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DOUBLE SUPPORT DURATION AS A PREDICTOR FOR STRESS URINARY INCONTINENCE IN WOMEN

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ABSTRACT
Background: Stress Urinary Incontinence (SUI) is one of the common conditions in women which negatively affect life quality such as bladder control. Such common conditions are associated with gait abnormalities, and this association was not fully understood. Thus, the current study aims to compare the physical characteristics and gait parameters of women with and without SUI to uncover the condition's functional limitations.**Methods:** We compared women diagnosed with SUI and a control women group. All participated individuals had anthropometric. **Results:** Women in the SUI group had insignificant body weight and age than the non-SUI group. While women in the SUI group had greater BMI ($p < 0.05$). The frequency of gait abnormalities was higher in the SUI group (80% SUI vs 20% control, $p < 0.001$). Compared to controls, women with SUI had lower cadence (-27.5 steps/min, $p < 0.001$, effect size = -0.65), walking speed (-0.5 m/s, $p < 0.001$, effect size = -0.70) and step length (-24.5 cm, $p < 0.001$, effect size = -0.60). On the other hand, SUI group had higher duration of double support (+120 ms, $p < 0.001$, effect size = 0.55) and step duration (+150 ms, $p < 0.001$, effect size = 0.65). **Conclusion:** Women with SUI had slower walking, taking shorter steps, and spending more time in double support and step durations. SUI had compensatory adaptations in the gait to improve walking stability. Thus, the need for gait rehabilitation, pelvic floor therapy, and weight control are recommended.

KEYWORDS: Stress Urinary Incontinence; Gait Analysis; Biomechanics; Postural Stability; Pelvic Floor Dysfunction.

INTRODUCTION
Urinary incontinence, or UI, is a common health issue. Particularly among adult women, UI has a profound impact on quality of life. Such disorder is characterized by involuntary loss of urine, which causes different implication degrees and hinders daily activities 1. Urinary incontinence (UI) can lead to complications concerning an individual's physical, emotional, falling and limits mobility 2. On the physical side, constant moisture can lead to skin irritations (such as dermatitis) and infections (such as urinary tract infections or UTIs). Having such condition might cause one to feel sadness, embarrassment, anxiety, and depression, and individuals might avoid social gatherings or physical activity due to the fear of leakage to the point of social isolation and a withdrawal of the quality of life 3, 4. Unmanaged UI could also lead to a sedentary lifestyle that can, in turn, lead to bigger problems like obesity or immobility 5, 6. Among all types of UI, Stress urinary incontinence (SUI) represents the most common type and accompanied by urine loss when a person engages in certain physical activities like coughing, sneezing, or even exercising 7, 8.
Globally, the incidence of urinary incontinence within this demographic has been documented to exhibit considerable variation across different studies, with reported rates varying from 14.4% to 80% 9. In Egypt, the global prevalence of UI is 25-45%. There is a notable Egyptian study indicating a prevalence of 54.8% among women, with 14.8% of the cases as SUI 8.
The SUI in women causes deficiencies in walking mechanisms and consequently reduce leakage while walking. This leads to shorter strides (stride length), changes in pace (cadence), and adjustments in the distance between their legs while walking (step width). The former compensatory mechanisms work together to maintain control and stability 10.

Management strategies are therefore needed to meet the UI challenges. Although prior research has documented the association between UI and depression, social isolation, and other psychosocial factors, there has been scant exploration of the relationship between SUI and gait parameters.
Many investigations have been conducted to evaluate the relationship between UI and functional fall risk. For instance, Schniepp, Huppert 11 studied fall prediction in neurological gait disorder through clinical assessment and gait analysis in patients with vestibular and cerebellar diseases. A cross-sectional observational study by Betteridge, Mobbs 12 examined the walking patterns in lumber spinal stenosis by using wearable accelerator device to countify the spatiotemporal gait metrics. A study by Bortone, Sardone 13 estimated a heterogenous component in gait measurement as an indicator for adverse health related outcomes in clinical, cognitive and physical domain in frail older adults. The SUI not only impacts bladder control but also affects the individual's control over the patterns and stability of their ambulation. It is important to grasp that developing holistic management plans must incorporate the interplay between urinary difficulties and issues with movement 14. Limited studies are conducted to estimate the relation between SUI and gait parameters by spatiotemporal gait analysis in adult women.
This study aims to provide more insight into how SUI can change gait mechanics. Understanding SUI is critical to addressing this gap through analysis spatial and temporal aspects. This study between urology and physical therapy can provide new ways in treating pelvic floor and urological disorders. The value of this research lies in its capacity to inform intervention and rehabilitation frameworks on SUI-related conditions Rehabilitation frameworks on SUI-affected conditions.

MATERIALS AND METHODS

The participants were referred from Mansoura University Hospital, Obstetrics and Gynecology Department. This research was carried out at the Faculty of Physical Therapy - Delta University, Motion Analysis Laboratories. The ethical committee of the Faculty of Physical Therapy, Kafr El-Sheikh University granted study approval with the approval number [KFSIRB200-249]. All subjects gave written consent after they were fully briefed on the study aims, the study procedures, possible advantages, privacy, and how data would be used.

Sample size determination:

Sample size calculation used a Z-score of 1.96 along with mean and standard deviation from earlier studies which showed a mean of 12.5 and standard deviation of 3.3. Given these figures and a margin of error of 4.17, a 95% confidence interval was estimated which justified 124 participants to be included in the study 15.

Participants' Selection:

We analyzed data from 124 participants in this observational comparative research study focusing on examining the gait parameters of women with and without Stress Urinary Incontinence (SUI). The studied individuals were separated into two groups: 62 women with SUI and 62 women without SUI. The diagnosis of SUI in the SUI patients was made by a gynecologist and corroborated by a urologist through the use of the Incontinence Severity Index (ISSI). Inclusion criteria: Participants in the study needed to be 40 to 60 years old, have a BMI of 30 or more, and have no gynecological conditions that could bias the study results. Furthermore, only multiparous women with a diagnosis of mild SUI who signed the informed consent form were included. Exclusion criteria: Certain individuals were excluded from the study if they were pregnant, had neurological disorders including Parkinson's disease or multiple sclerosis, had significant issues with their musculoskeletal system, or had prior pelvic surgery. Additionally, the exclusion criteria considered severe cognitive impairment, significant medical conditions that impacted the gait, or any form of pain while ambulating.

Procedures:

Different tools and materials were used for data collection. For self-assessment, the ISSI was used to gauge the severity of the UI. Additionally, a Force Platform and STT Systems Three-Dimensional Motion Analysis System (3DMA) System were used to evaluate gait parameters, including cadence, speed, step length, double support time, and step time. Each participant began with a comprehensive history-taking session. This included detailing chief complaints and explaining the onset, aggravation, and patterns of symptom streams. Furthermore, the voiding habits of the patient and other relevant facets of the patient's lifestyle were discussed.
Following this, the administrators of the ISSI attempted to gauge the seriousness of the UI symptomatology. As the manufacturers of the ISSI provided instructions, the participants were asked to either stand or walk on the platform while the GRFs were being recorded. Regarding the STT (3DMA) system, participants were equipped with reflective markers following the STT Helen Hayes Protocol, and the system was adjusted to the initial position prior to each session to guarantee the collection of reliable and valid data.
Demographic data collection: Along with age, weight, height, and BMI, demographic information was also collected. (BMI) The Body Mass Index was calculated using the following formula: (Weight, kg) /(Height, m2).

Incontinence Symptom Severity Index (ISSI)

While allocating groups, those with stress urinary incontinence were classified dependent on their Incontinence Symptom Severity Index (ISSI) score. They filled out the ISSI questionnaire which includes validated questions meant for assessing UI symptom severity. The questionnaire used a Likert scale of frequency problems from 0 to 4. The items asked about the severity of urinary leakage, its impact on daily activities, and its impact on daily activity. Increased scores indicated increased severity of the symptoms. For the last four weeks, the participants had to indicate what symptoms they had. They could fill the questionnaire by themselves, but for those who had difficulties with literacy, interviewers were there to help. Data collected also had the ISSI total scores. Data were kept safe and stored for analysis in an encrypted file (Excel) electronic database 15.

Three-dimensional motion analysis

Using the STT (3DMA) system, which employs multiple high-speed cameras with variable frame rates ranging from 50 to 1000, a comprehensive 3D motion analysis was performed. Markers were accurately tracked and data precision was enhanced due to the careful arrangement of cameras around the capture area. Prior to data collection, a calibration procedure was completed with a calibration wand to correct for lens and camera placement, ensuring accurate 3D marker tracking. In order to improve accuracy of joint kinematics and decrease errors associated with soft tissue artifacts, reflective markers were positioned on the appropriate anatomical landmarks according to standardized six degrees-of-freedom (6DOF) protocols. For advanced biomechanical analysis, the motion capture system was combined with force platforms. Data processing was executed by STT proprietary software, which supports various file formats of Optitrack, Vicon, Simi, C3D, TRC, which provides data compatibility and effective data management. Certain techniques were applied for filtering, and the sampling rates were modified to the specific movement analyses requirements as required to reduce noise and improve the data quality. For consistency and to minimize outside factors, all evaluations were performed in a controlled lab environment. The system software provided data acquisition and analysis for the study in real time. Its permanent license and compatibility with Windows 10 and 11 ensured seamless functioning during the entire study 16.

Force platform

To evaluate participants' posture control and movement mechanics, grounding reaction forces through the platform's load cells was evaluated. Each platform's load cells helps gauge biomechanical parameters. A force platform (Sensor Medica) was used to measure static and dynamic balance through biomechanical parameters. Participants uniformly performed a range of standardized assignments consisting of quiet standing and dynamic balance activities. This was done while capturing force data at 1000 Hz. The data acquisition system used integrated software for simultaneous viewing and calculation of important values such as center of pressure (COP) displacement, sway velocity, and force distribution. For the sake of uniformity in performance, detailed instructions were given and participants had a chance to orient themselves to the platform prior to the testing phase. Prior to participants taking part in the study, ethical approval was obtained from the institutional review board, and all participants provided informed consent 17.

Statistical analysis:

The statistical analysis covered multiple methods. For both the variable index of severity of urinary incontinence symptoms and the absence/presence of certain gait abnormalities, the frequencies and percentages were calculated. Descriptive statistics were calculated for the physical variables and the changes in gait. Continuous variables across the two groups were compared using Student's t-test. Correlation, regression analysis, and principal component analysis (PCA) were performed using data for studied variables under women with SUI to evaluate the association between the severity of SUI and various gait parameters. All statistical tests were performed at a significance level of $p<0.05$ in order to yield dependable, robust outcomes. The tools used for statistical assessment were SPSS for Windows, version 26 (SPSS, Inc., Chicago, IL) and XLSTATA2025.

RESULTS

In terms of the incontinence symptom severity Index (ISSI), and specific gait abnormalities (SGA), Table 1 depicts a clear distinction between the experimental and control groups. For the (ISSI), all 62 members of the control group scored zero, indicating a homogenous distribution. This suggests that this group has no sense of self-sufficiency at all. However on the ISSI, no member of the experimental group received a score of 0. They scored between 1 and 6, with a noticeable concentration at higher index values. With 22 participants (35.5%) scoring both 4 and 6, and 12 people (19.4%) scoring both 4 and 6, the highest frequency was found at an index value of 5. This distribution strongly suggests that the experimental group's perceived self-sufficiency increased significantly because of the intervention.

Table 1. Frequencies and percentages of ISSI, and SGA for the control and experimental groups.

Index value	**ISSI**				**SGA**			
	E G		**C G**		**E G**		**C G**	
	Fer.	**Perc.**	**Fer.**	**Perc.**	**Fer.**	**Perc.**	**Fer.**	**Perc.**
0	**0**	**0.0**	**62**	**100.0**	**-----**	**-----**	**-----**	**-----**
1	**3**	**4.8**	**-----**	**-----**	**3**	**4.8**	**62.0**	**100.0**
2	**5**	**8.1**	**-----**	**-----**	**59**	**95.2**	**-----**	**-----**
3	**8**	**12.9**	**-----**	**-----**	**-----**	**-----**	**-----**	**-----**
4	**12**	**19.4**	**-----**	**-----**	**-----**	**-----**	**-----**	**-----**
5	**22**	**35.5**	**-----**	**-----**	**-----**	**-----**	**-----**	**-----**

6	12	19.4	-----	-----	-----	-----	-----	-----
Total	**62**	**100.0**	**62**	**100.0**	**62**	**100.0**	**62**	**100.0**

ISSI: Incontinence Symptom Severity Index; SGA; specific gait abnormalities; EG: Experimental group; CG: Control group; Fer: frequency; perc: percent.

In terms of overall self-evaluation, the control group likewise had a consistent outcome, with all 62 participants (100%) scoring on the SGA 1 index. But there was a noticeable change in the experimental group. 59 participants (95.2%) changed to an SGA 2 index score, whereas only 3 participants (4.8%) kept their SGA 1 index score. This suggests that, in comparison to the control group, the experimental group's general self-assessment has improved or changed for the better. This indicates the accuracy of the selection of items for both the experimental and control groups according to Incontinence Symptom Severity Index.

Table 2 present descriptive statistics for physical and walking variables, clearly differentiating between women without SUI and women with SUI. Both groups comprise 62 participants. According to the data, the average age of the 62 women in the control group (without SUI) is roughly 50.18 years, with a range of 40 to 59 years. The majority in this population are overweight, as indicated by their mean body mass index (BMI) of 26.86 kg/m². In terms of walking variables, the average step length was 70.34 cm, and the average walking speed was 1.34 m/s, with different values for "Double Support Duration" and "Step Duration."

The mean age of the experimental group (women with SUI) is 50.84 years, which is comparable to the control group's age range of 40 to 60. Their average body mass index (BMI) was found to be slightly higher, at 27.88 kg/m². This could suggest that this group is more likely to be overweight or obese. In terms of gait patterns, their average step length was much shorter (46.56 cm) and their average walking speed was significantly lower (0.93 m/s).

Table 2. Descriptive statistics for physical and walking variables for women with and without SUI.

Variable	(Women without SUI) (n=62)				(Women with SUI) (n=62)			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Age	40.0	59.0	50.18	5.71	40.0	60.0	50.84	5.38
BW	1.56	1.75	1.67	0.04	1.50	1.71	1.62	0.05
BH	58.0	90.0	75.3	9.43	60.0	84.0	72.69	5.67
BMI	20.57	29.76	26.86	2.96	21.77	32.87	27.88	2.10
CAD	90.00	120.0	105.8	7.20	56.00	110.0	80.21	7.86
WS	1.20	1.50	1.34	0.11	0.70	1.00	0.93	0.09
SL	6.0	82.0	70.34	10.14	40.0	54.00	46.56	4.09
DSD	200.0	300.0	242.6	31.49	240.0	360.0	292.7	38.39
SD	600.0	800.0	716.0	60.89	800.0	990.0	910.6	55.41

Min: Minimum; Max; Maximum; SD: Standard deviation; Age: Age (Year); BW: Boody weight (kg); BH: Boody height (cm); BMI: Boody mass index (kg/m2); CAD: Cadence (steps/min); WS:Walking speed (m/s);SL: Step Length (cm); DSD:Double Support Duration (ms); SD:Step Duration (ms).

The gait variables showed clear differences between the two groups. The women with SUI had a slightly higher mean body mass index (BMI) and a significantly lower mean walking speed (0.93 m/s vs. 1.34 m/s), even when their ages, heights, and overall weights were similar. Additionally, the SUI group had a lower mean walking cadence (80.21 m/s vs. 105.8 m/s) and significantly shorter mean step length (46.56 cm vs. 70.34 cm). Furthermore, the SUI group had significantly higher "double support duration" and "step duration" values, indicating a slower and more cautious gait.

Table 3 shows a detailed comparison and outlines the differences between the two groups of women both with and without SUI. Women with SUI and without SUI, as \showed comparable age and body weight measurements (Age, p = 0.508; Body Weight, p = 0.060). However, the two groups differed with respect to the rest of the measurements, especially Body Height (p<0.001), which shows that women with SUI tend to be shorter. Women with SUI also had a higher Body Mass Index as well with SUI, which shows that BMI could be a potential contributory factor (P = 0.029).

Women with SUI also demonstrated poor performance compared to the other group with respect to the all of the measured walking variables and clinical scores (p <0.001 for all). Women with SUI had lower Cadence, Walking Speed and Step Length. Moreover, they had their own unique walking patterns. Women with SUI exhibited their own unique walking patterns. Particularly, they had their own unique walking patterns. SII scores and the

Specific Gait Abnormality score were higher in the SUI group and thus proved that the condition caused significant clinical changes in perception and the observable walking.

Table 3. T test for physical and walking variables for Women with and without SUI.

Variable	Mean Difference	Std. Error Difference	CI 95%		T statistic	p- value
			Lower limit	Upper Limit		
Age	0.661	0.996	-1.311	2.634	0.664	0.508
BW	-2.661	1.397	-5.433	0.111	-1.905	0.060
BH	-0.059	0.008	-0.0755	-0.042	-6.922	<0.001
BMI	1.108	0.461	0.104	1.932	2.208	0.029
CAD	-25.548	1.353	-28.227	-22.869	-18.880	<0.001
WS	-0.406	0.018	-0.441	-0.371	-22.776	<0.001
SL	-23.774	1.388	-26.536	-21.012	-17.127	<0.001
DSD	50.03	6.306	37.548	62.515	7.934	<0.001
SD	194.54	10.455	173.85	215.24	18.607	<0.001
ISSI	4.306	0.177	3.951	4.661	24.260	<0.001
SGA	0.951	0.027	0.896	1.006	34.636	<0.001

Age: Age (Year); BW: Boody weight (kg); BH: Boody height (cm); BMI: Boody mass index (kg/m2); CAD: Cadence (steps/min); CI: Confidence Interval; Walking speed (m/s); Step Length (cm); Double Support Duration (ms); Step Duration (ms);ISSI: Incontinence Symptom Severity Index; SGA; specific gait abnormalities.

Correlation analysis in Table 4 reveals a statistical significant negative correlation between the Incontinence Symptom Severity Index (ISSI) and Double Support Duration (DSD) (where r = -0.386, p = 0.002). This data indicates that with increasing the severity of incontinence symptom, the double support duration were decreased. Conversely, cadence (p = 0.678), walking speed (p = 0.600), step length (p = 0.952), step duration (p = 0.761), and the variable (p = 0.973) had no statistically significant linear correlation with ISSI. These findings indicated that among the gait parameters, only DSD had a direct significant inverse relationship with the severity of incontinence symptoms.

Table 4. Correlation coefficient between ISSI and walking variables for women with SUI.

Variable	Incontinence symptom severity index (ISSI)	
	Correlation coefficient	p-value
CAD	0.054	0.678
WS	-0.068	0.600
SL	-0.008	0.952
DSD	-0.386	0.002
SD	-0.039	0.761
SGA	-0.004	0.973

CAD: Cadence (steps/min); Walking speed (m/s); Step Length (cm); Double Support Duration (ms); Step Duration (ms);ISSI: Incontinence Symptom Severity Index; SGA; specific gait abnormalities.

Table 5 shows the results of linear regression models for each of the listed gait variables on ISSI. Except for DSD, which had statistically significant (p <0.001), all models had insignificant statistical values (p > 0.05) according to the F-test. This indicates that each of these variables as dependent variables had a non-significant regression on ISSI.

Table 5. Regression analysis for walking variables (dependent) on ISSI (independent).

Variable	Regression model			Regression coefficients			
	R2	F statistic	p-value	Constant		β	
				Value	p-value	Value	p-value
CAD	0.05	0.174	0.678	78.91	<0.001	0.302	0.678
WS	0.07	0.279	0.600	0.952	<0.001	-0.004	0.600

SL	**0.01**	**0.004**	**0.952**	**46.66**	**<0.001**	**-0.023**	**0.952**
DSD	**0.39**	**10.51**	**0.002**	**338.32**	**<0.001**	**-10.608**	**0.002**
SD	**0.04**	**0.094**	**0.761**	**917.28**	**<0.001**	**-1.564**	**0.761**
SGA	**0.01**	**0.001**	**0.973**	**1.955**	**<0.001**	**-0.001**	**0.973**

CI: Confidence Interval; Age: Age (Year); BW: Boody weight (kg); BH: Boody height (cm); BMI: Boody mass index (kg/m2); CAD: Cadence (steps/min); Walking speed (m/s); Step Length (cm); Double Support Duration (ms); Step Duration (ms);ISSI: Incontinence Symptom Severity Index; SGA; specific gait abnormalities.

Nevertheless, there were significant differences in these models' capacity to explain the variance in the dependent variable (measured as R2). While the "double support duration" model had ≈ 39% of the variance (R2 = 0.39%), additional factors such as step length and specific gait disturbances had ≈ 1 to 7% of the variance. This suggests that none of these models aside from DSD had a considerable amount of the variance.

Examining the regression coefficients (β) and corresponding p-values, we find that the double support duration variable on ISSI had a relative large positive coefficient and a highly significant coefficient (p-value = 0.002), suggesting that an increase in ISSI was linked to an increase in the DSD.

We included ten components in the principal components analysis of the physical, walking, and ISSI variables. Such analysis was based on dividing the total variance of the studied variables into unrelated orthogonal components.

Table 6. Eigenvalue, variability (%), Cumulative % for five components, and component loadings for physical and walking variables for women with and without SUI for the first third components.

PC	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
Eigenvalue	**2.079**	**1.938**	**1.657**	**1.145**	**0.986**
Variability (%)	**20.791**	**19.385**	**16.565**	**11.449**	**9.856**
Cumulative %	**20.791**	**40.176**	**56.741**	**68.190**	**78.046**
Variable	**Factor loadings**				
	PC1	**PC2**	**PC3**	**PC4**	**PC5**
Age	**0.248**	**0.697**	**-0.019**	**-0.473**	**-0.090**
BH	**-0.419**	**0.593**	**0.404**	**-0.384**	**0.019**
BW	**0.440**	**0.781**	**0.276**	**0.244**	**0.041**
BMI	**0.760**	**0.314**	**-0.045**	**0.555**	**0.029**
CAD	**-0.101**	**0.325**	**-0.519**	**-0.182**	**0.579**
WS	**-0.550**	**0.301**	**-0.088**	**0.154**	**-0.489**
SL	**-0.507**	**0.245**	**-0.452**	**0.271**	**0.371**
DSD	**-0.263**	**0.019**	**0.728**	**0.143**	**0.126**
SD	**-0.545**	**0.364**	**-0.286**	**0.418**	**-0.278**
ISSI	**0.367**	**0.056**	**-0.568**	**-0.284**	**-0.412**

Age: Age (Year); BW: Boody weight (kg); BH: Boody height (cm); BMI: Boody mass index (kg/m2); CAD: Cadence (steps/min); Walking speed (m/s); Step Length (cm); Double Support Duration (ms); Step Duration (ms);ISSI: Incontinence Symptom Severity Index; SGA; specific gait abnormalities.

Table 6 presents the eigenvalues, variance percentage, and cumulative percentage of variance for the first five components as they contained 78.046% of the total variance. And since each component has an Eigen value that expresses its importance and must be greater than 1 to be statistically significant, two components (PC1 and PC2) were discovered with an eigen value larger than one with values of 2.079 and 1.938, respectively. These components were retained and accounted for 40.18% of the total variation among the traits with variance percentage 20.791 and 19.385 for first and second component, respectively.

The distribution of traits in the PCA biplot in fig. 1 explained the high variability of traits for principal components PC1 and PC2. In PC1 BMI, WS, SL, and SD have positive loadings, while Age, BH, and BW have positive loading in PC2.

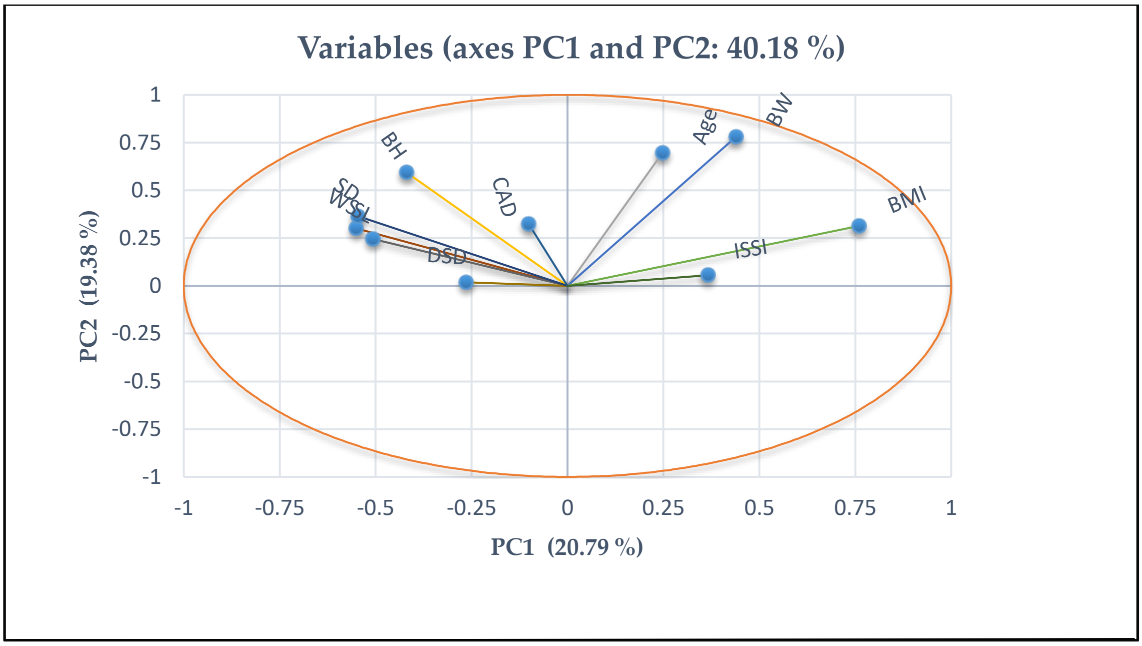

Figure 1. Biplot for the first two principal component (PC1 and PC2) for studied variables. Age: Age (Year); BW: Boody weight (kg); BH: Boody height (cm); BMI: Boody mass index (kg/m2); CAD: Cadence (steps/min); Walking speed (m/s); Step Length (cm); Double Support Duration (ms); Step Duration (ms);ISSI: Incontinence Symptom Severity Index

DISCUSSION

The current findings show the impact SUI has on the gait and physical characteristics of women. Among the findings of the study, women with SUI had a lower cadence, velocity, and step length, along with greater double support and step duration, compared to women without SUI. The gait abnormalities have clinical relevance and the accompanying statistical significance indicates a greater risk of falls and a greater reduction in functional mobility.

Although studies on urinary incontinence exist, none have considered the possible correlations with gait. One study even reported the absence of references to locomotion in 76 reviews, textbooks, or guidelines on the subject. This gap suggests many possibilities for examining the connection between the severity of the symptoms and different aspects of the gait 18. Theoretical and biomechanical links indicate that the mechanics of gait which may both cause and reflect the degree of stress urinary incontinence 19. Many gait parameters allow for quantitative measurement, and connections to different demographic and clinical variables have been recorded.

The current investigation found observable differences in gait variables between the two groups. Even when their ages, heights, and overall weights were comparable, the women with SUI had a mean body mass index (BMI) that was slightly higher and a mean walking speed that was significantly lower. Moreover, the SUI group exhibited a lower average walking cadence accompanied by a significantly shorter average step length. In addition, the SUI group demonstrated significantly greater values in 'double support duration' and 'step duration', suggesting that their gait is slower and more cautious. This finding may be due to repositioning strategies and changes in motor control during walking due to pelvic floor dysfunction, indicating a possible connection between the instability of gait and the stress urinary incontinence symptom severity 9.

Moreover, pelvic floor muscles (PFMs) help with trunk and postural stability during walking. Besides their continence role, PFMs are integrated as a deep core muscle subsystem with transversus abdominis, multifidus, and diaphragm as they span the lumbopelvic region. If weakness or dysfunction occurs within the subsystem, especially the pelvic floor muscles, the stability of the trunk is compromised. Consequently, the decreased or delayed PFM activation may hinder optimal load shift between the pelvis and trunk, which may compromise postural control, alter gait pattern, and increase compensatory actions.

These data correlate with the literature demonstrating that changes in gait may be related to the increased degree of stress urinary incontinence symptom severity in women. Thus, changes in gait may be an objective indicator of the evolution of symptoms and the impact of treatment 20. This comparative analysis shows clear differences among women with SUI and women without SUI across the different parameters. Although Age and Body Weight did not have statistically significant variances ensuring group comparability for these baseline metrics, other physical characteristics did. In particular, body height showed a significant difference indicating women with SUI are possibly shorter.

Additionally, women with SUI had a higher Body Mass Index (BMI), indicating that SUI could be associated with higher BMI. The literature reports similar findings, noting that managing one's weight may reduce symptom severity, and improve quality of life 21, 22. The possible correlation between elevated BMI and the occurrence of SUI can be attributed to the added intra-abdominal pressure and weakness of the pelvic floors, which imply

that the management of weight may address the symptoms and be of help in directing future studies toward possible interventions 23, 24.
The scientific explanation lie in complex neuromuscular interactions and compensatory mechanisms that link pelvic floor function with locomotor control 25, 26. The past literature shows an association of UI with reduced physical function. Research shows that women with SUI employ compensatory strategies that may lead to altered gait patterns as well as an increased risk of falling and sustaining injuries 27. Research has reported that the SUI group had a greater prevalence of gait abnormalities and suggests that this may be reflective of more careful and inefficient patterns of gait adopted due to fear of leakage when moving. Moreover, the differences in weight and BMI between the two groups strengthen the evidence that obesity might aggravate the symptoms of UI. Previous studies have indicated that increased BMI is associated with higher intra-abdominal pressure which may worsen urinary leakage. This emphasizes the importance of weight management as a component of the overall treatment plan for women with SUI 28. Our correlation analysis shows a positive statistically significant correlation between incontinence symptoms severity index (ISSI) and double support duration (DSD). This suggests that higher levels of incontinence symptom severity are associated with longer durations of double support.
Multiple studies show that, in general, the measurement of gait correlates with the severity of stress urinary incontinence. Therefore, it is possible that objective measurements of gait could provide useful information in the assessment and monitoring of symptom progression in women. 29.
Correlation coefficients provided a valuable contribution to this study by providing insight into the relationship between the severity of the UI and performance in gait. The negative correlations for cadence, velocity, and step length suggest that with greater SUI severity, there is decline in performance within the gait pattern, which aligns with and is in support of other research findings. The correlation emphasizes the need to tackle urinary symptom and mobility issues at the same time 30.
Future studies should use longitudinal designs more often to assess causality, use standardized protocols for gait assessment, and examine possible mediators such as pelvic floor muscle function, comorbidities, and hormonal status 29. Furthermore, research involving larger and more diverse groups is necessary to evaluate the generalizability across various populations of women.
In this analysis, I want to draw attention to the results of linear regression models pertaining to each mentioned gait variable on the ISSI. With the exception of DSD, which stands out as being highly statistically significant, the remainder of the models appear to lack statistical significance. This suggests that each of these variables, as dependent variables, show no significant regression on ISSI. Other studies noted a similar trend, suggesting that the effect of these gait parameters on ISSI severity continues to be non-significant across varying analytic frameworks 31, 32. Hence, upcoming research should focus on longitudinal studies, larger cohorts, and the standardized measurement of both gait metrics and the severity of incontinence to shed light on possible relationships and mediating factors related to time.
Nonetheless, these models differ significantly in their ability to explain variance in the dependent variable. The "double support duration" model explains roughly 15% of variance, while extra variables such as step length and certain gait disturbances explain only 1 to 7% of the variance. This shows that the DSD model has adjusted for a large portion of the variance, which is helpful to understanding the correlation between the mechanics of gait and the severity of symptoms.
The variables of Interest, the DSD, and the ISSI, are the focus of the investigation. Considering the regression coefficients (β) and related p-values, we note that the double support duration variable on ISSI has a considerably high and positive coefficient, in addition to a very significant coefficient. This suggests that as the DSD increases, there is a positive relationship to an increase in ISSI. The scientific reason might show changes in the neural control of the lower urinary tract and the function of the pelvic floor 33, 34. Subsequent research should clarify the mediating impact of neural pathways and longitudinal data to ascertain whether changes in gait parameters precede worsening the ISSI or vice versa. Moreover, combining validated quality-of-life and symptom scales with objective gait analysis may elucidate the clinical significance of these associations in different cohorts of women.
Using principal component analysis on the physical, walking, and ISSI variables warrants an explanation. Since principal component analysis divides the total variance among the studied variables into orthogonal, unrelated components, we created ten components. The first five components are shown in Table 6, which has been reported to contain 78.046% of the total variance (eigenvalues, percentage of variance, and cumulative percentage of variance). Given that every component possesses an Eigen value indicative of its significance, and that this value has to be greater than one for it to be considered statistically relevant, two components (PC1 and PC2) were found that have eigen values greater than one, specifically 2.079 and 1.938. These components were retained, accounting for 40.18% of the total variance among the traits, with variance percentages of 20.791 for the first component and 19.385 for the second component.
The PCA biplot illustrated in Figure 1 accounts for the great variance of features across principal components 1 and 2. In regard to component 1, positive loadings are attributed to BMI, WS, SL, and SD, and in component 2, Age, BH, and BW loadings are positive. These findings may indicate the layers of variation in body composition and metabolic factors pertaining to pelvic floor function, and future research ought to quantify these relationships in a broad range of populations 35, 36.

Another explanation could be the variability across studies in measuring the severity of symptoms, including the different characteristics of the samples, the different assessment tools, and how this may impact the relationship between urinary incontinence symptoms and gait parameters in women. 37, 38. This analysis confirms the complex and multi-faceted nature of SUI and the impact on gait. However, to gain a clearer picture, it is necessary to explore the mediating influence of neural pathways along with other clinical factors.

Recent preliminary evidence suggests that the evaluation of gait parameters and symptom severity in women with stress urinary incontinence is viable, meriting further investigation of these relationships. Future research should focus on the creating standardized protocols for gait assessment so that comparisons can be made across studies. Other approaches include the use of longitudinal cohorts to elucidate potential the relationships of gait and stress urinary incontinence over time; the use of a multimodal approach, including imaging and biomechanical analyses, to understand the causal architectures of stress urinary incontinence; and the conducting of intervention studies to assess whether changes in gait parameters relieve urinary symptoms.

Limitations and Future Directions

While this study investigates the relationship between SUI and gait parameters in women, there are still important aspects of this topic that need to be acknowledged. The sample may be acceptable for preliminary analysis, although it may still be biased, and may not fully represent the population of women with SUI. A more diverse and expanded sample may allow for the generalization of the results and a more comprehensive understanding of the effects of SUI on gait in different populations. Furthermore, the cross-sectional design of the study limits our ability to make causal inferences.

Longitudinal studies would provide greater clarity about these connections. Self-reporting SUI may pose problems in this case, as respondents may report their symptoms incorrectly or even fail to capture or even report their symptoms, resulting in a false grouping for a variety of participants. Urodynamic tests could provide better insight to the level of intensity related to UI.

Moreover, the study did not take into account the effect of psychological factors, including anxiety and depression, which may impact the outcomes of both the UI and gait. Such factors should be addressed in future studies in order to provide a more comprehensive understanding of the determinants of gait in women with SUI. Finally, the study focused on specific aspects of gait and did not take into consideration other dimensions of mobility such as balance and the dynamic execution of activities of daily living. The addition of these factors would enhance understanding of SUI and its effects on the overall functional physical well-being of the individual.

There is a need for more research on the effectiveness of pelvic floor rehabilitation and gait training on urinary symptoms and gait performance. More robust randomized control trials would provide stronger evidence for the effectiveness of these interventions in improving clinical care of women suffering from SUI. Future research should also examine the role of psychological factors such as anxiety and depression in relation to UI and gait. To address SUI problems, healthcare professionals working with impacted women should take a multidisciplinary approach. It is important to incorporate professionals like physical therapists, urologists, and mental health specialists to assist in managing mobility and other SUI-related difficulties.

Patients should be informed about the possible influence of SUI on gait and mobility. Educating women on the value of physical activity and pelvic floor strengthening exercises can empower them to manage their symptoms. As best practice, routine screening for gait abnormalities should be incorporated into standard care for women with a diagnosis of SUI. Early detection of gait issues helps take preventative measures to avoid falls and improve quality of life. Because of the connection between greater Body Mass Index and stress urinary incontinence, weight loss should be incorporated into the management plan. Positive lifestyle changes can enhance urinary incontinence and gait outcomes.

The proposed strategies and future studies will further our understanding of SUI and its implications on women's health. Ultimately, this will improve the management and quality of life of the impacted individuals.

CONCLUSION

This study showcased how SUI impacts certain physical characteristics of women, including their gait patterns. Women suffering from SUI had increased body weight and BMI. Moreover, this group had a higher prevalence of gait abnormalities, indicative of possible problems related to stability and mobile functionality. The factors of lower cadence, slower walking speed, shorter step lengths, and longer durations of double support and step duration, suggested control with compensation to protect and maintain balance. The study results noted the value of combining body weight management, pelvic floor rehab, and gait training, as all are necessary for improving functional mobility and reducing fall risk. Future research aimed at enhancing the quality of life for women with SUI should emphasize investigating the primary causes of these changes in gait and determining possible solutions.

REFERENCES

1.Batmani S, Jalali R, Mohammadi M and Bokaee S. Prevalence and factors related to urinary incontinence in older adults women worldwide: a comprehensive systematic review and meta-analysis of observational studies. BMC Geriatr. 2021; 21: 212.

2.Murphy C, De Laine C, Macaulay M, Hislop Lennie K and Fader M. Problems faced by people living at home with dementia and incontinence: causes, consequences and potential solutions. Age and Ageing. 2021; 50: 944-54.
3.AlQuaiz AM, Kazi A, AlYousefi N, Alwatban L, AlHabib Y and Turkistani I. Urinary Incontinence Affects the Quality of Life and Increases Psychological Distress and Low Self-Esteem. Healthcare. 2023; 11: 1772.
4.Alsararatee HH. The impact of urinary and bowel incontinence: psychological and physical effects and interventions. Gastrointestinal Nursing. 2024; 22: S17-S24.
5.Sussman RD, Syan R and Brucker BM. Guideline of guidelines: urinary incontinence in women. BJU Int. 2020; 125: 638-55.
6.Hartigan E, McAuley JA, Lawrence M, et al. Hip Angles, Joint Moments, and Muscle Activity During Gait in Women With and Without Self-reported Stress Urinary Incontinence. The Journal of Women's & Pelvic Health Physical Therapy. 2020; 44.
7.Chow P-M, Chuang Y-C, Hsu KCP, Shen Y-C and Liu S-P. Impact of Female Stress Urinary Incontinence on Quality of Life, Mental Health, Work Limitation, and Healthcare Seeking in China, Taiwan, and South Korea (LUTS Asia): Results from a Cross-Sectional, Population-Based Study. International Journal of Women's Health. 2022; 14: 1871-80.
8.Ghaly RM, Karim Eldin AMA, Mohamed AbdelRahman DA and Elassal MH. Prevalence of urinary incontinence and its relation to occupational status among Egyptian female patients presenting with chronic cough. The Egyptian Journal of Bronchology. 2025; 19: 15.
9.Meseci E, Soysal P, Tanriverdi I, et al. The prevalence of functional urinary incontinence and its association with comprehensive geriatric assessment parameters in older women. Aging Clin Exp Res. 2025; 37: 325.
10.Ron NJ, Dolbinski SC, Hodonicky EG, et al. Associations between running mechanics, functional lower extremity strength, and stress urinary incontinence in parous female runners. J Womens Pelvic Health Phys Ther. 2024; 48: 147-53.
11.Schniepp R, Huppert A, Decker J, et al. Fall prediction in neurological gait disorders: differential contributions from clinical assessment, gait analysis, and daily-life mobility monitoring. J Neurol. 2021; 268: 3421-34.
12.Betteridge C, Mobbs RJ, Fonseka RD, et al. Objectifying clinical gait assessment: using a single-point wearable sensor to quantify the spatiotemporal gait metrics of people with lumbar spinal stenosis. J Spine Surg. 2021; 7: 254-68.
13.Bortone I, Sardone R, Lampignano L, et al. How gait influences frailty models and health-related outcomes in clinical-based and population-based studies: a systematic review. J Cachexia Sarcopenia Muscle. 2021; 12: 274-97.
14.Abidi S, Ghram A, Ghroubi S, et al. Impact of Urinary Incontinence on Physical Function and Respiratory Muscle Strength in Incontinent Women: A Comparative Study between Urinary Incontinent and Apparently Healthy Women. Journal of Clinical Medicine. 2022; 11: 7344.
15.Elsersy MA. Tension-free transobturator vaginal tape and autologous rectus fascia transobturator vaginal sling for the treatment of urinary stress incontinence: a prospective clinical study. International Journal of Reproduction, Contraception, Obstetrics and Gynecology. 2017; 6: 1174+.
16.Subak LL, Richter HE and Hunskaar S. Obesity and Urinary Incontinence: Epidemiology and Clinical Research Update. The Journal of Urology. 2009; 182: S2-S7.
17.Kumar D, Villarreal DJ and Meuret AE. Walking on the bright side: Associations between affect, depression, and gait. PLoS One. 2021; 16: e0260893.
18.Le Berre M. Comparison of lower limb muscle strength, balance, mobility, and function in elderly women with urge or mixed urinary incontinence and elderly women without incontinence. Rehabilitation Sciences. Montreal, Quebec, Canada: Faculty of Medicine, University of Montreal, 2018.
19.DeLancey JOL. Why do women have stress urinary incontinence? Neurourol Urodyn. 2010; 29: S13-S7.
20.Steimling M, Roberto M and Steimling M. Running gait retraining in the management of a multiparous runner with chronic stress urinary incontinence: A case study. The Journal of Women's & Pelvic Health Physical Therapy. 2023; 47: 114-21.
21.Miskovic-Wheatley J, Bryant E, Ong SH, et al. Eating disorder outcomes: findings from a rapid review of over a decade of research. Journal of Eating Disorders. 2023; 11: 85.
22.Steptoe A and Frank P. Obesity and psychological distress. Philosophical Transactions of the Royal Society B: Biological Sciences. 2023; 378.
23.Chilaka C, Toozs-Hobson P and Chilaka V. Pelvic floor dysfunction and obesity. Best Practice & Research Clinical Obstetrics & Gynaecology. 2023; 90: 102389.
24.Lim CC. Obesity, incontinence, and pelvic floor dysfunction. Handbook of Obesity in Obstetrics and Gynecology. Academic Press, 2023, p. 117-23.
25.Auchincloss CC. The Influence of Posture on Pelvic Floor Muscle Activation and Sensory Awareness in Women With and Without Stress Urinary Incontinence. Rehabilitation Science. Kingston, Ontario, Canada: Queen’s University, 2023.
26.Mestanza Mattos FG. Unraveling the effects of neurorehabilitation in persons with neurological disorders: recovery versus compensation. Translational Medicine. Milan, Italy: Università degli Studi di Milano, 2025.

27.Li Q, Huang Y, Wang Q, Xue K and Zhou F. The prevalence and risk factors of different degrees of stress urinary incontinence in Chinese women: A community-based cross-sectional study. Nursing Open. 2023; 10: 5079-88.
28.Chiverton PA, Wells TJ, Brink CA and Mayer R. Psychological Factors Associated with Urinary Incontinence. Clin Nurse Spec. 1996; 10.
29.Koroknai E, Rátonyi D, Pákozdy K, et al. Correlation between the female pelvic floor biomechanical parameters and the severity of stress urinary incontinence. BMC Urol. 2023; 23: 198.
30.Dumoulin C, Hay-Smith J, Habée-Séguin GM and Mercier J. Pelvic floor muscle training versus no treatment, or inactive control treatments, for urinary incontinence in women: A short version Cochrane systematic review with meta-analysis. Neurourol Urodyn. 2015; 34: 300-8.
31.Rezapour M, Seymour RB, Medda S, et al. Analyzing Gait Dynamics and Recovery Trajectory in Lower Extremity Fractures Using Linear Mixed Models and Gait Analysis Variables. Bioengineering 12: 67 (2025).
32.Blyton SJ, Snodgrass SJ, Pizzari T, Birse SM, Likens AD and Edwards S. The impact of previous musculoskeletal injury on running gait variability: A systematic review. Gait Posture. 2023; 101: 124-33.
33.Sakakibara R, Yamamoto T, Sekido N and Sawai S. How brain diseases affect the lower urinary tract function? Bladder (San Franc). 2023; 10: e21200001.
34.Dequirez P-L, De Wachter S and Biardeau X. Sacral neuromodulation for low urinary tract dysfunction: overview and mechanisms of action. Auton Neurosci. 2025; 261: 103337.
35.Kuutti MA, Hietavala E-M, Juppi H-K, Sipilä S, Aukee P and Laakkonen EK. Association of body composition with the symptoms of pelvic floor disorders in middle-aged women: a longitudinal study. Menopause. 2025; 32.
36.dos Santos Sousa AJ, Mattiello SM and Driusso P. Relationship of female pelvic floor muscle function and body composition: cross-sectional study. Arch Gynecol Obstet. 2024; 310: 3297-303.
37.Jones DR, Ruiz JM, Schreier HMC, et al. Mean affect and affect variability may interact to predict inflammation. Brain, Behavior, and Immunity. 2023; 109: 168-74.
38.Bölte S, Neufeld J, Marschik PB, Williams ZJ, Gallagher L and Lai M-C. Sex and gender in neurodevelopmental conditions. Nature Reviews Neurology. 2023; 19: 136-59.