empty; BF, bladder full; $dCOP_{ML}$, range of COP displacement in the mediolateral direction; RMS, root mean square; $vCOP_{AP}$, mean velocity of COP displacement in the anteroposterior direction; $vCOP_{ML}$, mean velocity of COP displacement in the mediolateral direction.
↑Represents an increase compared to the reference condition.
*Significant interaction between condition and bladder.

displacement of the lumbar spine was not different between groups in the present study. However, as EMG activity was increased in women with SUI it is likely that trunk stiffness was also increased. Thus, we cannot exclude the possibility that segmental spinal movement may be different between groups and may affect balance.

It is also possible that increased trunk muscle activity may compromise balance in women with SUI via an effect of muscle activity on proprioception. Although it has been suggested that low level muscle activity can increase proprioceptive acuity,[36] co-contraction of muscles surrounding a joint has been associated with decreased movement detection threshold.[37] It has been argued that "noise in the system" due to increased fusimotor discharge rates may lower the sensitivity of the muscle spindle to stretch and impair balance.[34,37]

Finally, increased COP displacement in women with SUI may be related to distraction associated with possible leakage of urine. As attention to cognitive tasks is associated with increased postural sway,[38,39] cognitive attention to continence may affect balance in this population.

Effect of Bladder Filling

When the bladder was moderately full, COP displacement increased in continent and incontinent women. This suggests that bladder fullness is associated with decreased balance ability. As reported previously,[1,11–14] abdominal muscle EMG was also increased when the bladder was moderately full. Thus, for all reasons mentioned above (i.e., decreased trunk mobility, decreased proprioception, and distraction due to possible urine leakage), increased abdominal muscle activity and bladder fullness may impair balance.

When subjects stood on foam with their eyes closed movement of the lumbar spine and sacrum was decreased when the bladder was moderately full. As this task was associated with the greatest disturbance to balance, it is possible that increased muscle activity may be exaggerated in this condition due to fear of falling,[40] and may result in decreased trunk motion. This may represent a motor control strategy used to attempt to control, or decrease, COP displacement and maintain balance in a challenging situation.

Women with SUI had decreased PF EMG when the bladder was moderately full compared to empty. Previous studies have identified decreased resting and postural PF EMG[1] and decreased PF muscle endurance[41] in women with SUI following bladder filling. Although there are also reports of increased PF activity during bladder filling with a urethral catheter,[42] it is uncertain whether the presence of the catheter affects the response.

The combination of decreased PF EMG and increased abdominal muscle EMG in women with SUI would be expected to negatively affect continence. Although the transmission of increased intra-abdominal pressure to the urethral may be a mechanism to assist in urinary continence,[43] in the absence of an increase in PF muscle activity intra-urethral pressure would not likely exceed intra-vesical pressure.[44] Thus, increased abdominal muscle activity and increased

TABLE IV. Results (*P*-Values) for Post-Hoc Analysis of Angular Motion Measures for the Different Balance Tasks Compared to the Eyes Open Condition for Women With and Without Incontinence

		Eyes closed	Eyes open foam	Eyes closed foam	Short base	Tandem stance
AP sacrum range		0.19	0.13	<0.001↑	0.001↑	0.16
RMS AP sacrum		0.15	0.093	<0.001↑	<0.001↑	0.26
ML sacrum range		0.14	<0.001↑	<0.001↑	<0.001↑	0.022
RMS ML sacrum*	BE	0.16	<0.001↑	<0.001↑	<0.001↑	<0.001↑
	BF	0.081	<0.001↑	<0.001↑	<0.001↑	0.008↑
AP lumbar range*	BE	0.46	0.50	<0.001↑	0.38	0.45
	BF	0.52	0.39	0.003↑	0.060	0.31
RMS AP lumbar		0.47	0.46	<0.001↑	0.15	0.48
AP hip range		0.13	<0.001↑	<0.001↑	<0.001↑	0.006↑
RMS AP hip		0.13	0.003↑	<0.001↑	<0.001↑	0.12

RMS, root mean square; AP, anteroposterior; ML, mediolateral; BE, bladder empty; BF, bladder full.
↑Represents an increase compared to the reference condition.
*Significant interaction between condition and bladder.

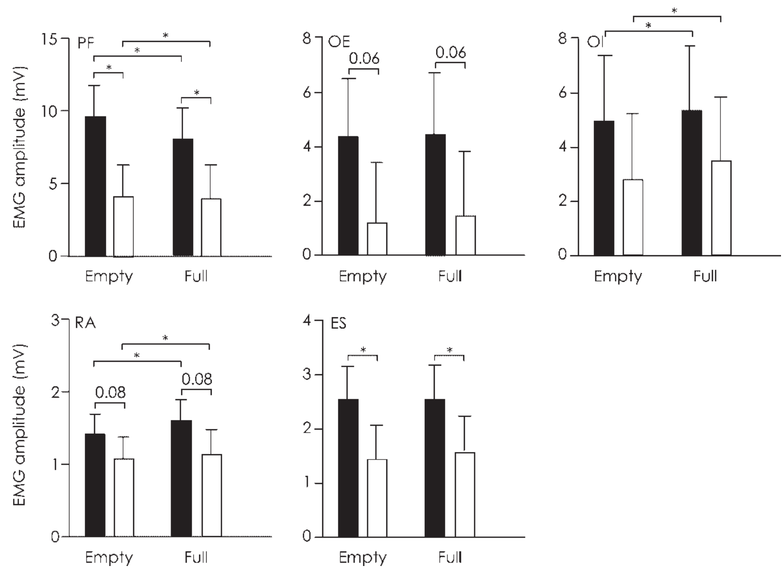

Fig. 3. EMG amplitude when standing on a firm surface with eyes open. Mean raw EMG of the pelvic floor (PF), obliquus internus abdominis (OI), obliquus externus abdominis (OE), rectus abdominis (RA) and erector spinae (ES) muscles are shown for incontinent (solid) and continent (open) women when the bladder was empty and moderately full; $^*P < 0.05$.

intra-abdominal pressure may challenge continence. Furthermore, if continence is compromised and urine leakage occurs, attention may be diverted from the balance task and performance may be impaired.

Methodological Considerations

Women were eligible to participate in this study based on reported urine leakage during activities that are associated with increased intra-abdominal pressure, but a diagnosis of SUI was not confirmed with urodynamics testing. The severity of SUI among participants ranged from mild (drops or splashes of urine leakage at least a few times a month) to more severe (splashes of urine leakage daily) symptoms. Although inclusion of women with mild symptoms is representative of a large portion of the population with SUI,[45] differences in balance between continent and incontinent women may have been larger if inclusion was limited to women with moderate and severe symptoms.

Repeated balance testing is associated with learning.[46,47] To compare COP displacement with an empty and moderately full bladder, balance tasks were repeated after $\sim$20 min. This may have led to an improved ability to perform the balance tasks which would have decreased the likelihood of detecting any increase in COP displacement when tasks were performed with the bladder moderately full. For this reason we may have underestimated the differences with bladder fullness.

As discussed previously, there are limitations to EMG normalization in this population as normalization to maximal voluntary contraction is not possible. However, we did not expect any difference in the soft tissue between the muscle and electrode that would affect the use of raw EMG data to compare between groups of women. Furthermore, as muscle mass has been suggested to be less in incontinent women,[48–50] we would expect PF EMG to be smaller rather than larger in this these women. Thus, if muscle mass contributes to EMG changes, differences in EMG in this study may be underestimated.

Clinical Implications

Although risk of falls is multifactorial, postural sway, and COP displacement are related to falls and are included in falls risk assessments.[51–53] Links have been established between area of sway and ML COP displacement and falls in elderly individuals,[51,54,55] and improvement in COP displacement is associated with decreased falls risk.[56,57] Thus, it is possible that as COP displacement is greater in women with SUI, they may have an increased risk of falling.

Although research suggests that urinary incontinence is associated with a higher risk of falls in elderly individuals,[58–63] only one study has specifically investigated falls in people with SUI.[59] That study found that self-diagnosis of SUI did not independently predict self-report of falls in older women (mean age of 78 years).[59] However, as balance decreases with age,[64] factors other than SUI may negatively affect balance in women of this age. Thus, further research is needed to investigate falls risk in women with SUI of all ages.

It must also be considered that people with poor balance secondary to increased trunk muscle activity may be prone to SUI. As abdominal muscle activity increases pressure within the bladder, demand on the PF muscles and other structures in the pelvis to maintain the position of the bladder neck and sufficient urethral pressure to ensure continence is increased. Thus, decreased balance ability and increased risk of SUI may have a common underlying mechanism related to altered control of the trunk muscles.

CONCLUSIONS

This study has demonstrated that women with SUI have greater COP displacement than continent women. This suggests that balance is impaired, and risk of falls may be increased in this population. Increased activity of the PF and trunk muscles in women with SUI may impair balance as a result of a reduced contribution of trunk movement to postural correction or compromised proprioceptive acuity. Alternatively, distraction due to conscious effort to maintain

continence may divert attention from the balance task. Further research is warranted to investigate the mechanism underlying decreased balance in women with SUI, and the effect of training programs to improve balance in this population.

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