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Comparison of Postural Control of Females with and without Urinary Incontinence: A Case-Control Study

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Abstract

Background: So far, there is much less information about the effects of urinary incontinence on postural control. Therefore the aim of this study is to investigate the differences in postural control using linear and non-linear analyses of the center of pressure (COP) time-series in anteroposterior (AP) and mediolateral (ML) directions between females with and without stress urinary incontinence (SUI).

Methods: This case-control study included 22 continent females and 22 SUI females. In this study, static postural control during four different postural tasks was evaluated using a force plate. All participants performed separate 60-sec standing trials with eyes open in the empty bladder and full bladder conditions. Mean, range, velocity, area circle of COP displacements, and approximate entropy (ApEn) of COP time-series were calculated from the 60-sec standing trials for all participants. The independent sample t-test was also used to compare COP variables between the two groups and paired sample t-test was used to assess changes between the full bladder and empty bladder conditions within each group. The effect size of Cohen's d was used to assess the magnitude of the differences between the two groups.

Results: The findings revealed a significant group × task interaction for the mean of ML displacement and ApEn of COP. SUI females showed more AP displacement range in the full bladder (pvalue= 0.020, effect size=0.74) and a higher velocity (empty bladder: p=0.040, effect size=0.63) (full bladder: p=0.020, effect size=0.75) than the continent group. Generally, the SUI females had lower ApEn than the continent females, although the differences were not significant. While the variables of COP were unaffected by bladder fullness in the continent group, the SUI group in full bladder condition experienced more AP range (p=0.030), and area circle (p=0.007) of COP sway in quiet standing.

Conclusion: These results provide more support for the hypothesis that postural control can be impaired following SUI, although future investigations on this topic are recommended.

Keywords: Urinary Incontinence, Pelvic Floor Disorder, Postural Control, Balance, Center of Pressure

Conflicts of Interest: *None declared*
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Introduction

Postural control is the result of a complex and proper interaction between physiologic systems of the human body (1-3). Two main purposes of the postural control system are the ability to maintain appropriate body orientation in

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↑What is "already known" in this topic:
Human balance can be affected through the impairment of any one of the sensorimotor systems. Appropriate function of these systems to maintain an ideal balance is crucial. Stress urinary incontinence (SUI) is a common disorder among females. So far, there is much less information about the effects of urinary incontinence on postural control.

→What this article adds:
Our results revealed there were statistical differences between the females with and without SUI in the linear parameters of COP trajectories. Additionally, in the full bladder condition, the SUI group experienced more challenges in postural control. While the non-linear analysis of COP time-series showed no significant difference between the two groups.

space and body stability during functional activities (1). Appropriate function of the sensorimotor control systems, including the visual, vestibular, s omatosensory, and musculoskeletal, to maintain an ideal postural control is crucial (2). The final output of the postural control system has been reported to can be affected through the impairment of any one of the sensorimotor systems (4).

Few studies reported an altered postural balance in the presence of stress urinary incontinence (SUI). SUI is defined as the complaint of any involuntary loss of urine during physical activities, coughing, or sneezing. It has been displayed that the SUI subjects had a different postural control compared to the continent subjects in full bladder condition (5, 6). Furthermore, It has previously been shown that the function and coordination of the pelvic floor and the trunk muscles have been impaired in SUI subjects, and the studies reported that compared to the continent women, SUI subjects experienced an increase in the trunk and abdominal muscles activity and a delay in the onset of the pelvic floor muscles activity during functional movements (7-9). It seems when the bladder is under full condition, due to possible reasons such as an increase in trunk muscle activity, increased demand on the pelvic muscles, and delay in postural responses of pelvic floor muscle, postural balance following urinary incontinence may be altered and compromised.

To determine the center of pressure (COP) displacement using the force plate in quiet standing is one of the most common methods for measuring postural control (3, 4). The COP is not considered as an anatomical point. It is the point location of the application of the ground reaction force on the plantar surface of the foot that is used for representing whole-body dynamics (4, 10). The COP trajectories have two dimensional including anterior-posterior (AP) and medial-lateral (ML) (4, 10).

Data from the studies suggest that there are two analysis techniques to interpret the behavior of the COP time-series, including traditional linear (e.g., mean of displacement, range of displacement, the velocity of COP) and non-linear analyses (1). In the traditional method, any variation from the mean of the mentioned parameters is noticed as noise or error in the output of postural control systems (11).

Recently, considerable literature has grown up around the theme of non-linear analyses of COP time-series such as approximate entropy (ApEn) for postural control assessment. ApEn is an alternative method to show the amount of the complexity, irregularity, and variability of COP time-series. A decreased ApEn shows more regularity of the COP time series. The increasing regularity of the COP (lower ApEn) is indicative that the postural control system is more predictable and may be less able to adapt to the environmental conditions and perturbations, so the stability of the system is maintained using the repetitive sway behavior (1, 4). Previous investigations have established that based on the ApEn, in the healthy control group in upright standing, there is an irregular COP time series with small amplitude (1, 12, 13).

To date, few studies exist in the field of evaluation of postural control in incontinent subjects and it is not exactly clear whether the presence of SUI can be related to the alternation and impairment in the postural control.

Additionally, the studies in this field have only focused on linear analyses of COP time-series while in our study to provide a better understanding of the effects of SUI on the postural control, the ApEn of COP trajectories also was employed.

So, the primary objective of this study was to compare linear parameters of COP time-series between women with and without SUI, and for secondary objective was to investigate the differences in the amount of the irregularity of COP sway using ApEn between the two groups that to determine whether the postural control could be disturbed by SUI.

Methods

Participants

Twenty-two continent females and twenty- two females with SUI participated in this case-control study. This study was carried out from April 2019 to October 2019 at the biomechanics lab of the physiotherapy department of Iran University of Medical Sciences. In this study, group or frequency matching was used, and the number of delivery and BMI were matched between groups. The procedures of this study were approved by the ethics committee of Iran University of Medical Sciences (approval ethical code: IR.IUMS.REC.1397.820).

The participants with SUI were referred by gynecologists, and urologists and continent subjects were recruited from the staff of the university. One of the investigators in this study (A, N), who had greater than 10 years of experience in the field of the examination and treatment of various types of pelvic floor dysfunctions, performed the clinical examination to determine the pelvic floor muscles strength in both groups and severity of the SUI in the incontinent group.

Inclusion criteria for selecting the incontinent group were as follows: having stress or mixed urinary incontinence during activities such as jumping, lifting, coughing, sneezing, running, and heavy lifting, and MBI<25. Participants in the incontinent groups were excluded from the study if they had: pure urge urinary incontinence, fecal incontinency, pregnancy within the last 2 years, history of ankle sprain in the past 1 year, low back pain, and knee pain more than 3 according to visual analog scale (VAS), receiving conventional or surgical treatment for urinary incontinence within the last 1 year, history of fracture in the lower extremity and pelvic within the last 1 year, neurological disorders such as MS, Parkinson, and respiratory diseases such as chronic obstructive pulmonary disease. The exclusion criteria for the continent group were the same as for the incontinent group, and having stress, urge, or mixed urinary incontinence. The written informed consent was provided from all participants before the data collection. Demographic and baseline data including age, weight, height, number of the childbirth, type of childbirths, and time of the last childbirth, were recorded for both groups.

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Sample size

The sample size was calculated for exploring a significant difference in linear parameters of COP between the females with and without SUI. Considering α=0.05, power= 0.8, mean (SD) of continent group=3(0.98), and mean (SD) of SUI group=3.82 (0.82) (5), the sample size was estimated 22 subjects in each group.

Assessment of pelvic floor muscles strength

Strength assessment of pelvic floor muscles for all participants was performed by (A, N) using the Modified Oxford Scale. The modified Oxford Scale is a common, simple, and reliable method to evaluate pelvic floor muscles strength (14). First, the participants were given a verbal description of the test procedure. Then the participants were asked to lie in the crock lying position and to perform maximal contraction of pelvic floor muscle. Next, the participants were instructed to relax the pelvic floor muscles, and after that, the examiner inserted the index and middle fingers approximately 4 cm inside their vagina. Finally, the strength of pelvic floor muscles was ranged quantitatively using the Modified Oxford Scale as follows: grade 0 "no contraction", grade 1 "minor muscle flicker", grade 2 "weak muscle contraction", grade 3 "moderate muscle contraction", grade 4 "good muscle contraction", and grade 5"strong muscle contraction". Before testing, the participants of both groups had emptied their bladders. Each participant performed pelvic floor muscle contraction three times and the strongest contraction was selected for further analyses.

Evaluation of severity of SUI

In this case-control study, two questionnaires, including QUID (Questionnaire for Urinary Incontinence Diagnosis) and severity index, were used to assess SUI severity.

QUID is a 6-item questionnaire divided into 2 subscales: SUI subscales (3 items (item1, item 2, item 3)) and urges urinary incontinence subscale (3 items (item4, item 5, item 6)). A six-point Likert scale is used to determine the severity of each item. (None of the time, rarely, once in a while, often, most of the time, and all the time) (15). All items are scored from 0 to 5, and the higher score in each subscale indicates the higher severity of urinary incontinence (Table 1).

In addition to the QUID, the severity index is a two-item scale that is widely used to measure the frequency and severity of the SUI. In this tool, a four-point Likert scale is used to determine the frequency of the episodes of urine loss (less than once a month, one or more times a month, and one or more times a week, every day), and the severity of the SUI is measured based on the amount of urine loss (one drop or less and two drops or more). The Scores for this scale are ranged from 1-2 (mild urinary incontinence), 3-5 (moderate urinary incontinence), and 6-8 (severe urinary incontinence) (16) (Table 1).

Recording of COP measurements

The sway and fluctuations of COP were recorded using a stable force plate (model: Kistler, info@kistler.com) with a sampling frequency of 100 Hz and a low pass filter with a cutoff frequency of 10 Hz (5, 6). The test procedures were fully explained to the participant before the actual trial recording. The participants were asked to stand upright on the force plate without shoes with their feet shoulder-width apart, their arms at the side along the body, to locate their feet on the center of the force platform, and to face forward. They must not have crossed their legs onto the other on the force platform.

With open eyes, each participant randomly performed four different trials in the two conditions including empty bladder condition and full bladder condition as follows: (1) Double Leg standing on the rigid surface (DL) (empty bladder/ full bladder (single task)), (2) Double Leg standing on the Unstable surface (foam) (DLU) (empty bladder/ full bladder (single task)), (3) Double Leg standing on the rigid surface with a Cognition task (backward counting)(DLCo) (empty bladder/ full bladder (dual-task)), (4) Double Leg standing on Unstable surface (foam) with a Cognition task (backward counting) (DLUCo) (empty bladder/ full bladder (dual-task)). All trials were conducted in both conditions of the empty and full bladder.

For empty bladder conditions, the instruction was given to the subjects to void their bladder before the start of trials. In full bladder condition, the subjects were asked to drink 3-4 glasses of water until they said need to empty their bladder, and 15-20 min after water consumption, the measurements were performed with full bladder condition. For the dual-task trials, the participants were given a random number between 100 and 130 and asked to count backward aloud in steps of three. For each participant, the order of the bladder conditions was randomly assigned, and also the sequence of the trials for each bladder condition was randomized to eliminate the possible learning effects due to test order. Importantly, the participants first completed the trials with a bladder condition (empty or full) then, the trials with the other bladder condition were carried out (empty or full). Each trial was recorded after a 5-second standing on the force platform, lasted 1 min, and was repeated two times. The mean value of the two repetitions was used for statistical analyses. A 30-second rest was given between two repetitions, and a two-minute rest was considered between trials to decrease participant fatigue. The participants also had a period of rest from 30 min to 1 h between two bladder conditions. To standardize the foot position for each participant, the position of the feet of each participant was drawn on a piece of paper putting on the force platform, and the participant was instructed to hold their feet on the marked place.

Data from the force platform were saved and transferred onto a personal computer. The Linear and non-linear variables of COP were extracted by a written customized program using MATLAB software version 2014-a by a skilled investigator (H, GH). The linear outcomes in this study included the following: 1) mean of displacement of COP in antero-posterior (Mean $dCOP_{AP}$) and mediolateral (Mean $dCOP_{ML}$) directions (inempty bladder/full bladder), 2) range of displacement of COP in antero-posterior (Range $dCOP_{AP}$) and mediolateral (Range $dCOP_{ML}$) directions (in empty bladder/full bladder), 3) velocity of COP displacement in antero-posterior (Vel $dCOP_{AP}$) and medi-olateral (Vel $dCOP_{MI}$) directions (in empty bladder/full bladder), 4) area circle of the COP trajectories (AC COP) (in empty bladder/full bladder).

The only non-linear variable obtained from the analysis of COP trajectories included approximate entropy (ApEn) in both directions of antero-posterior ($ApEn_{AP}$) and me-diolateral ($ApEn_{MI}$) (in empty bladder/full bladder).

Statistical analysis

All analyses were performed using STATA (Software for Statistics and Data Science) version 14.2.

Data distribution was checked using the skewness, kurtosis, and p-p (probability–probability) plot. Data transformation was performed using the neperian logarithm (ln) for linear and non-linear variables of COP that did not meet the assumptions of normal distribution.

Baseline variables were compared between the two groups using the exact chi-squared test for nominal variables, the independent sample t-test for the variables with a normal distribution (age, weight, height, BMI, last time of the childbirth), and the Mann-Whitney U test for the variables that did not have the assumptions of normal distribution (number of childbirth, last time of the birth).

The interactions between the postural tasks (Double Leg standing on the rigid surface (DL), Double Leg standing on the Unstable surface (foam) (DLU), Double Leg standing on the rigid surface with a Cognition task (backward counting) (DLCo), Double Leg standing on Unstable surface (foam) with a Cognition task (backward counting) (DLUCo)), and one independent factor (groups (the SUI group and continent group)) were assessed using 4x2 repeated measures analysis of variance (RM-ANOVA) separately for bladder conditions (empty bladder and full bladder condition.). Each variable was analyzed with a separate analysis of variance (ANOVA).

The independent sample t-test was also used to compare the mean values of non-linear and linear variables of COP between the two groups. To assess changes between the full bladder and empty bladder conditions within each group, the paired sample t-test was used.

One-way ANOVAs with pairwise comparisons (Bonferroni adjustment) identifying the location of significant difference were used to assess the differences between continent group and different levels of the severity of inThe magnitude of the differences between the two groups was evaluated using standardized mean differences (SMD) of Cohen's d. It is interpreted as follows: SMD from o to 0.19 (trivial zone), SMD from 0.2 to 0.49 (small correlation zone), SMD from 0.5 to 0.79 (medium correlation zone), and SMD≥ 0.8 (large correlation zone) (17). A $p<0.05$ was statistically considered significant.

Results

The general characteristics of all participants are shown in Table 1. No significant differences in demographic variables, parity, type of childbirth, last time of childbirth were found between the two groups ($p>0.05$). It also can be seen from the data in Table 1 that compared to the SUI group, the continent group had stronger pelvic floor muscles ($p<0.001$).

Of the incontinent group, three participants had mixed-urinary incontinence, and the other participants had SUI. According to the severity index of urinary incontinence, of the 22 women with SUI participating in this study, 40.1% had mild urinary incontinence, 27.2% had moderate uri nary incontinence, and 31.8% reported severe urinary incontinence. Among the women suffering from SUI, 63.6% reported using a sanitary pad during activity daily living (ADL).

Primary results

Linear parameters of COP time-series

Figures 1-4 present the mean and 95% CI of mean for all linear parameters of COP during different postural tasks

Table 1. General characteristics of the continent group and SUI group

Variables	Continent group (n=22)	SUI group (n=22)	*P* value
Age (years)	40.95 (±5.79)	44.50 (±8.48)	0.110
Weight (kg)	66.95 (±5.75)	69.59 (±5.22)	0.110
Height (cm)	162.36 (±7.10)	162.09 (±5.85)	0.891
BMI (kg/m^2)	20.63 (±1.73)	21.48 (±1.68)	0.101
Number of deliveries	2 [2,1]	2 [2,1]	0.420
Strength of pelvic floor muscles	4 [4,3]	2 [3,2]	<0.001
Type of childbirth			
Vaginal delivery	5 (22.7%)	10 (45.5%)	0.090
Cesarean	14 (63.6%)	12 (54.5%)	
Both	3 (13.6%)	0	
Last time of childbirth (year)	10.72 (±6.24)	12.59 (±8.34)	0.400
Using pad	63.6% (14)	0%	
Leakage according to QUID			
Sneeze/cough	10 (22.7%)	-	
Bending/lifting	-	-	
Jog/walking/exercise	2 (4.5%)	-	
Two activities or more	10 (22.7%)	-	
Severity index for urine incontinence			
Mild incontinence	9 (40.1%)	-	
Moderate incontinence	6 (27.2%)	-	
Severe incontinence	7 (31.8%)	-	

BMI=Body mass index, IQR= interquartile range, SUI=stress urinary incontinence, SD= standard deviation, QUID= questionnaire for urinary incontinence diagnosis.

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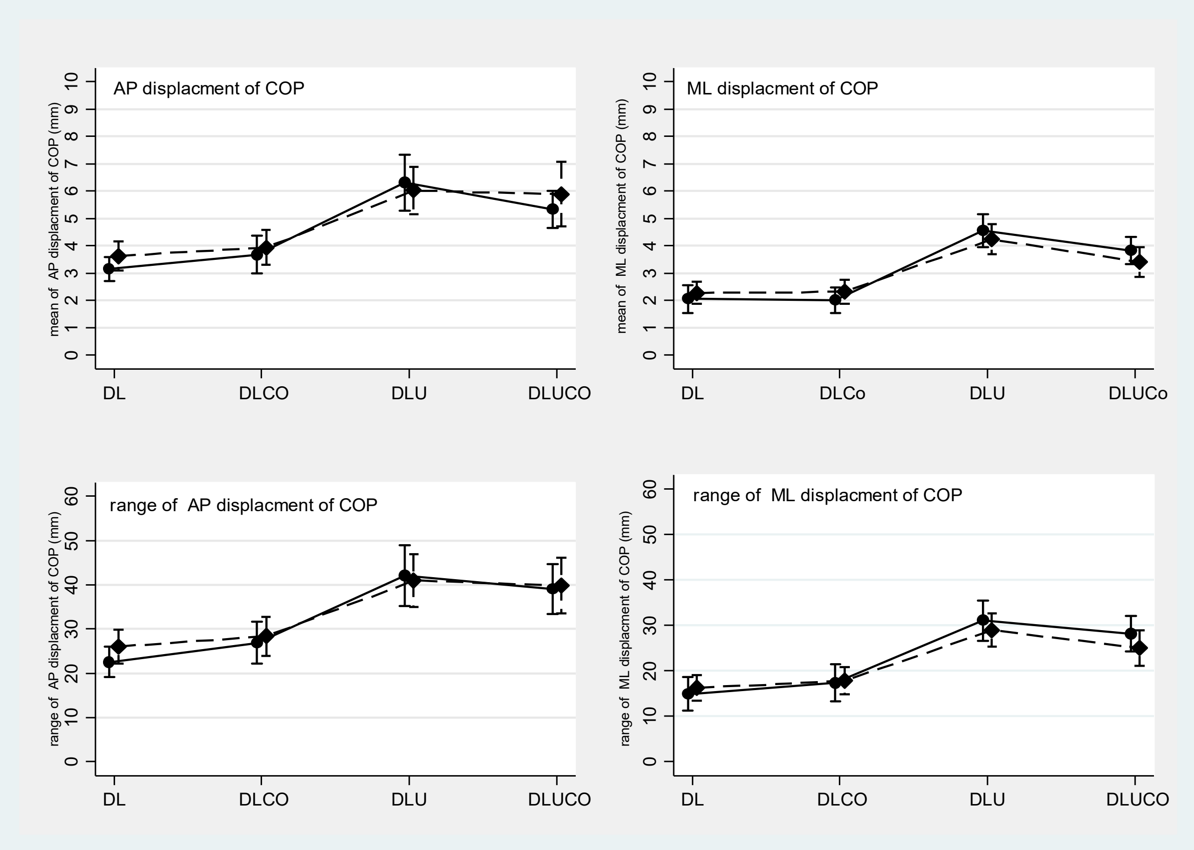

Fig. 1. Mean and 95% CI of the mean of COP displacement and range of displacement of COP in the anteroposterior and mediolateral directions of four postural tasks in empty bladder condition: Double Leg standing on the rigid surface (DL), Double Leg standing on the rigid surface with the Cognition task (backward counting) (DLCo), Double Leg standing on the Unstable surface (foam) (DLU), Double Leg standing on Unstable surface (foam) with the Cognition task (backward counting) (DLUCo).
Continent group (solid line), SUI group (dash line)

for both groups. No group × task interaction was revealed for linear parameters of COP including mean and range of displacement, velocity, and area circle of COP time-series in both bladder conditions and there was a similar trend in the two groups for the changes of linear variables of COP during four postural tasks. A significant group × task interaction was found for the mean of displacement of COP in the ML direction (Mean $dCOP_{ML}$) in the empty bladder condition.

The results, as shown in Tables 2 and 3, indicate that task effect for all linear variables of COP time-series in both bladder conditions is significant. As Figures 1-4 present, the results demonstrated that both groups had a tendency of increased sway from task1 (standing on the rigid surface (DL)) to task 4 (standing on the foam surface and backward counting (DLUCo)) regardless of bladder condition, and the highest and lowest mean values of displacement, range, and area circle of COP time-series were in the tasks of standing on the foam surface (DLU) and standing on the rigid surface (DL), respectively.

Mean values (SD) of displacement (Mean dCOP) , and range of displacement of COP (Range dCOP) for the task of standing on the rigid surface (DL) were: [empty bladder condition: SUI group: Mean dCOP in AP/ML=3.63 (1.2) / 2.28 (0.9) mm, Range dCOP in AP/ML=26.02 (8.7) / 16.26 (6.31) mm , continent group: Mean dCOP in AP/ML=3.15 (1) / 2.05 (1.13) mm, Range dCOP in AP/ML=22.58 (7.9) / 14.93 (8.30) mm] [full bladder condition: SUI group: Mean dCOP in AP/ML=3.91 (1.11) / 2.44 (0.94) mm, Range dCOP in AP/ML=28.29 (9.3) / 16.98 (5.29) mm, continent group: Mean dCOP in AP/ML=3.36 (1.2) / 2.21 (1.33) mm, Range dCOP in AP/ML=22.46 (7.58) / 16.24 (8.87) mm].

Mean values (SD) of displacement (Mean dCOP), and range of displacement of COP (Range dCOP) for the task of standing on the foam surface (DLU) were [empty bladder condition: SUI group: Mean dCOP in AP/ML=6.02 (1.94) / 4.24 (1.24) mm, Range dCOP in AP/ML=40.98 (13.43) / 28.94 (8.20) mm (continent group: Mean dCOP in AP/ML=6.31 (2.31) /4.55 (1.36) mm, Range dCOP in AP/ML=42.06 (15.49) / 31.04 (10.1) mm] [full bladder condition: SUI group: Mean dCOP=6.49 (3.34) / 4.4 (1.21) mm, Range dCOP=41.96 (11.97) / 29.58 (7.58) mm (continent group: Mean dCOP=6.45 (1.99) / 4.69 (1.17) mm, Range dCOP=41.08 (10.31) / 29.41 (8.42) mm].

Mean values of area circle of COP sway (AC COP) for the task of standing on the rigid surface (DL) were [SUI group in empty bladder/full bladder=304.10 (220.46) /387.74 (20.69) mm^2, continent group=239.79 (182.61) / 281.53 (248.54) mm^2] and mean values of area circle of

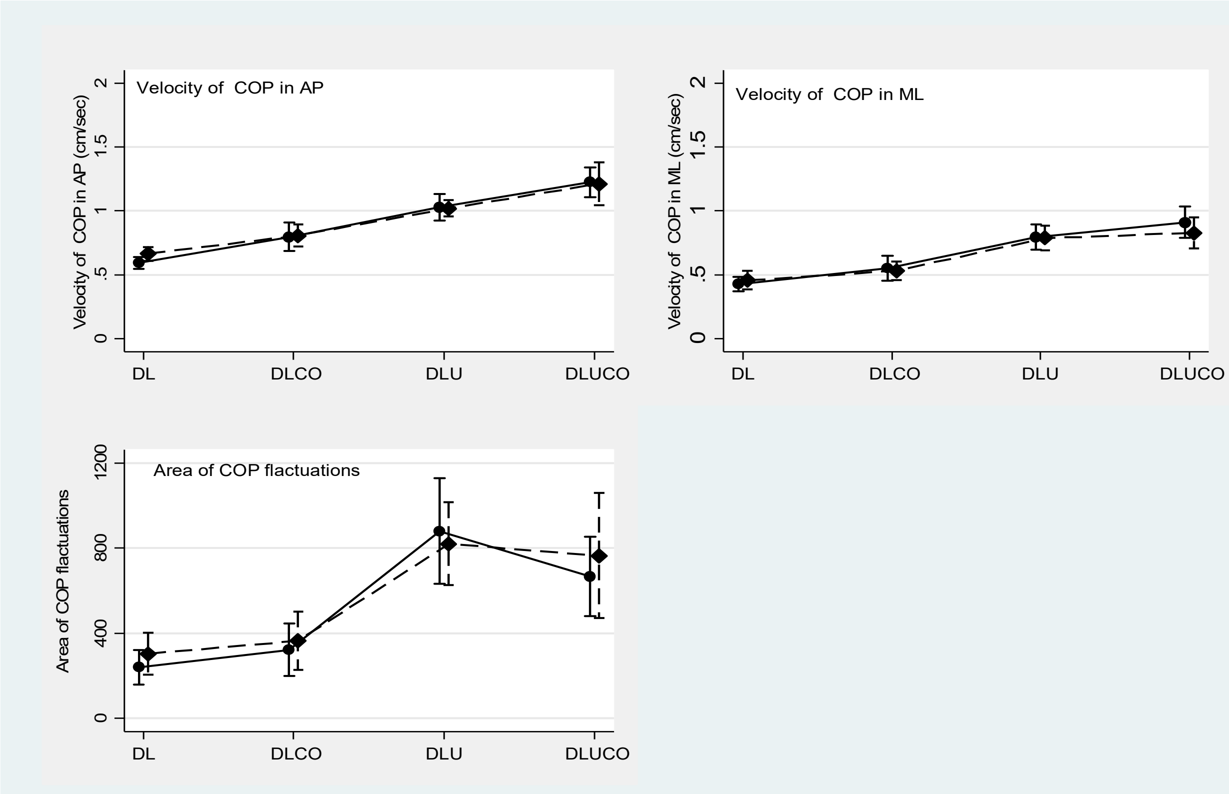

Fig. 2. Mean and 95% CI of the mean of COP velocity in the anteroposterior and mediolateral directions and area of COP fluctuations of four postural tasks in empty bladder condition: Double Leg standing on the rigid surface (DL), Double Leg standing on the rigid surface with the Cognition task (backward counting) (DLCo), Double Leg standing on the Unstable surface (foam) (DLU), Double Leg standing on Unstable surface (foam) with the Cognition task (backward counting) (DLUCo).)
Continent group (solid line), SUI group (dash line)

COP sway (AC COP) for the task of standing on the foam surface (DLU) were [SUI group in empty bladder/full bladder=820.69 (440.92) / 892.82 (641.31) mm^2, continent group=879.72 (557.83) / 839.21(420.48) mm^2].

Additionally, the mean of the velocity of COP time-series (Vel dCOP) was not similar throughout all conditions, and in the task of standing on the foam surface and backward counting (DLUCo), both groups experienced the highest velocity and the lowest mean of velocity was related to the task of standing on the rigid surface (DLU).

Between-group comparisons in the empty bladder condition showed that there were no significant differences between the two groups in the mean dCOP, range dCOP, AC COP in both directions of AP and ML, and Vel dCOP in the ML direction. While the velocity in AP direction (Vel dCOP$_{AP}$) showed a statistical difference between the two groups and compared to the continent group, the SUI group had more velocity in the AP direction (p=0.040) (Table 2).

When the bladder was full, no significant differences were found between the two groups in the variables of mean dCOP $_{AP/ML}$, range dCOP $_{ML}$, Vel dCOP$_{ML}$, and area circles of COP time-series (p>0.05). While mean of Vel dCOP$_{AP}$ (p=0.020) and range dCOP $_{AP}$ (p=0.020) of COP were significantly larger in the SUI group compared to the continent group (Table 3).

In addition to the statistical significance, the magnitude of the differences between the two groups was determined using Cohen's d effect size. When the bladder was empty, the effect sizes were between the trivial region and small region (effect size<0.5) and only for the Vel dCOP$_{AP}$ [0.63 (0.02 to 1.23)], the size of differences beween the two groups was medium (Table 2).

In the full bladder condition, for the mean dCOP $_{AP/ML}$, range dCOP $_{ML}$, Vel dCOP$_{ML}$, and area circles of COP, the magnitude of differences between the continent and incontinent groups were low (effect size<0.5). While the effect size for range dCOP $_{AP}$ [0.74 (0.13 to 1.35)] and Vel dCOP$_{AP}$ [0.75 (0.13 to 1.35)] was medium (Table 3).

Secondary results

Approximate entropy (ApEn)

The results of RM-ANOVA revealed no group × task interaction for the approximate entropy (ApEn) in AP direction in both bladder conditions, while group × task interaction in the ML direction in empty and full bladder conditions was significant. The main effect of the task on the mean of ApEn in the ML and AP directions for both bladder conditions was significant (Table 4).

Figure 5 provides the mean and 95% CI of the mean for different postural tasks in both groups. In the AP direction in both bladder conditions, the SUI group had lower ApEn mean values than the continent group for all postural tasks. In the ML direction, the SUI group generally showed greater ApEn mean values than the continent group in the postural tasks of standing on the foam surface

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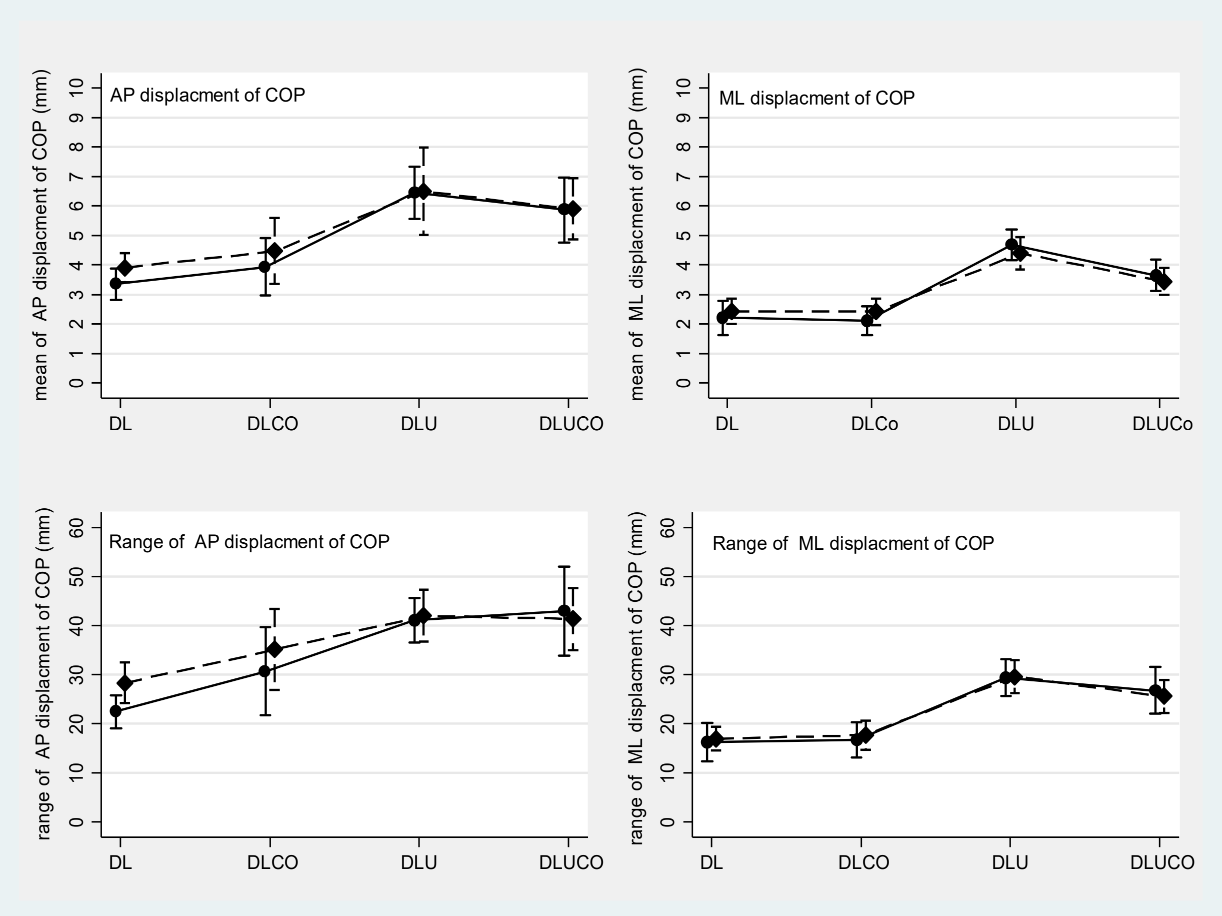

Fig. 3. Mean and 95% CI of the mean of COP displacement and range of displacement of COP in the anteroposterior and mediolateral directions of four postural tasks in full bladder condition: Double Leg standing on the rigid surface (DL), Double Leg standing on the rigid surface with the Cognition task (backward counting) (DLCo), Double Leg standing on the Unstable surface (foam) (DLU), Double Leg standing on Unstable surface (foam) with the Cognition task (backward counting) (DLUCo).
Continent group (solid line), SUI group (dash line)

(DLU) in both bladder condition and standing on the foam surface and backward counting (DLUCo) in full bladder condition. However, between group-comparison using independent sample t-test showed no significant differences between the two groups for ApEn $_{AP/ML}$.

In addition to the statistical testing, the effect size values of ApEn $_{AP/ML}$ were between the trivial zone and small association zone and had a wide confidence interval. Only the difference magnitude of ApEn $_{ML}$ means between the two groups in the task of standing on the rigid surface with backward counting (DLCo) showed a medium effect size [-0.59 (-1.19 to 0.02)], although the difference between the two groups did not reach a significant level (p=0.061).

Post-hoc results

Full bladder vs. empty bladder

When linear parameters of COP were compared between empty bladder condition and full bladder condition, in the continent group, there was no difference in the mean dCOP $_{AP/ML}$, range dCOP $_{AP/ML}$, Vel dCOP$_{AP/ML}$, and area circles of COP sway between two bladder conditions (p>0.05) (Table 5).

In the SUI group, when the bladder was full, the subjects showed a significant increase in the range dCOP $_{AP}$ (p=0.030) and area circle of COP sway (p=0.007) in the task standing on the rigid surface (DL) compared to the empty bladder condition. In comparison, the other linear variables of COP were unaffected by bladder fullness (p>0.05) (Table 5).

For the ApEn $_{AP/ML}$ parameter, no significant difference between the two bladder conditions was evident, and compared to the full bladder condition, the mean values of ApEn $_{AP/ML}$ did not statistically differ from empty bladder condition in both groups (p>0.05) (Table 5).

Analysis based on the severity of incontinence

Among the SUI group, 9, 6, and 7 participants were classified with the severity index of incontinence mild, moderate, and severe, respectively. Results of the one-way ANOVA revealed that there was a significant difference between the four groups of no incontinence (n=22), mild incontinence (n=9), moderate incontinence (n=6), severe incontinence (n=7) in the velocity of COP sway in ML direction (Vel dCOP $_{ML}$) of the task of standing on the rigid surface (DLU) (F=2.98, p=0.043), when the bladder

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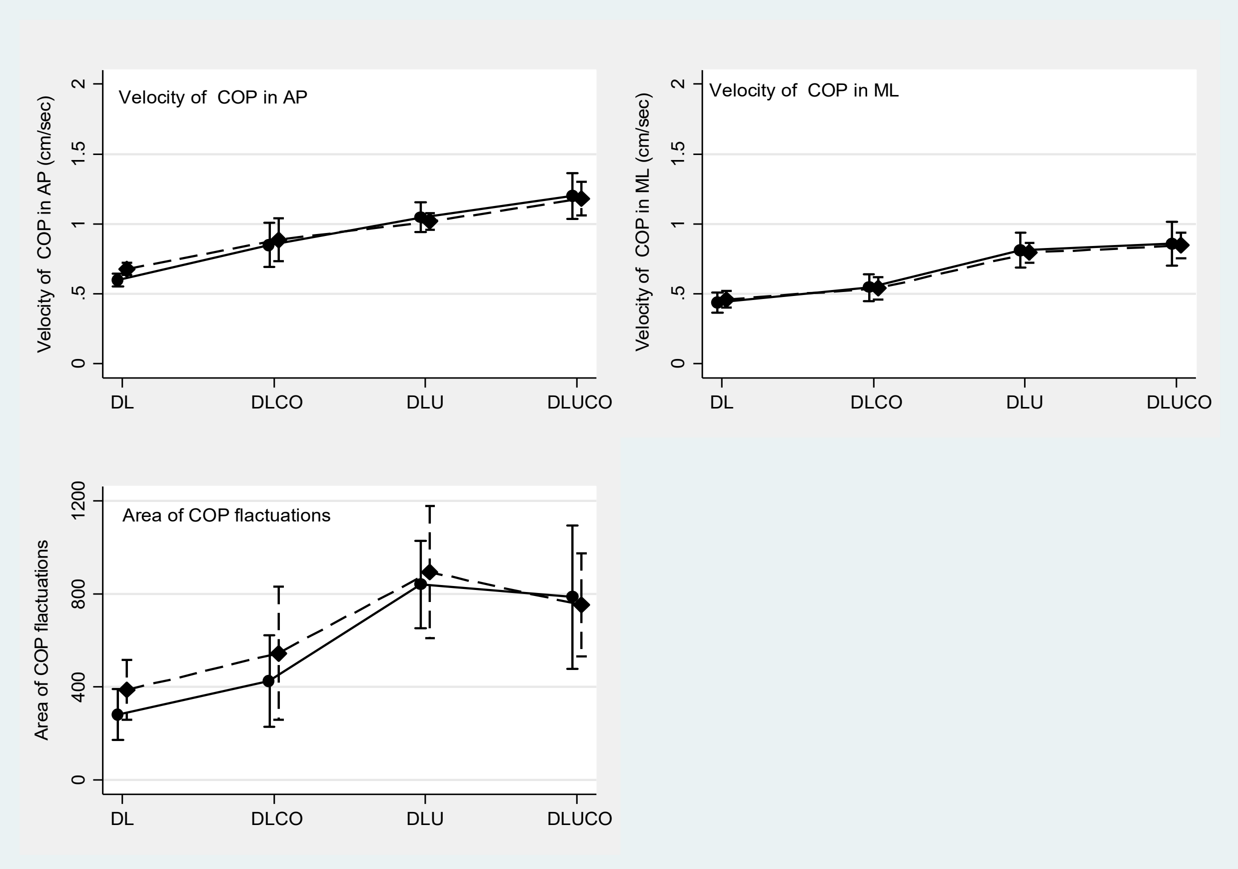

Fig. 4. Mean and 95% CI of the mean of COP velocity in the anteroposterior and mediolateral directions and area of COP fluctuations of four postural tasks in full bladder condition: Double Leg standing on the rigid surface (DL), Double Leg standing on the rigid surface with the Cognition task (backward counting) (DLCo), Double Leg standing on the Unstable surface (foam) (DLU), Double Leg standing on Unstable surface (foam) with the Cognition task (backward counting) (DLUCo).Continent group (solid line), SUI group (dash line)

was empty. The post-hoc pairwise comparison with Bonferroni adjustment (t=2.82, p=0.045) revealed significantly greater velocity in the ML direction in the mild incontinence group (mean (SD) =0.56 (0.18) cm^2/sec) compared to the severe incontinence group (mean (SD) =0.36(0.11) cm^2/sec).

No significant differences were found between the four groups in the other linear variables and ApEn (p>0.05).

Discussion

This study was designed to investigate the differences in postural control between the females with and without SUI during simple and dual tasks. In contrast to little evidence about the relationship between urinary incontinence and postural control, the effect of urinary incontinence on postural control has not been known yet.

In the current study, for linear parameters of COP, no group × task interactions were observed, and the interaction was only significant for the mean $dCOP_{ML}$ in empty bladder condition. In other words, as shown in Figures 1-4, the changes of the linear parameters during the four postural tasks were similar in the two groups. The highest sway and area of COP time-series were observed in the standing on the foam surface (DLU), and the groups experienced the most velocity in the standing on the foam surface with backward counting (DLUCo).

The results of the linear analysis revealed that in the empty bladder condition, the SUI females had more significant velocity in the AP direction in the DL task compared to the continent subjects, and when their bladder was full, these subjects showed the more significant range of displacement and velocity in the AP direction compared to the continent group, suggesting that the SUI group might have experienced more challenge by bladder fullness. There were no significant differences between the females with and without SUI in the other linear postural control variables.

Our linear results seem to be consistent with previous research. Chmielewska et al. (5) observed that compared with the continent control group, the subjects with urinary incontinence significantly swayed more in the AP and ML directions and had more velocity in the ML direction during standing with eyes closed when their bladder was full. However, they did not find a significant difference between the continent and incontinent groups when eyes were open. In our study, all static balance tasks were performed with eyes open. The study of Smith et al. (6) showed that the SUI group presented a higher displacement range of COP in the AP direction compared to the continent group. In their study, the details of the type of task presenting the difference in linear parameters of COP

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Table 2. Results of RM-ANOVA and post-hoc comparison to compare linear parameters of COP in empty bladder condition between the continent group (22 subjects) and SUI group (22 subjects)

Linear variables of COP	Interaction group × task F (*p*-value)	Task effect (*p*-value)	Group comparison (mean SUI group – mean continent group) p-value* [Cohen's d (95%CI)]			
			DL	DLCO	DLU	DLUCO
AP displacement (mm)	1 (0.350)	<0.001	0.150 [0.44 (-0.16 to 1.04]*	0.390 [.26 (-0.33 to 0.85)]*	0.660 [-0.13 (-0.72 to 0.46)]	0.550 [0.18 (-0.41 to 0.77)]*
ML displacement (mm)	3.7 (0.020)	<0.001	0.301 [0.32 (-0.28 to 0.91)]*	0.180 [0.41 (-0.19 to 1)]*	0.430 [-0.24 (-0.83 to 0.36)]	0.190 [-0.4 (1 to-0.19)]*
AP range (mm)	1 (0.330)	<0.001	0.140 [0.45 (-0.15 to 1)]*	0.530 [0.19 (-0.4 to 0.78)]*	0.850 [-0.06 (-0.65 to 0.53)]*	0.940 [0.02 (-0.53 to 0.65)]*
ML range (mm)	2 (0.130)	<0.001	0.350 [0.28 (-0.31 to 0.87)]*	0.550 [0.18 (-0.41 to 0.77)]*	0.450 [-0.23 (-0.82 to 0.36)]	0.220 [-0.37 (-0.96 to 0.23)]*
AP velocity (cm/sec)	1.13 (0.330)	<0.001	0.040 [0.63 (0.02 to 1.23)]*	0.760 [0.1 (-0.5 to 0.68)]*	0.890 [-0.04 (-0.63 to 0.55)]	0. 680 [-0.13(-0.72 to 0.47)]*
ML velocity (cm/sec)	0.99 (0.380)	<0.001	0.620 [0.15 (-0.44 to 0.74)]*	0.840 [-0.06 (-0.65 to 0.53)]*	0.880 [-0.04 (-0.63 to 0.55)	0.320 [-0.3 (-0.89 to 0.29)]
Area circle (mm^2)	1.19 (0.310)	<0.001	0.160 [0.42 (-0.17 to 1.02)]*	0.390 [0.26 (-0.33 to 0.85)]*	0.810 [-0.07 (-0.66 to 0.52)]*	0.790 [0.08 (-0.51 to 0.67)]*

Abbreviations: DL: Double Leg standing on the rigid surface, DLCo: Double Leg standing on the rigid surface with the Cognition task (backward counting) , DLU: Double Leg standing on the Unstable surface (foam), DLUCo: Double Leg standing on Unstable surface (foam) with the Cognition task (backward counting), SUI=stress urinary incontinence
* Indicates data transformation using the neperian logarithm (ln)

Table 3. Results of RM-ANOVA and post-hoc comparison to compare linear parameters of COP in full bladder condition between the continent group (22subjects) and SUI group (22 subjects)

Linear variables of COP	Interaction group ×task F (*p*-value)	Task effect (*p*-value)	Group comparison(mean SUI group – mean continent group) *p*-value [Cohen's d(95%CI)]			
			DL	DLCO	DLU	DLUCO
AP displacement (mm)	1.27 (0.290)	<0.001	0.090 [0.54 (-0.06 to 1.14)]*	0.280 [0.33 (-0.27 to 0.92)]*	0.803 [-0.06 (-0.65 to 0.53)]*	0.910 [0.03 (-0.56 to 0.62)]*
ML displacement (mm)	2.11 (0.120)	<0.001	0.260 [0.35 (-0.25 to 0.94)]*	0.340 [0.29 (-0.3 to 0.88)]*	0.420 [-0.24 (-0.84 to 0.35)]	0.660 [-0.13 (-0.72 to 0.46)]*
AP range (mm)	2 (0.121)	<0.001	0.020 [0.74 (0.13 to 1.35)]*	0. 312 [0.32 (-0.28 to 0.91)]*	0.830 [0.06 (-0.53 to 0.65)]*	0.950 [-0.01 (-0.61 to 0.57)]*
ML range (mm)	0.32 (0.750)	<0.001	0.410 [0.25 (-0.34 to 0.84)]*	0.702 [0.12 (-0.47 to 0.71)]*	0.940 [0.02 (-0.57 to 0.61)]	0.940 [-0.02 (-0.61 to 0.57)]*
AP velocity (cm/sec)	1.42 (0.251)	<0.001	0.020 [0.75 (0.13 to 1.35)]	0.550 [0.18 (-0.41 to 0.77)]*	0.803 [-0.14 (-0.73 to 0.45)]	0.830 [-0.06 (-0.65 to 0.53)]
ML velocity (cm/sec)	0.26 (0.770)	<0.001	0.540 [0.19 (-0.4 to 0.78)]*	0.980 [-0.007 (-0.6 to 0.6)]*	0.905 [0.04 (-0.55 to 0.63)]*	0.903 [-0.04 (-0.63 to 0.55)]
Area circle (mm^2)	1.58 (0.201)	<0.001	0.061 [0.6 (-0.01 to 1.19)]*	0.290 [0.32 (-0.27 to 0.91)]*	0.830 [0.06 (-0.53 to 0.65)]*	0.840 [0.06 (-0.53 to 0.65)]*

Abbreviations: DL: Double Leg standing on the rigid surface, DLCo: Double Leg standing on the rigid surface with the Cognition task (backward counting) , DLU: Double Leg standing on the Unstable surface (foam), DLUCo: Double Leg standing on Unstable surface (foam) with the Cognition task (backward counting), SUI=stress urinary incontinence.
* Indicates data transformation using the neperian logarithm (ln)

between the two groups were not explained.

In the linear analysis of COP time-series, an increase in the COP sway during static and dynamic tasks is attributed to a decrease and impairment in postural control (11). In the present study, the SUI subjects showed more sway and velocity in the AP direction, and the effect size of Cohen's d (17) confirmed a medium difference (0.5< Cohen's d <0.8) between the two groups and an increase in the range dCOP (in full bladder condition) and Vel dCOP (in empty and full bladder conditions) in the AP direction. Other linear measures had small effect sizes (Cohen's d<0.5).

Multiple factors influence postural control. It has been argued that postural control dysfunction in SUI patients may be due to pelvic floor muscles weakness, delay in pelvic muscles activation, and impairment in the postural function of these muscles. Hodges et al. (9) reported a postural function for pelvic floor muscles. They found in the healthy subjects, during rapid bilateral movement of the upper limb, pelvic floor muscles showed a feed-forward postural adjustment to prepare the body for internal perturbation in the standing position.

In line with those of previous studies (14, 18, 19), our study found that the SUI group had stronger pelvic floor muscles than the continent group. A systematic review (20) reported in the continent women during upper extremity movements and coughing, pelvic floor muscles showed an early activity compared to the other trunk muscles and shoulder muscles while pelvic floor muscles in the incontinent women activated later. Smith et al. (8) found that SUI women had a delay in the onset of pelvic muscle activation during arm flexion and extension compared to the continent women. In their study (8), the pelvic floor muscles of the continent women activated before primary movement muscles while in the SUI women, the pelvic floor muscle activated after primary movement muscles. In addition to the delay in the activation of pelvic floor muscles, they reported (8) that in SUI subjects, abdominal muscle showed an early activation compared to pelvic floor muscles. Madill et al. (21) found during coughing, although SUI subjects had as strong as continent subjects, they showed a delay in the onset of activity

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Table 4. Results of RM-ANOVA and post-hoc comparison to compare ApEn of COP in empty and full bladder conditions between the continent group (22subjects) and SUI group (22 subjects)

ApEn		Interaction Group × task F (*p*-value)	Task effect (p-value)	Group comparison(mean SUI group – mean continent group) *p*-value [Cohen's d(95%CI)]			
				DL	DLCO	DLU	DLUCO
Empty bladder	AP	0.8 (0.481)	<0.001	0.430 [-0.24 (-0.83 to 0.35)]	0.320 [-0.3 (-0.9 to 0.3)]	0.580 [0.17 (-0.43 to 0.76)]*	0.320 [-0.3 (-0.89 to 0.29)]
	ML	2.90 (0.040)	<0.001	0.120 [-0.47 (-1.07 to 0.13)]	0.060 [-0.59 (-1.19 to 0.02)]	0.640 [0.14 (-0.45 to 0.73)]	0.640 [-0.14 (-0.73 to 0.45)]
Full bladder	AP	0.33 (0.780)	<0.001	0.410 [-0.25 (-0.84 to 0.34)]	0.120 [-0.47 (-1 to 0.13)]	0.610 [-0.15 (-0.74 to 0.44)]	0.480 [-0.21 (-0.8 to 0.38)]*
	ML	3.35 (0.030)	<0.001	0.140 [-0.45 (-1.04 to 0.15)]	0.210 [-0.38 (-0.97 to 0.22)]	0.340 [0.29 (-0.3 to 0.88)	0.203 [0.39 (-0.2 to 1)]

Abbreviations: AP= anteroposterior direction, DL: Double Leg standing on the rigid surface, DLCo: Double Leg standing on the rigid surface with the Cognition task (backward counting) , DLU: Double Leg standing on the Unstable surface (foam), DLUCo: Double Leg standing on Unstable surface (foam) with the Cognition task (backward counting),ML= mediolateral direction, SUI=stress urinary incontinence.
* Indicating data transformation using the neperian logarithm (ln)

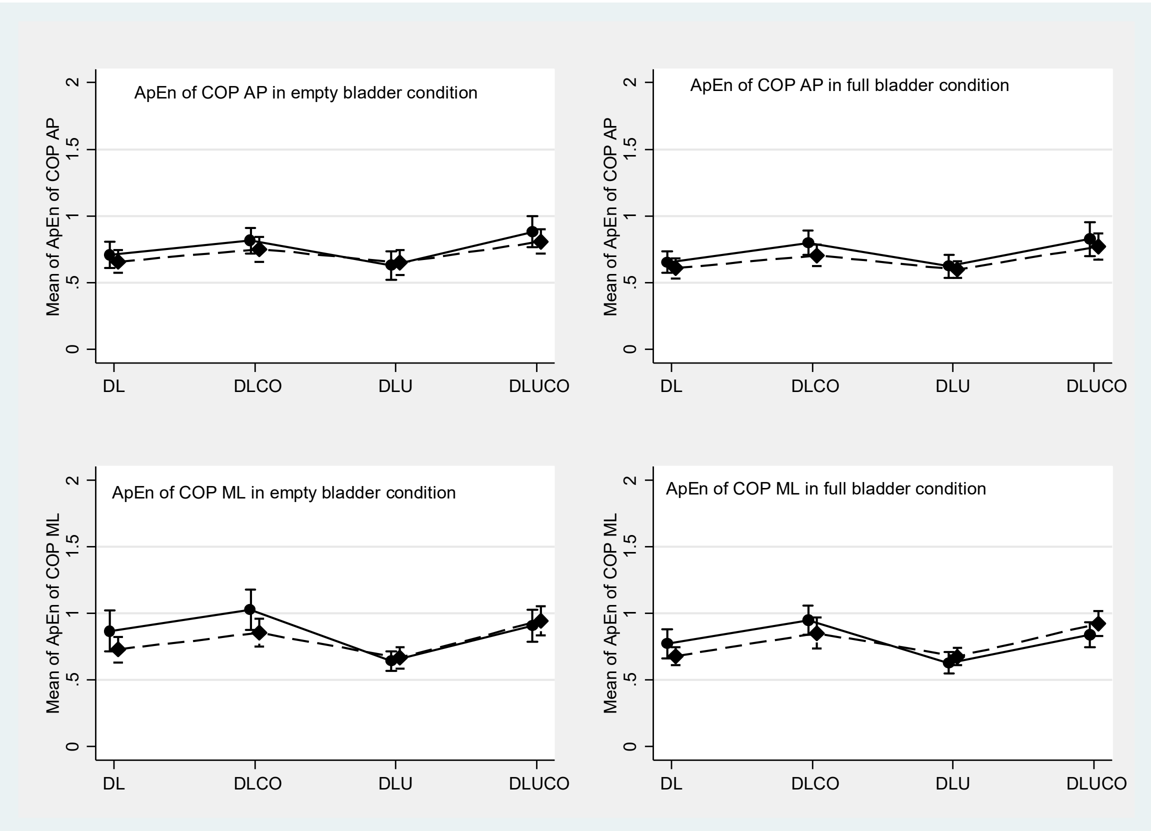

Fig. 5. Mean and 95% CI of the mean of approximate entropy (ApEn) of COP in the anteroposterior and mediolateral directions of four postural tasks in empty and full bladder conditions: Double Leg standing on the rigid surface (DL), Double Leg standing on the rigid surface with the Cognition task (backward counting) (DLCo), Double Leg standing on the Unstable surface (foam) (DLU), Double Leg standing on Unstable surface (foam) with the Cognition task (backward counting) (DLUCo). Continent group (solid line), SUI group (dash line)

of pelvic floor muscles.

Smith et al. (6) also reported that compared to continent women with the empty bladder, muscle activation of erector spinae increased, and when the bladder was moderately full, the activation of internal oblique and rectus abdominis muscles increased in the SUI group. Increased trunk muscles stiffness through reduction of trunk movements in postural adjustments has been attributed to impairment in postural control (7).

The combination of the factors, including weakness and delay in postural activation of pelvic floor muscles, increased trunk and abdominal muscles activation, could be a possible explanation for postural control impairment following SUI.

Another possible explanation for postural control impairment might be the effect of bladder fullness. It has been reported in the full bladder condition, pelvic floor muscle activity is increased (7, 22). Also, bladder filling has been associated with an increase in abdominal muscles and trunk muscle activity. With Adding a postural challenge, the demand is increased on the pelvic floor muscles. In this situation, if the activity level of pelvic floor muscles is unable to adjust to the increased demand, the continence or postural control might be compromised (7). The studies such as that conducted by Chmielewska (5) have shown that in the continent women, the postural

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Table 5. Results of paired sample t-test to compare linear parameters of COP and ApEn between the full bladder and empty bladder conditions in both groups (control/ continent group= 22subjects), (SUI group = 22 subjects)

Linear variables of COP	Group comparison(full bladder condition–empty bladder condition) pvalue[Mean difference]							
	DL		DLCO		DLU		DLUCO	
	Control G	SUI G	Control G	SUI G	Control G	SUI G	Control G	SUI G
AP displacement (mm)	0.370[0.21]*	0.240[0.29]*	0.690[0.26]*	0.091[0.53]*	0.491[0.14]*	0.370[0.47]*	0.333[0.53]*	0.951[0.02]*
ML displacement (mm)	0.300[0.16]*	0.301[0.16]*	0.670[0.1]*	0.4502[0.1]*	0.631[0.14]	0.430[0.16]	0.561[0.17]*	0.831[0.03]*
AP range (mm)	0.930[-0.12]*	0.031[a][2.27]	0.402[3.8]*	0.061[6.69]*	0.950[-0.98]*	0.480[0.97]*	0.941[3.91]*	0.460[1.48]*
ML range (mm)	0.160[1.30]*	0.301[0.71]*	0.831[-0.63]*	0.611[-0.1]*	0.510[-1.62]	0.640[0.64]	0.372[-1.27]*	0.510[0.59]*
AP velocity (cm/sec)	0.810 [0.006]*	0.450[0.01]*	0.611[0.05]*	0.131[0.08]*	0.720[0.02]	0.940[-0.002]	0.742[-0.02]*	0.531[-0.03]*
ML velocity (cm/sec)	0.730[0.01]*	0.522[0.006]*	0.831[-0.07]*	0.901[0.01]*	0.730[0.02]*	0.810[0.007]*	0.233[-0.05]	0.612[0.02]
Area circle (mm^2)	0.290 [41]*	0.007[a][83]*	0.491[103]*	0.061[180]*	0.860[-40]*	0.312[72]*	0.892[118]*	0.850[11]
ApEn AP	0.210[-0.06]	0.091[-0.05]	0.601[-0.02]	0.220[-0.05]	0.911[-0.005]	0.230[-0.05]	0.231[-0.05]	0.312[-0.04]
ApEn ML	0.141[-0.09]	0.230[-0.05]	0.340[-0.08]	0.901[-0.002]	0.712[-0.01]	0.790[0.009]	0.271[-0.07]	0.623[-0.02]

Abbreviations: DL: Double Leg standing on the rigid surface, DLCo: Double Leg standing on the rigid surface with the Cognition task (backward counting) , DLU: Double Leg standing on the Unstable surface (foam), DLUCo: Double Leg standing on Unstable surface (foam) with the Cognition task (backward counting), SUI=stress urinary incontinence.

* indicating data transformation using the neperian logarithm (ln), a indicating significant difference $p<0.05$.

control was not affected by bladder condition, while in the SUI women, the full bladder condition was associated with more COP displacement.

Consistent with the literature, our study found that participants reporting SUI in the full bladder condition showed more statistical range of displacement and the velocity of COP in the AP direction than the continent group, while in empty bladder condition, there was a significant difference between the two groups only in the velocity of COP in the AP direction. Another important finding in the present investigation is when the two bladder conditions were compared, in the continent group, compared to the empty bladder condition, none of the linear parameters of COP significantly differed while in the SUI group, when the bladder was full, the females significantly experienced more range of displacement in the AP direction and area circle of COP. These findings show that bladder fullness can be associated with changes in the postural control of SUI subjects in quiet standing.

In addition to the described reasons, the relationship between urinary incontinence and postural control impairment may partly be explained by the severity of incontinence. It has been suggested that the severity of urinary incontinence is associated with decreased static balance. Our finding showed that compared to the women with severe incontinence, mild incontinent women showed higher velocity in the ML direction. However, the findings of the current study did not support the findings of Kim et al. (23). This is most likely due to their method for measuring postural control.

In addition to the linear dynamic analysis, to provide further insight into the complexity of postural control, the non-linear analysis of the COP time-series using approximate entropy (ApEn) in both directions was performed (1). The ApEn value quantifies the complexity, irregularity, and variability of the COP trajectories (1, 4). Previous studies have reported following aging and disease the irregularity and complexity of the COP time-series may be considerably decreased (12, 13, 24, 25).

Our study showed that the interaction group × task of ApEn in the ML direction was significant. In most of the tasks, the SUI females had a lower ApEn (increased regularity), but the differences between the two groups were not statistically significant. Despite no statistical significance, the findings demonstrated a medium effect size (Cohen's d= -0.59) for the DLCo task in the ML direction when the bladder was empty. It seems that SUI may reduce the complexity and irregularity of the postural control system. However, it must be interpreted with caution because our study was not able to demonstrate a statistical difference in ApEn values between the females with and without SUI.

In addition to the above, the influence of the bladder fullness and severity of SUI on the changes of the ApEn was not significant.

A limitation of this study was that the level of activity of abdominal, trunk, and pelvic floor muscles using electromyography during the postural task in both bladder conditions was not measured.

Conclusion

In this case-control study, the aim was to assess and compare postural control between females with and without SUI using the linear and non-linear analysis of COP time series.

The linear analyses results indicated that compared to the continent females in the quiet standing, the SUI females had more significant velocity and range of displacement with a medium effect size in the AP direction.

Non-linear analysis of COP time-series in both directions showed that the SUI group in most situations had lower ApEn than the continent group, although the differences between the two groups did not reveal a statistical significance.

Compared to the empty bladder condition, when the bladder was full, the continent group showed no significant changes in the linear variables and ApEn, while the SUI group experienced more challenge in the displace-

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ment range in AP direction and area circle of the COP sway.

The findings of the present study complement those of earlier investigations. In general, therefore, it seems that postural control may be affected by SUI. However, further work is needed to fully understand the effect of SUI on the postural control system.

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Conflict of Interests

The authors declare that they have no competing interests.

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