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Research

Pelvic floor muscle function differs between supine and standing positions in women with stress urinary incontinence: an experimental crossover study

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KEY WORDS

Pelvic floor
Stress urinary incontinence
Standing position
Evaluation study
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ABSTRACT

Question: In women with stress urinary incontinence, how does pelvic floor muscle (PFM) function differ between supine and standing when assessed using manometry, vaginal palpation, dynamometry and electromyography? **Design**: An experimental crossover study. **Participants**: A total of 101 women with stress urinary incontinence were included. **Intervention**: The PFM evaluations were performed and compared in supine and standing positions. The participants were assigned to either Group 1 (assessments in supine followed by standing) or Group 2 (assessments in standing followed by supine). **Outcome measures**: The primary outcome was the PFM pressure during the maximum voluntary contraction (MVC). Secondary outcomes were the measures of PFM pressure at rest; PFM function (PERFECT scheme); active and passive forces (dynamometry); and PFM electromyography (EMG) activity. **Results**: The mean MVC pressure was significantly lower in standing (MD −7 cmH_2O, 95% CI −10 to −4). The mean PFM resting pressure was higher in standing (7 cmH_2O, 95% CI 5 to 10). Three measures of PFM function derived from vaginal palpation were better in supine than in standing. The PFM active and the passive forces measured using dynamometry were higher in standing (0.18 kgf, 95% CI 0.16 to 0.20). The resting EMG activity was higher in standing than in supine (MD 3.6 μV, 95% CI 2.6 to 4.5), whereas EMG activity during MVC was higher in supine than standing (MD −8.7 μV, 95% CI −12.5 to −4.8). **Conclusion**: The pressure and EMG activity during MVC, and PFM function were lower in standing. The resting pressure, the passive and active forces of the PFM and the resting EMG activity of the PFM were higher in standing. **[Gimenez MM, Fitz FF, de Azevedo Ferreira L, Bortolini MAT, Lordêlo PVS, Castro RA (2022) Pelvic floor muscle function differs between supine and standing positions in women with stress urinary incontinence: an experimental crossover study. *Journal of Physiotherapy* 68:51–60]**

Introduction

Arnold Kegel suggested pelvic floor muscle (PFM) contractions for the treatment of stress urinary incontinence (SUI) and observed a cure rate > 84%.[1,2] Since then, PFM training has been extensively studied, and it is currently considered the first-line treatment for SUI,[3] with a success rate of around 60 to 75% when it is performed under the supervision of a physiotherapist.[4,5] The training aims to improve muscle impairment components such as reduced strength, altered activation time or poor muscle coordination, and to decrease the symptoms of PFM dysfunction such as SUI.[6] Thus, assessing PFM function before and after training is important to determine whether the intervention yields significant changes.[7]

Methods commonly used by physiotherapists for PFM assessment include the clinical inspection of the movement of the perineum, vaginal palpation, manometry, electromyography (EMG) and dynamometry.[8] Some studies have reported that physiotherapists and patients prefer to perform the evaluation in the supine position;[9,10] it is usually easy to standardise and therefore recommended in clinical practice.[9]

To date, few studies have evaluated PFM function in the standing position in women with SUI. Among them, one study investigated PFM strength measured by manometry in standing compared to supine positions in women with SUI after a 3-month intensive PFM training program.[9] The authors showed that vaginal resting pressure was significantly higher in the standing position, and neither maximal strength nor holding time were different between the two positions.[9] Three studies have assessed PFM contraction using ultrasonographic parameters, with divergent results.[11–13] Arab et al reported that PFM contraction is greater in the standing position in relation to the supine position in women because the base of the bladder is displaced further in the cranial direction, irrespective of continence status.[11] Dietz and Clarke observed that the effect of a pelvic floor contraction was not influenced by posture in women with urinary symptoms,[12] and Peng et al observed a decrease in the activation of PFM to contain the increase in intra-abdominal pressure in

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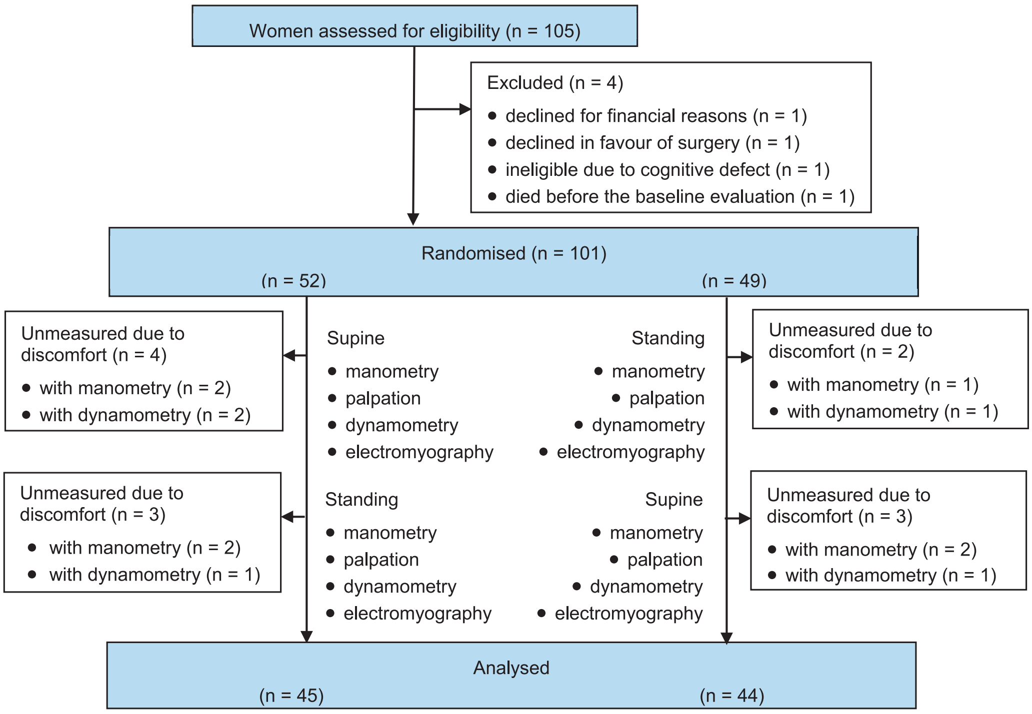

Figure 1. Design and flow of participants through the trial.

women with SUI in the standing position.[13] Two studies have evaluated PFM activity using EMG.[14,15] Aukee et al (2003) showed less muscular activation in incontinent women compared with asymptomatic ones mainly in the standing position; however, those authors used the prototype of a biofeedback device that was not previously tested as a valid instrument.[14] Aukee et al (2002) reported increased PFM strength in women with SUI in both supine and standing positions after 12 weeks of PFM training with and without biofeedback,[15] but the influence of the standing position on PFM function was not discussed. One study evaluated the PFM with digital muscle testing, manometry and transabdominal ultrasound in standing and supine positions. Digital muscle testing and vaginal squeeze-pressure scores were highest in the supine position, and vaginal resting pressure and transabdominal ultrasound scores were highest in the standing position.[10] However, the study recruited pelvic health physiotherapists as study participants to have their PFM function assessed; only a minority of these physiotherapists reported any urinary incontinence symptoms, which were mild.

The evaluation of PFM contraction in the standing position potentially allows a more functional PFM assessment in women with SUI because urine loss occurs in the upright position, with gravity influencing the muscles' function. Therefore, it is important to investigate PFM contraction in the standing position where urinary incontinence usually occurs, and whether different tools produce different results when the body position changes.

Methodological studies with high accuracy are required to find optimal assessment protocols, with sensitive, reproducible and valid instruments to measure PFM function and strength in the standing position, so that the relationship between body position and SUI mechanism can be understood.[9]

This study was developed to use four different PFM measurement tools, each of which evaluates different aspects of PFM contraction, in order to give the scientific community and clinicians a broader understanding of PFM function. The primary aim was to assess and compare the maximum voluntary contraction (MVC) pressure of the PFM in standing and supine positions by manometry in women with SUI. The secondary aims of the study were to assess in both positions: the resting pressure by manometry; the pelvic floor function by vaginal palpation (PERFECT scheme); the muscle strength (active force) and resting tone (passive force) by dynamometry; and the EMG activity of the PFM at rest and during MVC.

Therefore, the research question for the observational study was:

In women with stress urinary incontinence, how does pelvic floor muscle function differ between supine and standing when assessed using manometry, vaginal palpation, dynamometry and electromyography?

Method

Design

This observational, cross-sectional, analytical study was performed between June 2018 and February 2020. The study occurred in the Sector of Urogynecology and Reconstructive Pelvic Surgery at the Universidade Federal de Sao Paulo, Brazil. The purpose and content of the study were explained to potentially eligible women, and those who agreed to participate in the study provided written informed consent. The PFM were assessed by a single physiotherapist with 16 years of experience in PFM rehabilitation (MMG). The exam was performed in a single day and lasted about 1 hour. Participants served as their own control by undergoing the assessments in both supine and standing (order randomised) as shown in Figure 1. The STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines were followed for reporting this study.[16]

Participants

Consecutive patients with urinary symptoms were evaluated by a urogynaecologist who performed a clinical examination (patient history and physical examination, including a stress cough test) and 1-hour pad test[17] as part of routine standard care. Patients with SUI or mixed urinary incontinence with predominant SUI symptoms were considered candidates for conservative treatment. SUI was diagnosed based on the patient's report of leakage during physical stress and the condition that bothered them the most in the case of mixed urinary incontinence (stress urinary or urgency urinary incontinence), and the diagnosis was confirmed by positive cough stress test results and pad test findings ($\geq$ 1.5 g of leakage).[18] The patients were referred to a physiotherapist for PFM examination. Women were excluded if they: had chronic degenerative diseases, uncontrolled metabolic diseases, or neurological or psychiatric diseases; had previously participated in pelvic floor re-education programs and/or undergone pelvic floor surgery; were undergoing another type of treatment for UI; had pelvic organ prolapse greater than stage I on the Pelvic Organ Prolapse Quantification system;[19] were unable to contract their PFM; or reported discomfort with the PFM assessment.

Before the PFM evaluation, the physiotherapist (MMG) instructed all women about the location of the PFM with anatomical figures and muscle function was explained verbally. The subjects were instructed how to contract their PFM properly. The correct contraction was identified by vaginal palpation and observation of inward movement of the perineum during contraction. Feedback on their performance was provided by the physiotherapist,[20] with discouragement of pelvic tilt and synergistic contractions of abdominal, hip adductors and gluteal muscles. Participants unable to perform the correct contraction of the PFM after receiving instructions were not included in the study.

Pilot testing of the measurement procedures

To test the intra-rater reliability, 10 women were evaluated on two different occasions separated by a 1-week interval prior to beginning the study. To determine the intraclass correlation coefficient (ICC) of the qualitative variable (Oxford scale), the Cohen's Kappa criteria was used. The weighted Kappa 95% for the Oxford scale was 1.000 for the supine position and 1.000 for the standing position. To determine the ICC of quantitative variables (manometry, endurance, fast contraction, EMG, dynamometry), Cronbach's alpha was used. Cronbach's alpha for the resting pressure and MVC pressure of the PFM (manometry), endurance and fast contraction (vaginal palpation), muscle resting activity and PFM contraction strength (dynamometry) was 1.000 in the supine position and 1.000 in the standing position. Chronbach's alpha for the resting PFM electrical activity was 0.982 in the supine position and 0.997 in the standing position. Chronbach's alpha for MVC electrical activity was 0.997 in the supine position and 0.999 in the standing position.

Measurement procedures

The participants were assigned with equal probability to either Group 1 (assessment in supine then standing) or Group 2 (assessment in standing then supine). The allocation sequence was generated by a research assistant (FFF) using a computer-generated random number table in a ratio of 1:1 and it was concealed in sequentially numbered, sealed, opaque envelopes. The envelopes were kept in a closed locker, which only the research assistant could access, at the centre. The envelopes were given to the physiotherapist (MMG) immediately prior to the PFM examination. In both the supine and standing positions, the same sequence was used to evaluate the PFM: resting and MVC pressures were measured in cmH_2O using a commercial manometer[a];[21] muscle function was assessed by vaginal palpation (strength, endurance and fast contraction);[22] resting (passive force) and unidirectional compression strength and antero-posterior forces (active force) were measured in kilogram-force (kgf) by dynamometry[b];[23] and electrical activity at rest and during the MVC was measured in microvolts (μV) through surface EMG[b].[24]

During PFM assessment in supine, the participants adopted a dorsal recumbent position in a gynaecological chair with the body slightly elevated, the feet positioned on stirrups, the knees flexed to 30 deg and the upper limbs placed alongside the trunk. During PFM assessment in standing, the participants stood with the feet hip-width apart, the knees extended to maintain the vertical alignment of the trunk with physiological curvatures of the spine, the upper limbs relaxed beside the trunk and the gaze directed towards the horizon. When movement of the perineum during the contraction was to be observed, this was facilitated by a mirror placed between the participant's feet.

The same verbal instructions were used for all evaluations of the PFM. For assessment of the PFM resting tone, the women were instructed to keep their body and PFM relaxed and to breathe normally. For assessment of the PFM during MVC, they were asked to squeeze and lift their PFM as if they were preventing the escape of flatus and urine.[25] Between each measurement tool and each position, the participants had a 5-minute rest to minimise fatigue.

Resting and MVC pressure of the PFM by manometry

The MVC pressure of the PFM was evaluated using a commercial manometer[a]. The catheter was covered with a new sterile condom for each patient and inserted into the vagina until the entire length of the compressible part of the device was above the level of the hymenal ring, and the resting pressure of the PFM was measured in cmH_2O for 3 minutes. Then the device was reset to zero, three consecutive MVCs were performed with an interval of 10 seconds between each contraction,[21] and the best of the three values was recorded (primary outcome).[24] Only the contractions during which an inward movement of the balloon catheter was observed and synergistic contractions of the hip adductors and gluteal muscles or pelvic tilt were not observed were included in the analysis. Figure 2 illustrates the positions of the assessor and the probe in the vagina.

PFM function by vaginal palpation

The PFM function was assessed by vaginal palpation and quantified according to the PERFECT scheme.[22] The PFM strength was assessed by the modified Oxford Grading Scale (0 to 5).[17] The participants were instructed to perform three contractions lasting 5 seconds, each with the greatest strength possible (maximum PFM contractions). The periods of contraction were separated by 1-minute rest periods. Endurance was expressed as the length of time for up to 10 seconds that a maximal vaginal contraction could be sustained. Thus, the contraction was timed until the muscle started to fatigue. The fast contraction variable was recorded as the number of fast maximal PFM contractions that could be repeated (up to 10).[22] Figure 3 illustrates the position of the assessor and the fingers in the vagina.

PFM active and passive forces by dynamometry

A wireless unit with dynamometer[c] was used to assess the PFM. In brief, the dynamometer comprises a computerised central unit, a peripheral unit and a dynamometric speculum. The dynamometer was calibrated prior to PFM assessment. After thorough disinfection, the probe was covered with a new condom and appropriately lubricated with water-soluble jelly. The dynamometer probe was equipped with a 2-cm load cell on its base, and the passive force and the maximal PFM strength (active force) were measured in kgf. The passive force was recorded over a period of 10 seconds. The mean value was considered an index of PFM tonicity. Then, the maximal PFM strength was recorded.[23] Three 10-second contractions separated by a 3-minute rest period were performed. The best of three contractions was used for analysis.[23] Figure 4 illustrates the position of the assessor and the probe in the vagina.

PFM electrical activity by surface EMG

The surface EMG of the PFM was performed using a transvaginal probe. To eliminate external interference, a reference electrode[d] was used on the styloid process of the radius.[26] The electrodes were connected to a wireless unit with electromyograph[c], and the EMG signal, expressed in μV, was recorded by commercial software[e] and stored on a portable computer. To evaluate the mean value of electromyographic activity of the PFM at rest, a 10-second period was used. Then, the electromyographic activity of the PFM during an MVC was recorded. Three 10-second contractions separated by 3 minutes of rest were performed, and the surface EMG signals were recorded according to the surface EMG for the non-invasive assessment of muscles (SENIAM) guidelines.[27] The best of three trials was used for analysis.[24] To minimise possible confounding in the EMG signals, the evaluations were always performed in the morning and the size of the electrodes was also standardised, but hydration was not standardised. Figure 5 illustrates the position of the assessor and the probe in the vagina.

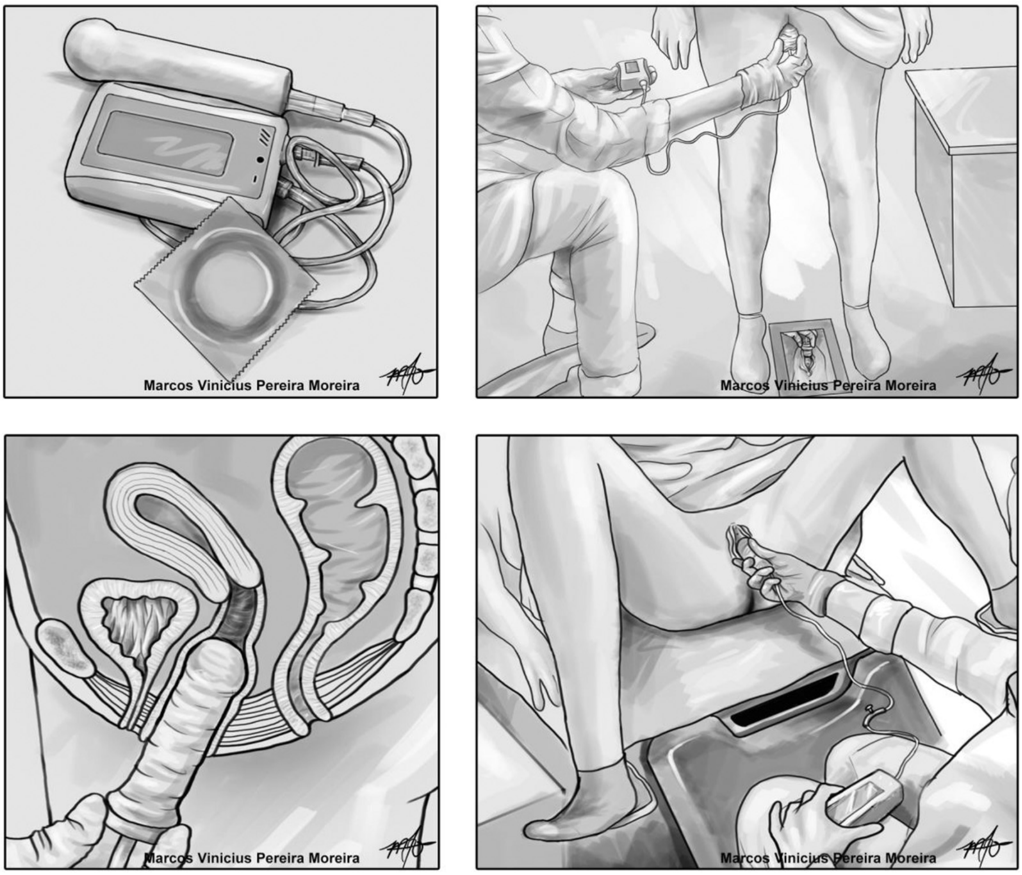

Figure 2. Manometry: positions of the assessor and the probe in the vagina.

Figure 3. Vaginal palpation/visual observation: positions of the assessor and the fingers in the vagina.

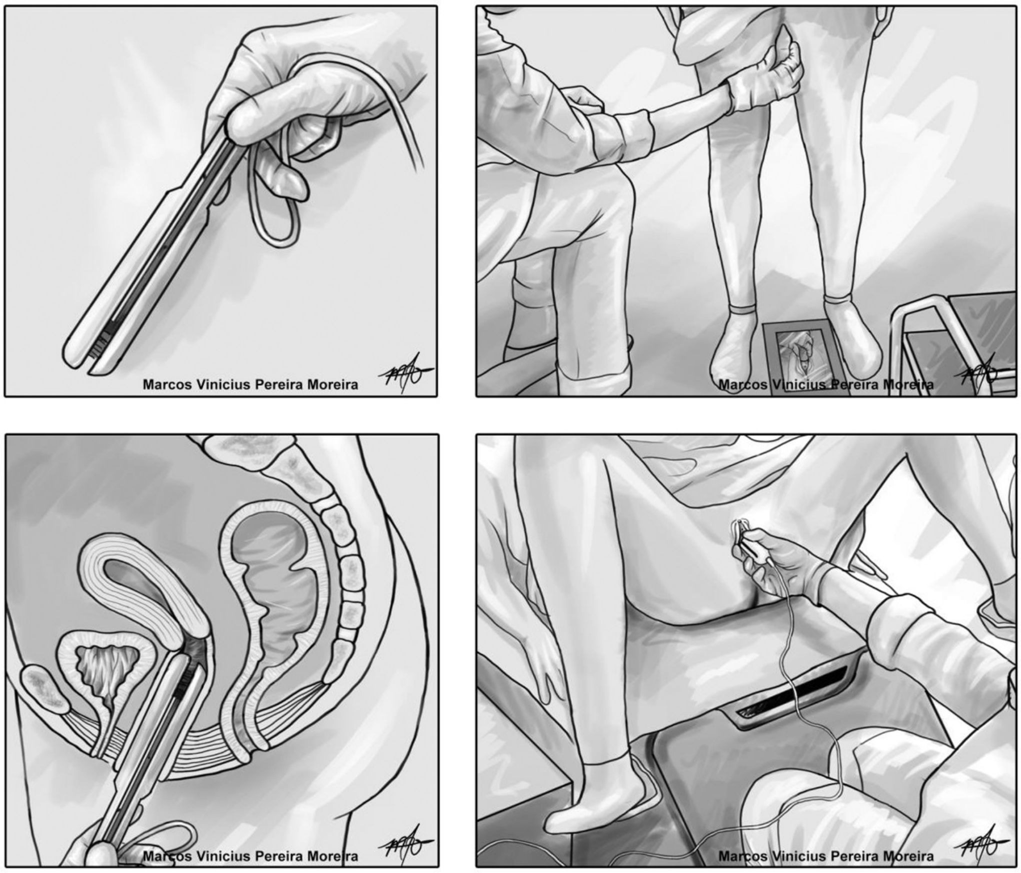

Figure 4. Dynamometry: positions of the evaluator and the probe in the vagina.

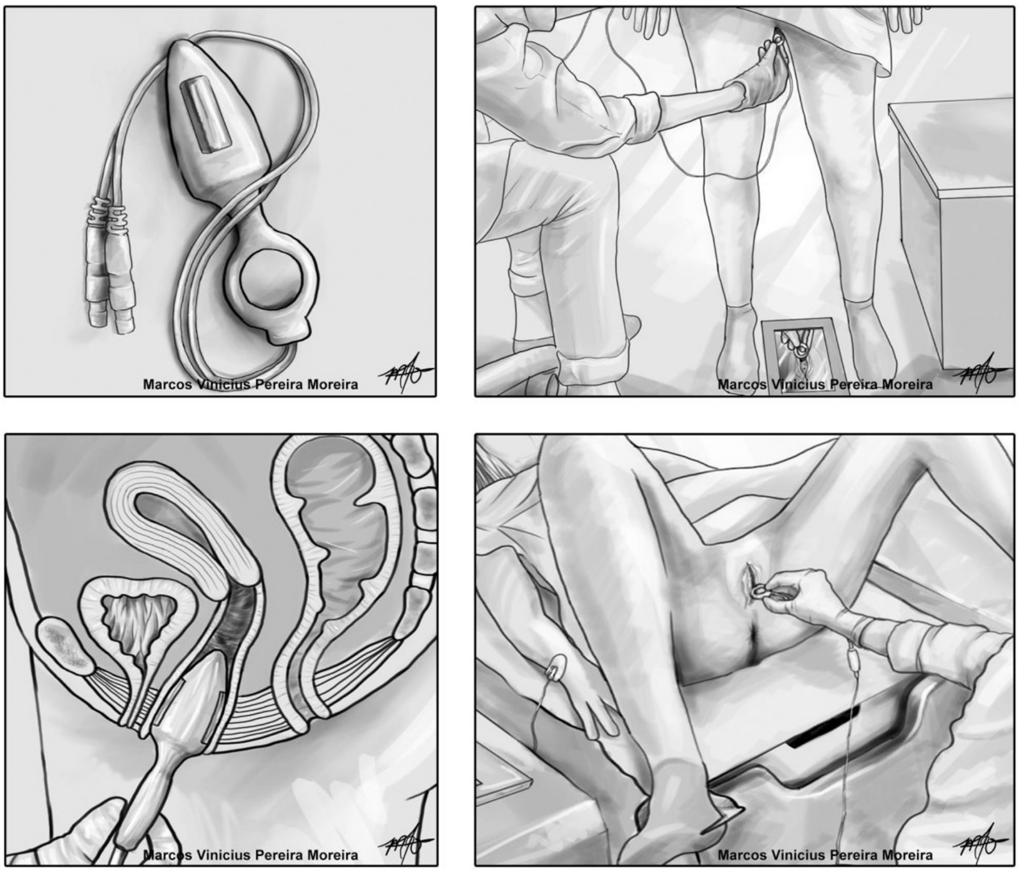

Figure 5. Electromyography: positions of the assessor and the probe in the vagina.

Table 1
Demographic and clinical characteristics of the study participants.

Characteristic	Total (n = 101)	Group 1 (assessed in supine then standing) (n = 52)	Group 2 (assessed in standing then supine) (n = 49)
Age *(yr)*, mean (SD)	54 (11)	53 (11)	55 (12)
Body mass index *(kg/m²)*, mean (SD)	29.4 (5.3)	28.9 (5.2)	29.9 (5.4)
Marital status, n (%)			
single	19 (19)	9 (17)	10 (20)
married	62 (61)	32 (62)	30 (61)
divorced	12 (12)	7 (14)	5 (10)
widowed	8 (8)	4 (8)	4 (8)
Education level, n (%)			
primary/secondary	86 (85)	44 (85)	42 (86)
university	15 (15)	8 (15)	7 (14)
Ethnicity, n (%)			
Asian	1 (1)	1 (2)	0 (0)
Black	7 (7)	2 (4)	5 (10)
Caucasian	49 (49)	25 (48)	24 (49)
Mixed race	44 (44)	24 (46)	20 (41)
Type of UI diagnosed, n (%)			
stress	51 (51)	24 (46)	27 (55)
mixed	50 (50)	28 (54)	22 (45)
UI symptom duration *(mth)*, median (IQR)	36 (24 to 96)	36 (24 to 60)	36 (24 to 120)
Obstetric history *(n)*, median (IQR)			
pregnancy	3 (2 to 4)	3 (2 to 4)	3 (2 to 4)
caesarean	0 (0 to 1)	0 (0 to 1)	1 (1 to 2)
vaginal birth	1 (0 to 2)	1 (0 to 2)	1 (0 to 3)
Pad test *(g)*, median (IQR)	6 (2 to 18)	6 (2 to 18)	6 (3 to 19)
Positive cough test, n (%)	101 (100)	52 (100)	49 (100)
Menopause age *(yr)*, mean (SD)	48 (6)	50 (5)	47 (6)

UI = urinary incontinence.
Some percentages do not sum to 100 due to the effects of rounding.

Data analysis

The sample size calculation was based on published data.[9] In a conservative approach, the values were always rounded so that the difference decreased and the variability increased, thereby increasing the sample size. The following statistical parameters were used: normal distribution, type-I error < 0.05 (two-tailed) and statistical power of 80%. The primary outcome used to calculate the sample size was a difference of 2 cmH_2O (SD 4) between the PFM MVC pressures in the supine and standing positions. Thus, the sample size required to achieve a statistical power of 80% was at least 63 patients. To allow for loss to follow-up, the initial sample size was increased to 101.

Data analyses were performed by another professional who was blinded to group allocation. Commercial statistical software[f] was used for the statistical analyses. The categorical data are presented as the absolute number and the respective percentage, and the continuous data are presented as the mean and the respective standard deviation. The related samples from the two different positions were compared with tests for paired data. For inferential statistical analysis of the continuous data, the normality of all the data was tested with the Kolmogorov-Smirnov test, and the Wilcoxon test was subsequently used in place of the paired t-test, where applicable. Spearman correlation was used to identify the degree of association between two variables (eg, rest and maximum voluntary contraction) and between the measurement tools (eg, manometry, dynamometry and electromyography). The degree of association between the variables was classified as high (0.80 to 1.00), moderate (0.60 to 0.80) or weak (< 0.59), according to the criteria reported by Richman et al.[28] The adopted level of significance was 5%.[29]

To determine the intraclass correlation coefficient (ICC) of the ordinal variables (Oxford scale), the following Cohen's Kappa criteria for the level of agreement were used: 0 = zero, 0.10 to 0.39 = weak, 0.40 to 0.69 = moderate, 0.70 to 0.99 = strong and 1 = perfect. To determine the ICC of continuous variables (endurance, fast contraction, EMG, manometry and dynamometry), the following Cronbach's alpha criteria were used: < 0.21 = small, 0.21 to 0.40 = reasonable, 0.41 to 0.60 = moderate, 0.61 to 0.80 = substantial and 0.81 to 1.00 = perfect. A significance level of 5% was used.[30,31]

Results

Participants

A total of 105 women were contacted; of them, 101 met the eligibility criteria, with 52 randomised to assessment in supine before standing and 49 randomised to assessment in standing before supine. After inclusion, 12 women were excluded because they reported discomfort during the PFM assessment (Figure 1). The mean age of all the included women was 54 years (SD 11). The two randomly allocated groups had similar demographics and clinical characteristics. Most participants were married (61%), Caucasian (49%) or mixed race (44%), with primary and secondary education level (85%). About half had SUI and about half had MUI with predominant SUI symptoms. They had a median of three pregnancies, mean body mass index of 29.4 kg/m^2, mean menopausal age of 48 years and a mean duration of urinary symptoms of 36 months (Table 1).

Effect of body position on PFM assessment using manometry

The pressure recorded using manometry during an MVC (primary outcome) was lower in standing than in supine, with a mean difference of −7 cmH_2O (95% CI −10 to −4), as shown in Table 2. This effect of body position on the manometric pressure was observed regardless of which body position was tested first (see Table 3 on the eAddenda).

The pressure recorded using manometry at rest was higher in standing than in supine, with a mean difference of 7 cmH_2O (95% CI 5

Table 2
Manometric assessment of resting and MVC pressures of the pelvic floor muscles in the supine and standing positions, and the mean difference (95% CI) of standing relative to supine.

Manometry *(cmH_2O)*, mean (SD)	Supine (n = 89)	Standing (n = 89)	Mean difference (95% CI)
Resting	33 (9)	40 (9)	7 (5 to 10)
MVC	32 (18)	25 (13)	−7 (−10 to −4)

Shaded row indicates the primary outcome.
MVC = maximal voluntary contraction.

Table 4
Three aspects of function of the pelvic floor muscles assessed by vaginal palpation in the supine and standing positions, and the median difference (95% CI) of standing relative to supine.

Vaginal palpation, median (IQR)	Supine (n = 89)	Standing (n = 89)	Median difference (95% CI)
MOS *(0 to 5)*	2 (2 to 3)	2 (1 to 2)	0 (−1 to 0)
Endurance *(sec)*	4 (3 to 4)	2 (2 to 3)	−1 (−1 to −1)
Fast contractions *(n)*	6 (4 to 8)	3 (2 to 5)	−2 (−3 to −2)

MOS = Modified Oxford Scale.

to 10), as shown in Table 2. This effect of body position on the manometric pressure was observed regardless of which body position was tested first (see Table 3 on the eAddenda).

In standing, there was a correlation between the resting pressure and the MVC pressure: $r = 0.48$ (95% CI 0.30 to 0.62), which was a weak correlation.[28] This correlation was observed regardless of which body position was tested first (data not shown). In supine, no clear correlation was evident between the resting pressure and the MVC pressure: $r = 0.08$ (95% CI −0.13 to 0.28). This absence of correlation observed regardless of which body position was tested first (data not shown).

Effect of body position on PFM assessment using vaginal palpation

Modified Oxford Scale

Grading with the Modified Oxford Scale demonstrated weak PFM contractions without elevation of the vaginal wall in both groups and positions. The median score in each group was 2, although the distribution favoured the supine group, as shown in Table 4 and Figure 6a. This effect of body position on the Modified Oxford Scale score was observed regardless of which body position was tested first (see Table 5 on the eAddenda).

Endurance

The duration for which a maximal PFM contraction could be sustained was shorter in standing than in supine: median difference −1 second (95% CI −1 to −1), as shown in Table 4 and Figure 6b. This effect of body position on the duration of a sustained contraction was observed regardless of which body position was tested first (see Table 5 on the eAddenda).

Fast contractions

The number of fast maximal PFM contractions that could be repeated (up to 10) was lower in standing than in supine: median difference −2 (95% CI −3 to −2), as shown in Table 4 and Figure 6c. This effect of body position on the number of fast contractions was observed regardless of which body position was tested first (see Table 5 on the eAddenda).

Effect of body position on PFM assessment using dynamometry

The passive force of the PFM recorded using dynamometry was higher in standing than in supine, with a mean difference of 0.18 kgf (95% CI 0.16 to 0.20), as shown in Table 6. This effect of body position on the passive force of the PFM was observed regardless of which body position was tested first (see Table 7 on the eAddenda).

The active force of the PFM recorded using dynamometry was also higher in standing than in supine, with a mean difference of 0.14 kgf (95% CI 0.08 to 0.19), as shown in Table 6. This effect of body position on the active force of the PFM was observed, regardless of which body position was tested first (see Table 7 on the eAddenda).

In standing, there was a correlation between the active and passive forces: $r = 0.69$ (95% CI 0.56 to 0.78), which was a moderate correlation.[28] In supine, a weak correlation was evident between the active and passive forces: $r = 0.54$ (95% CI 0.37 to 0.67). These correlations were not influenced by which body position was tested first (data not shown).

Effect of body position on PFM assessment using surface EMG

The electrical activity recorded using EMG at rest was higher in standing than in supine, with a mean difference of 3.6 μV (95% CI 2.6 to 4.5), as shown in Table 8. This effect of body position on EMG activity was observed, regardless of which body position was tested first (see Table 9 on the eAddenda).

The electrical activity recorded using EMG during a MVC was lower in standing than in supine, with a mean difference of −8.7 μV (95% CI −12.5 to −4.8), as shown in Table 8. This effect of body position on EMG activity was observed regardless of which body position was tested first (see Table 9 on the eAddenda).

In standing, there was a correlation between the electrical activity at rest and during an MVC: $r = 0.58$ (95% CI 0.42 to 0.70), which was a weak correlation.[28] In supine, a weaker correlation was evident between the electrical activity at rest and during an MVC: $r = 0.32$ (95% CI 0.12 to 0.49). These correlations were not influenced by which body position was tested first (data not shown).

Individual participant data are available in Table 10 on the eAddenda.

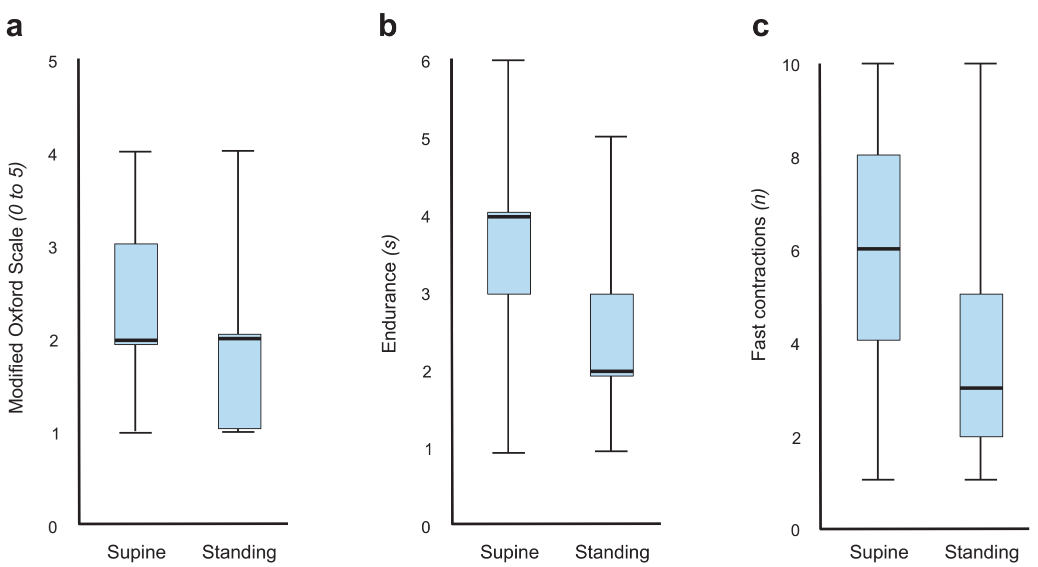

Figure 6. Distributions of scores derived from vaginal palpation in supine and standing: (a) Modified Oxford Scale, (b) duration of sustained maximal contraction and (c) number of fast maximal contractions.

Table 6
Dynamometric assessment of passive and active forces of the pelvic floor muscles in the supine and standing positions, and the mean difference (95% CI) of standing relative to supine.

Dynamometry *(kgf)*, mean (SD)	Supine (n = 89)	Standing (n = 89)	Mean difference (95% CI)
Passive	0.34 (0.11)	0.52 (0.12)	0.18 (0.16 to 0.20)
Active	0.74 (0.36)	0.88 (0.29)	0.14 (0.08 to 0.19)

Discussion

This study demonstrated that assessment of the PFM of women with SUI in supine versus standing led to differences in the scores obtained using manometry, vaginal palpation, dynamometry and EMG. Some of these assessment methods produced better results in standing, while others produced better results in supine. For each outcome measure, the difference in scores arising from testing in supine versus in standing was very consistent, regardless of which position was tested first.

When testing the pressure recorded using manometry during an MVC (primary outcome), the MVC pressure was significantly lower in the standing position. The same was demonstrated by Frawley et al, who investigated pelvic health physiotherapists who reported no or mild urinary incontinence symptoms.[10] In contrast, Bø and Finckenhagen did not find a difference in vaginal squeeze pressure between the two positions in women with SUI assessed after a 3-month intensive PFM training program;[9] the previous treatment may explain their better-than-expected scores in the standing position.[9] Vaginal squeeze pressure measurements can be invalid if there is involvement of other muscle groups that would increase the measured values. The simultaneous observation of the inward movement of the perineum indicates that the contraction is being performed correctly.[6] Anatomic placement of the device is another factor to record to achieve reproducible measurements.[32] In the present study, the physiotherapist held the catheter in position while the participant contracted her PFM, and ensured that the catheter did not move between the contractions. A mirror was placed between the participant's feet in the standing position to monitor the contraction.

This study detected a high resting pressure in the standing position when compared with the supine position, which is in agreement with previous reports by Bø and Finckenhagen[9] and Frawley et al.[10] There is still limited knowledge of the mechanisms underlying this, which need to be addressed in future research. Bø and Finckenhagen discussed that this higher resting pressure may be directly influenced by gravity, and speculated whether the increase in this pressure is a direct consequence of strong PFM and whether there is a positive association between high resting vaginal pressure, resting urethral pressure and continence.[9] Frawley et al did not consider the vaginal resting pressure to be a reliable method in upright positions and pointed out that this can limit the usefulness of the information obtained from this measure in vertical positions.[10] The results of our study suggest that in women with SUI with no previous treatment, gravity and intra-abdominal pressure impact the PFM (due to the higher resting pressure), which interferes with the voluntary PFM contraction (ie, lower MVC pressure). Factors that could interfere in the assessment of PFM in the standing position reported in the studies by Bø and Finckenhagen[9] (3-month intensive PFM training program, a small number of subjects) and Frawley et al[10] (a small, convenience sample of pelvic health physiotherapists) were controlled in this study: the sample size was calculated to answer the primary objective, the SUI was detected by the pad test and the participants had not previously performed PFM training.

Our evaluation of performance, endurance and muscle coordination by vaginal palpation, and using the PERFECT scheme classification revealed that PFM function score was lower in standing than in supine in women with SUI. Physiotherapists use vaginal palpation to assess PFM function because both the squeeze pressure and lift can be assessed, and this method is a low-cost and relatively easy method to conduct.[6] Frawley et al had few subjects grouped in each PFM grade and did not consider it appropriate to draw conclusions about their results.[10] The sensitivity of digital palpation using the modified Oxford scale in detecting the component of elevation of PFM activity has been questioned when compared to a more objective measure of elevation of PFM such as ultrasound. A separate qualitative scale of the elevation component of the PFM has been suggested for digital muscle testing.[10] The Oxford scale also evaluates the squeeze pressure of the PFM during contraction, and we believe that squeeze pressure produced by PFM in the standing position and assessed by vaginal palpation can reproduce the actual capacity of the PFM to contract when standing still in a manner to prevent loss of urine. During the vaginal palpation, the therapist can instruct the patient in how to perform a contraction correctly and tell her about coordination skills and strength. Testing in other positions and in dynamic tasks would be needed to assess the full picture of the function of the PFM.

We found that the EMG activity of the PFM during the MVC was lower in the standing position in women with SUI. This result is in accordance with Laycock,[33] who compared surface vaginal EMG signals for PFM and observed a significant lower PFM activity in standing compared with supine positions.[33] Rett et al[34] and Aukee et al[14] also reported similar results to ours, even though they evaluated PFM EMG activity after a pelvic floor training program.[14,34] Rett et al failed to show that the PFM contraction capacity would be similar in supine and standing positions after a PFM training program, and explained that a large force of gravity on the PFM in standing would have caused overload, and the capacity of the PFM to perform satisfactory muscle contractions would have decreased, thereby exhibiting smaller amplitudes of EMG signals.[34] Aukee et al did not discuss the influence of the standing position on PFM function.[14] Our study showed that the mean EMG amplitudes at rest were higher in the standing position, which was similar to that reported by Rett et al.[34] According to the authors, higher amplitudes in the standing position have also occurred in response to the action of gravity and activation of tonic fibres rather than phasic fibres, which are needed more during tasks requiring great effort.[34] EMG can be used to indicate denervation/reinnervation in striated PFM. In cases of mild-to-moderate partial denervation, EMG is very limited in providing data on muscle strength (which is logically impaired due to denervation).[35] Therefore, other methods in addition to EMG need to be used to evaluate PFM. Surface EMG is considered to be a reproducible measure; however, the quality of the electrical signals can be affected by many factors.[35] Factors that can influence the amplitude of surface EMG signals include the location and size of the electrodes, the hydration level of the individual and the diurnal variation in muscle bioelectric activity;[27] therefore, evaluation of PFM EMG activity may be more valid for the elaboration of PFM training considering the daily muscle condition, and not for evaluation of muscle function before and after treatment.

The passive and active forces of the PFM by dynamometry were higher in the standing position in our observation of women with SUI. Dynamometry is a reliable tool for assessing the PFM forces in the supine position in women with pelvic floor dysfunction.[36,37] The literature revealed a 92% increase in the resting vaginal closure force when a woman moves from the supine to the standing position, and the increased intra-abdominal pressure or greater resistance from the PFM would be two potential contributors for this result.[38] In relation to vaginal closure force, Morgan et al showed that the pelvic muscle force elevating the speculum is independent of body orientation.[38] Morgan et al also revealed that the subjects were able to isolate the PFM and avoid increasing the intra-abdominal pressure during the MVC in supine, but they had difficulty contracting the PFM without

Table 8
Electromyographic assessment of activity of the pelvic floor muscles at rest and during MVC in the supine and standing positions, and the mean difference (95% CI) of standing relative to supine.

Electromyography *(μV)*, mean (SD)	Supine (n = 89)	Standing (n = 89)	Mean difference (95% CI)
Resting	6.2 (2.7)	9.8 (4.3)	3.6 (2.6 to 4.5)
MVC	37.5 (19.9)	28.8 (13.7)	−8.7 (−12.5 to −4.8)

MVC = maximal voluntary contraction.

increasing intra-abdominal pressure while standing.[38] Therefore, the results need to be interpreted with caution because higher measures do not always indicate better PFM function.

According to the literature, the supine position is one of the easiest positions in which pelvic floor evaluations can be performed.[9,10,14] The standing assessment has the following disadvantages compared with supine assessment: patients experience discomfort, therapists require more time to complete the examination, there is no consensus about the best equipment to use,[9,14,34] and leakage of urine during the examination is more likely, which can embarrass the patient. The discomfort caused by the examinations in different positions was not evaluated and graded in this study; patients were only excluded if they reported discomfort with the devices when the examinations started (supine or standing). The position of the therapist was standardised during the evaluations to minimise possible discomfort. More time is usually required for the examinations in both supine and standing, and the costs associated with the longer examination time need to be considered.

Some factors need to be considered in the interpretation of the results of the present study. The literature has investigated the intra-abdominal pressures during physical activity and showed that the progression of the activity, such as walking to running, increases intra-abdominal pressure in a similar way. The increased intra-abdominal pressure in response to the increased demand for tasks may be due to the role that intra-abdominal pressure plays in the stability of the spine and is aggravated by the high acceleration of impact forces.[39] Identifying the values of intra-abdominal pressure (using specific and validated equipment) in the standing position can contribute to the understanding of its impact on PFM function and its capacity for muscle contraction. We did not evaluate intra-abdominal pressure because there is no specific instrument in our practice for measuring intra-abdominal pressure during assessment of PFM in the standing position.

In addition, our findings were obtained from evaluation of a specific low socioeconomic population of women who attended the public health system in Brazil. Brazil suffers from great social inequality, where people with a high socioeconomic and educational status usually are of low parity, with high rates of caesarean section and adequate access to private healthcare and nutrition, whereas those in the low-income population usually have higher parity and vaginal deliveries, less access to the public healthcare system and may have deficient nutrition, among other differences. Given that, the findings should be confirmed in other populations nationally and worldwide before being generalised.

This observational, cross-sectional, analytical study followed the standard guidelines for performance and report. Its strengths included randomisation of the order to perform the exams to minimise interference of the starting position on the assessments and the performance of the intra-examiner reproducibility test for all tools. The sample size calculation was performed properly and the intended sample of 101 participants with SUI was enrolled.

In conclusion, this study consistently showed that measurements of PFM function vary between standing and supine positions in women with SUI with no previous treatment. It demonstrated that the upright position influences the ability of women to perform satisfactory muscle contractions, as evidenced by manometry, EMG and vaginal palpation. Those findings suggest that the action of gravity and abdominal pressure in the standing position causes overload on PFM. Physiological differences in the function of PFM can have wide implications for patient care, which may explain the differences in symptom control and in the efficacy of the PFM training in the treatment of SUI in the literature. Although it is always more convenient to study the action of PFM in the supine position, the data obtained in the upright posture capture the natural action of the PFM in the position in which they work in daily life. So, the standing position may be more valid for analysing the function and mechanism of action of PFM in relation to SUI. The precise description of the PFM assessment in the standing position, as performed and illustrated in the present study, will help to standardise this assessment, so that future studies can be carried out, and thus allow comparison of findings between studies, consistency in publications and the grouping of knowledge, collaborating for a greater discussion in the scientific community.

What was already known on this topic: Pelvic floor muscles are commonly assessed in supine. The few studies that have compared pelvic floor muscle function in supine and standing in women with stress urinary incontinence have some conflicting results.
What this study adds: Measurements of pelvic floor muscle function vary between standing and supine positions in women with stress urinary incontinence with no previous treatment. The upright position influences the ability of women to perform satisfactory muscle contractions, where gravity and abdominal pressure may overload the pelvic floor muscles. Although examining these muscles in supine is convenient, data obtained in standing capture the natural action of the muscles in many activities of daily life. So, the standing position may be more valid for analysing the function and mechanism of action of the pelvic floor in relation to stress urinary incontinence.

Footnotes: [a] Peritron™, Cardio Design Pty Ltd, Oakleigh, Victoria, Australia.

[b] Miotec®, Porto Alegre, Rio Grande do Sul, Brazil.

[c] New Miotool Wireless, Miotec, Porto Alegre, Rio Grande do Sul, Brazil.

[d] Medi-Trace™, Kendall, Mansfield, MA, USA.

[e] Miotec Suite™ software, version 1.0, Miotec, Porto Alegre, Rio Grande do Sul, Brazil.

[f] SPSS Version 17.0, SPSS Inc, Chicago, USA.

eAddenda: Tables 3, 5, 7, 9 and 10 can be found online at https://doi.org/10.1016/j.jphys.2021.12.011.

Ethics approval: The Research Ethics Committee of the Universidade Federal de Sao Paulo (UNIFESP) in Brazil, approved this study (2.351.777). All participants gave written informed consent before data collection began.

Competing interests: The authors declare they do not have any conflicts of interest.

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