

# The Effect of Ankle Position on Pelvic Floor Muscle Contraction Activity in Women

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**Purpose:** Stress urinary incontinence is extremely common in women. Conservative management includes pelvic floor muscle exercises to increase strength and muscular contraction forces to improve incontinence. We examined the effects of passive and active ankle flexion on pelvic floor muscle activity during exercises.

**Materials and Methods:** A total of 31 married women performed random pelvic floor muscle contractions while standing, and in 8 passive and active positions while pelvic floor muscle activity was simultaneously measured by electromyography.

**Results:** All ankle positions resulted in greater pelvic floor muscle activity than the horizontal foot position. Significantly greater muscle activity was seen with ankles in the plantar position with raised arms ( $p = 0.0051$ ).

**Conclusions:** Pelvic floor muscle exercises performed with active ankle positions may increase the effectiveness of these exercises. Further studies are required to elucidate mechanisms for this finding.

## Abbreviations and Acronyms

DF = dorsiflexion

DFAU = DF and arms up

EMG = electromyography

HS = horizontal standing

MVC = maximal voluntary contraction

PF = plantar flexion

PFAU = PF and arms up

PFM = pelvic floor muscle

SUI = stress urinary incontinence

**Key Words:** urinary incontinence, stress; muscle, skeletal; ankle joint; pelvic floor; electromyography

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INCONTINENCE affects more than 10 million Americans<sup>1</sup> and SUI is the most common form in women. SUI causes involuntary urine loss during activities that cause abrupt increases in abdominal pressure, such as coughing, sneezing, laughing or exertion.<sup>2</sup> The etiology of SUI is anatomical or neuromuscular in origin and it is associated with various clinical conditions. Symptoms are associated with changes in urethral or sphincter function. It is not associated with high morbidity but it causes emotional distress in affected patients.<sup>2</sup>

Current therapeutic modalities include surgery, and exercise and drug therapies. The primary initial therapeutic approach is conservative, including PFM exercises, electrical stimulation therapy, and fluid intake and urination instruction.<sup>2</sup> Researchers have reported that PFM exercises are optimal for SUI because of efficacy, safety, low cost and patient receptivity.<sup>2,3</sup>

PFMs are strongly associated with female continence and, therefore, such exercises are compatible with the conscious PFM precontraction

used to prevent leakage during abrupt increases in abdominal pressure.<sup>3</sup> The American gynecologist Kegel reported that PFM exercises improved SUI and resulted in increased muscular strength, regular voluntary contractions and improved urethral activity control.<sup>4</sup> Regular exercises decreased the urinary leakage associated with abdominal pressure increases.<sup>5,6</sup> A recent study evaluated contraction sequences in superficial and deep PFM in continent and incontinent women in various positions and demonstrated that continent women had consistent contraction sequences that were not seen in incontinent women.<sup>7</sup> PFM exercises result in PFM hypertrophy and increased urethral pressure, structural support and sphincter responses.<sup>5,6</sup> Exercises strengthen PFMs and encourage MVCs, which assist with improving incontinence.<sup>8</sup>

Exercise testing guidelines suggest that muscle overload is important for PFM exercises since PFMs are skeletal muscles. The transverse abdominis and the diaphragm co-contract and activate during PFM contractions, which suggests that individuals should isolate and indirectly train the PFMs through transverse abdominis training.<sup>9</sup> Conversely another study suggests that current procedures supporting PFM precontraction and related strength training are preferred to indirect PFM training through primary abdominal muscle training.<sup>3</sup> Another study has suggested that co-activation of PFMs and the abdominal musculature results in simultaneous contraction of the 2 muscle groups in normal women.<sup>10</sup>

EMG is a useful tool for measuring skeletal muscle electrical activity that uses surface or intramuscular electrodes. Surface electrodes are suitable for large superficial muscle groups, while needle and wire intramuscular electrodes are most appropriate for small muscles located in deep body tissues. Surface EMG has limited use for deep intramuscular measurement because it detects signals from the surrounding musculature. Its accuracy depends on direct electrode placement. EMG suggests the muscular force magnitude but it cannot serve as an absolute measuring tool for contraction force. Needle electrodes can be applied directly to particular muscles. Needle EMG allows direct muscle separation for measurement, unlike surface EMG. Many muscles provide nonlinear rather than direct responses and it is difficult to directly compare single unit muscular data using EMG measurements, although recruitment thresholds between and within individuals are easily comparable.<sup>11</sup>

Position and postural changes influence PFM contractions and SUI control.<sup>12,13</sup> Postural changes such as leg crossing and forward bending have effectively decreased urine leakage in women with SUI.<sup>14</sup> Bo and Stien reported that hip adduction, and gluteal and abdominal muscle contraction

yielded synergistic PFM contraction.<sup>15</sup> Different heel heights resulted in different pelvic tilt angles in another study and there is additional evidence that ankle position differences result in increased PFM activity through enhanced pelvic tilt.<sup>14,15</sup> The effects of passive ankle position on PFM have been evaluated. To our knowledge there are no studies of the association between active ankle positions and PFM muscle activity. Active ankle positions can result in the co-activation of several muscle groups to facilitate indirect PFM activity.

We examined the effects of ankle position on PFM activity levels and hypothesized that active ankle positions would result in greater PFM activity. Active ankle positions were defined as those requiring active support of the subject in a DF or PF posture. Passive ankle positions were those in which subjects in the DF or PF posture stood on a flat surface with the feet passively raised 2.5 or 4.5 cm during PFM contraction, as previously described.<sup>12</sup>

## MATERIALS AND METHODS

### Subjects and Design

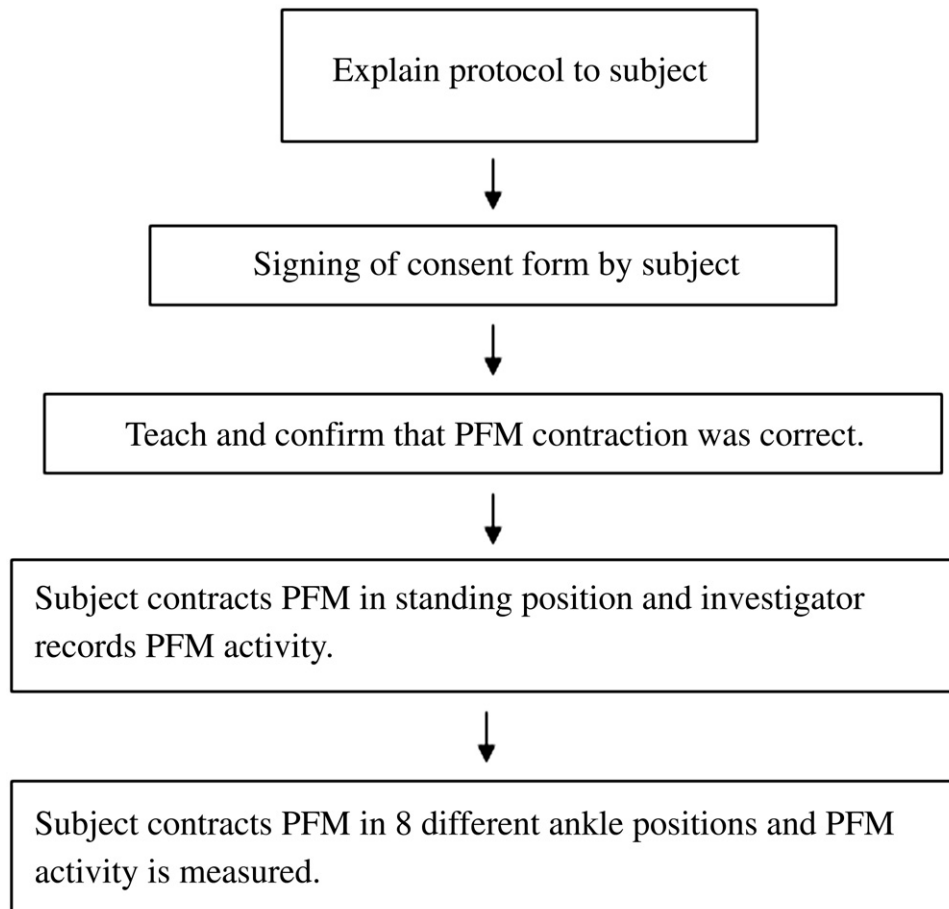
Study approval was obtained from the human ethics research committee, Cathay General Hospital, Taiwan. We recruited 31 women who were 26 to 60 years old from a teaching hospital in northern Taiwan between January 1 and December 31, 2007. Women who could correctly perform PFM contractions and could rise up on the toes during PF were eligible for study inclusion. Individuals who were pregnant, had undergone previous gynecological or pelvic surgery, and had knee and ankle joint disease were excluded from study. Study objectives and methods were explained before enrollment and written informed consent was obtained from all participants. Tests were done in a private room. Subjects were instructed to urinate before muscle activity measurements.

### Measurement of PFM

#### Activity During PFM Contractions

EMG technology uses biofeedback to measure PFM activity. The FemiScan™ EMG biofeedback instrument used in our study measures electronic signals using sterile intravaginal probes with surface electrode plates. FemiScan reliability was excellent in a recent study.<sup>16</sup> Continuous raw EMG signals were produced during vaginal muscle contractions and calculated signal averages were used to represent recorded EMG measurements of PFMs. Electrode placement allowed women to contract PFMs without feeling the probes.<sup>7</sup> PFM activity levels were extrapolated from average EMG values. PFM activity suggested the direction of PFM contraction force, although it cannot be interpreted as a direct proxy for PFM contraction force.<sup>11</sup> Participants inserted the probes and investigators confirmed correct placement. Participants were instructed in PFM contraction techniques and viewed EMG measurements on associated computer screens to confirm muscular activity.

Participants followed standardized instructions for position changes and PFM contractions (fig. 1). Passive and



**Figure 1.** Study procedure

active ankle positions were used in the study. Individuals actively supported themselves in DF and PF, while simultaneously contracting PFMs. Subjects raised arms maximally during PFM contraction in the DF and PF postures upon instruction. These positions were designated DFAU and PFAU, respectively. Participants stood on a flat surface with 2.5 and 4.5 cm wooden blocks placed under the toes or heels in a passive ankle position. Toe and heel heights were passively raised 2.5 or 4.5 cm in the DF or PF position with simultaneous PFM contraction. All subjects performed PFM contractions while standing and PFM activity was simultaneously recorded.

Subjects were asked to perform PFM contractions while assuming 8 ankle positions with PFMs recorded for each position. All 8 ankle positions were randomly performed by each subject, in addition to the HS position, for a total of 9 ankle positions, including HS, 2.5 cm DF, 4.5 cm DF, DF, DFAU, 2.5 cm PF, 4.5 cm PF, PF and PFAU (fig. 2). PFM activity was measured at each position and 3 contractions were performed while in each ankle position. Position order was randomly selected by the investigator from a box and contraction positions were based on the random order in this predefined, randomized schedule.

PFM MVCs were performed by each participant with a 10-second rest after each contraction. A 3-minute rest was allowed between each ankle position. Individuals immedi-

ately visualized muscular activity on the FemiScan monitor with each contraction. The equipment recorded the maximum and mean MVC amplitude in  $\mu\text{V}$ .

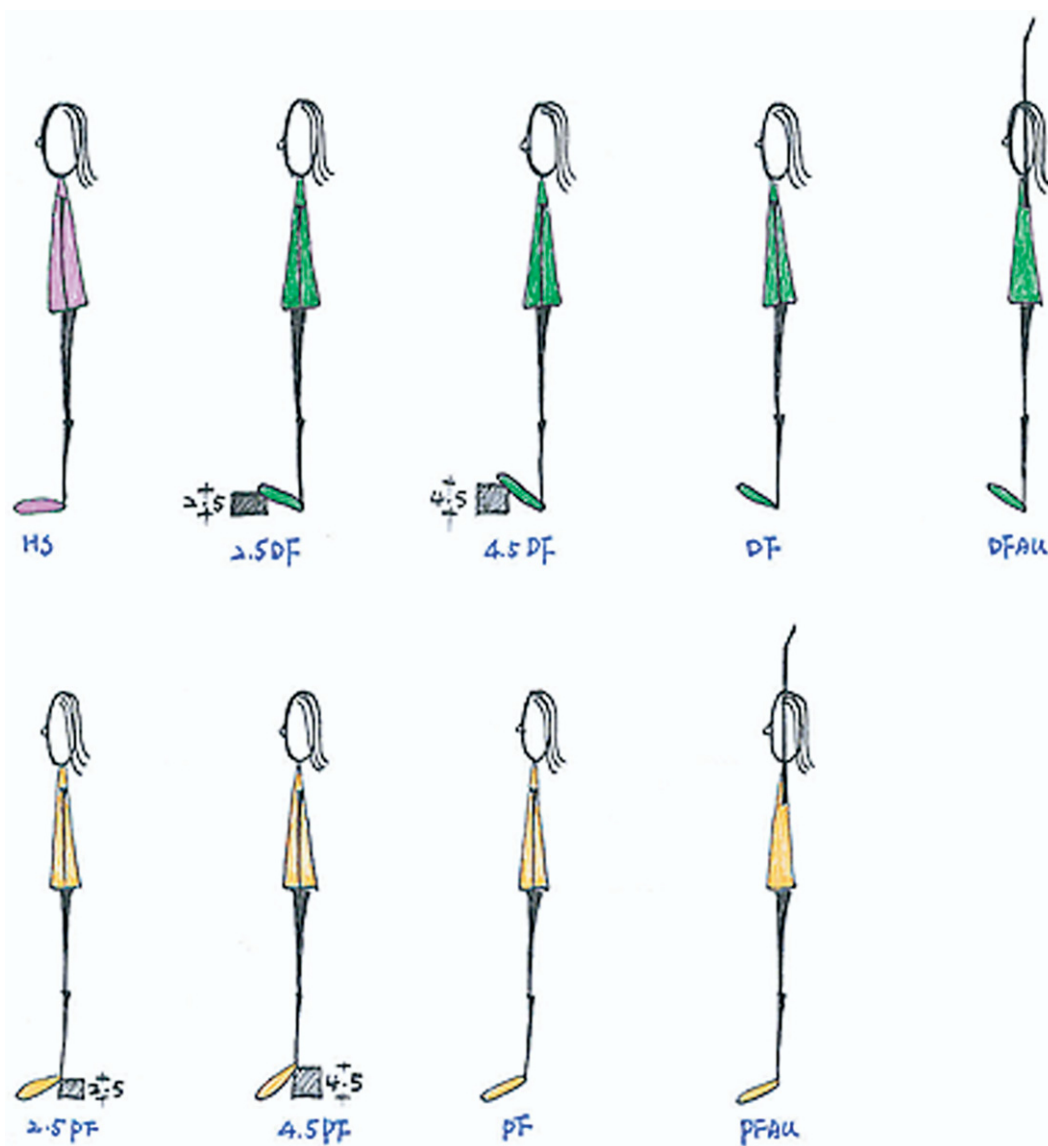
### Statistical Analysis

Data were analyzed using the SAS® 9.0. Nonparametric statistical tests were used since data were not normally distributed. Paired comparisons of PFM activity in 9 ankle positions were performed using the Wilcoxon signed rank test with statistical significance defined at  $p < 0.05$ .

## RESULTS

Mean  $\pm$  SD age of the 31 participants was  $46.48 \pm 7.24$  years (range 30 to 56). Of the participants 23 were members of the hospital staff. One woman in the group had experienced 5 pregnancies and another had 3 children.

Table 1 lists median of mean maximal PFM activity in different ankle positions. PFM activity in the HS posture ( $16.70 \mu\text{V}$ ) was the baseline value for comparisons. The highest PFM activity ( $21.30 \mu\text{V}$ ) was observed with subjects in the PFAU position. Median PFM activity for various passive ankle po-



**Figure 2.** Measurements of PFM activities of 9 ankle positions, including HS position, active and passive ankle positions, and positions with raised arms.

**Table 1.** Maximal PFM activity in 31 subjects in different ankle positions

| Ankle Position | PFM Activity  |                        |
|----------------|---------------|------------------------|
|                | Position Type | Median $\mu V$ (range) |
| HS             |               | 16.70 (7.57–37.50)     |
| 2.5 cm DF      | Passive       | 18.20 (5.00–46.80)     |
| 4.5 cm DF      | Passive       | 19.20 (6.10–41.60)     |
| DF             | Active        | 18.00 (7.80–37.60)     |
| DFAU           | Active        | 17.60 (10.60–37.60)    |
| 2.5 cm PF      | Passive       | 17.90 (6.10–43.00)     |
| 4.5 cm PF      | Passive       | 18.10 (4.40–40.90)     |
| PF             | Active        | 16.40 (5.80–40.96)     |
| PFAU           | Active        | 21.30 (10.70–37.20)    |

sitions was 18.20  $\mu V$  for 2.5 cm DF, 19.20  $\mu V$  for 4.5 cm DF, 17.90  $\mu V$  for 2.5 cm PF and 18.10  $\mu V$  for 4.5 cm PF. PFM activity at all 4.5 cm elevations was higher than at all 2.5 cm elevations regardless of subject position. Median PFM activity while in active ankle postures and in positions with raised arms was 18.00  $\mu V$  for DF, 17.60  $\mu V$  for DFAU, 16.40  $\mu V$  for PF and 21.30  $\mu V$  for PFAU.

PFM activity of the mean MVC while in all 8 ankle positions was greater than HS PFM activity. However, statistical significance was only achieved for PFAU ( $p = 0.0051$ ). PFM activity of the mean PFAU MVC was the greatest of all positions. Significant differences were noted between PFAU and all other ankle positions except 4.5 cm DF ( $p = 0.0614$ , tables 2 and 3).

**Table 2.** Differences in mean maximal PFM activity in different ankle positions

| Ankle Position | Median $\mu$ V PFM Activity (range) |                  |                 |                   |                  |                   |                   |                   |
|----------------|-------------------------------------|------------------|-----------------|-------------------|------------------|-------------------|-------------------|-------------------|
|                | 2.5 cm DF                           | 4.5 cm DF        | DF              | DFAU              | 2.5 cm PF        | 4.5 cm PF         | PF                | PFAU              |
| HS             | -0.7 (-8.1-17.7)                    | -0.7 (-9.5-12.5) | 0.5 (-8.3-10.4) | 1.0 (-13.0-5.5)   | 0.6 (-7.8-13.8)  | 1.0 (-8.4-11.8)   | 0 (-9.6-13.5)     | 2.6 (-6.3-12.9)   |
| 2.5 cm DF      |                                     | 0.1 (-7.9-5.1)   | 0.1 (-17.4-9.4) | 0.2 (-23.84-8.6)  | 1.0 (-12.4-8.9)  | 0 (-6.8-10.9)     | 0.7 (-12.2-11.9)  | 2.4 (-11.6-13.6)  |
| 4.5 cm DF      |                                     |                  | 0.9 (-12.2-9.3) | -0.9 (-18.64-9.0) | 0.4 (-10.2-9.4)  | -0.4 (-10.1-11.2) | -0.4 (-8.3-16.0)  | 2.2 (-7.7-14.2)   |
| DF             |                                     |                  |                 | 0 (-6.9-4.6)      | -0.1 (-9.8-12.0) | 0.1 (-9.7-14.0)   | 0.1 (-5.9-12.1)   | 2.9 (-7.4-13.3)   |
| DFAU           |                                     |                  |                 |                   | -0.4 (-7.7-12.2) | -0.8 (-7.9-17.94) | -0.5 (-7.7-11.64) | 2.5 (-4.7-12.24)  |
| 2.5 cm PF      |                                     |                  |                 |                   |                  | -0.5 (-11.0-6.5)  | 0 (-15.2-12.2)    | 2.3 (-12.8-15.2)  |
| 4.5 cm PF      |                                     |                  |                 |                   |                  |                   | 0.9 (-17.2-12.0)  | 2.8 (-13.9-10.8)  |
| PF             |                                     |                  |                 |                   |                  |                   |                   | 1.8 (-10.76-15.7) |

Significant differences were seen between the mean MVCs of active and passive PF ankle positions (18.0 vs 19.15  $\mu$ V,  $p = 0.0183$ ). However, no significant differences were detected between passive and active DF positions, or active and passive postures (table 4). No significant differences in PFM activity were noted among different ankle positions or postures.

## DISCUSSION

We analyzed the effects of different ankle joint positions on the MVCs of PFM. We hypothesized that maximum EMG signal amplitudes and PFM activities would occur in active ankle positions and exceed those in passive ankle positions. This is supported by our data. The PFAU posture produced the greatest MVC in PFM compared with other ankle positions, possibly due to muscle co-activation, as previously discussed.<sup>17</sup>

PFM activity was measured at passive ankle positions using wooden blocks of different heights and it was measured during active ankle joint changes by the participant. Participants did not simultaneously contract the back and abdominal muscles, as previously described for lumbar curve and trunk muscle activity with different heel heights and passive ankle joint support.<sup>12</sup> Our results suggest that PFM contractions in active ankle positions result in simultaneous abdominal, back, thigh and leg muscle

contractions. Such co-contraction and muscle co-activation were required to maintain posture, and the adductor magnus, adductor longus, pectineus, gluteus maximus, gluteus medius and levator ani muscles were contracted during primary PF and DF. The magnitude of muscle activity was directly related to the number of involved muscles and greater muscle activity resulted in co-activity. Therefore, active flexion resulted in greater total activity and more muscles were involved in active rather than passive ankle position contraction, resulting in increased co-activation and contraction force.

Hemborg et al examined the effects of respiration and muscle pattern activation on intra-abdominal pressure during lifting exercises in 20 healthy subjects by recording puborectalis EMGs in 3.<sup>18</sup> Results revealed that puborectalis muscle myoelectrical activity was activated while lifting. Sapsford et al found that pubococcygeus muscle electrical potential increased with abdominal muscle contracture in a co-activation study.<sup>9</sup>

Participants in our study experienced abdominal muscle and PFM contractions while in active ankle positions. Increased intra-abdominal pressure in this group may have resulted in the co-activation of other muscles, including PFM. PFM activity while in the active ankle position was greater than while in the passive ankle position, likely due to the co-

**Table 3.** Differences in mean maximal PFM activity where in different ankle positions

| Ankle Position | p Value (Wilcoxon signed rank test) |           |           |         |         |           |           |         |
|----------------|-------------------------------------|-----------|-----------|---------|---------|-----------|-----------|---------|
|                | HS                                  | 2.5 cm DF | 4.5 cm DF | DF      | DFAU    | 2.5 cm PF | 4.5 cm PF | PF      |
| HS             |                                     |           |           |         |         |           |           |         |
| 2.5 DF         | 0.9924                              |           |           |         |         |           |           |         |
| 4.5 DF         | 0.5849                              | 0.6154    |           |         |         |           |           |         |
| DF             | 0.3604                              | 0.6596    | 0.9466    |         |         |           |           |         |
| DFAU           | 0.4083                              | 0.7018    | 0.7815    | 0.7254  |         |           |           |         |
| 2.5 PF         | 0.3020                              | 0.5131    | 0.8184    | 0.8483  | 0.9847  |           |           |         |
| 4.5 PF         | 0.3708                              | 0.7788    | 0.5262    | 0.5849  | 0.6441  | 0.4421    |           |         |
| PF             | 0.3179                              | 0.5328    | 0.9238    | 0.6658  | 0.6736  | 0.6585    | 0.2263    |         |
| PFAU           | 0.0051*                             | 0.0148*   | 0.0614    | 0.0062* | 0.0003* | 0.0270*   | 0.0110*   | 0.0386* |

\* Significant ( $p < 0.05$ ).

**Table 4.** Maximal PFM activity while in passive and active ankle positions

|                                     | Median $\mu$ V PFM Activity (range) |                   |                  |
|-------------------------------------|-------------------------------------|-------------------|------------------|
|                                     | DF                                  | PF                | DF + PF          |
| Ankle position:                     |                                     |                   |                  |
| Passive                             | 18.55 (5–46.8)                      | 18.0 (4.4–43.0)   | 18.25 (4.4–46.8) |
| Active                              | 17.7 (7.8–37.6)                     | 19.15 (5.8–40.96) | 18.0 (5.8–40.96) |
| p Value (Wilcoxon signed rank test) | 0.8980                              | 0.0183*           | 0.0793           |
| Ht (cm):                            |                                     |                   |                  |
| 2.5                                 | 18.20 (5.0–46.8)                    | 17.90 (6.1–43.0)  | 18.05 (5.0–46.8) |
| 4.5                                 | 19.20 (6.1–41.6)                    | 18.10 (4.4–40.9)  | 18.60 (4.4–41.6) |
| p Value (Wilcoxon signed rank test) | 0.5131                              | 0.5262            | 0.9463           |

\* Significant ( $p < 0.05$ ).

activation of abdominal muscles and PFM. Muscular co-activation probably contributed to effective PFM exercises.

The body provides structural support to maintain stability and trunk extension, which is related to muscular strength, muscle endurance and neuromuscular control strategies for synergistic coactivation.<sup>19</sup> Abdominal muscle and PFM co-activation contributes to the maintenance of spinal stability.<sup>9,18</sup> PFAU is a complicated posture that involves the actions of many muscles. Therefore, PFM contraction in this posture may induce greater muscle contraction forces. PFM activity in PFAU was significantly higher than in all other ankle positions in this study. PFAU requires individuals to simultaneously contract the back and abdominal musculature. Abdominal muscle contraction was also induced during trunk extension and greater contraction of abdominal muscles occurred when individuals raised their arms. This is consistent with the results of another study, which revealed that the abdominal muscle stretch reflex increased muscular co-activation and muscular force.<sup>20</sup> Our study suggests that this mechanism results in greater muscular forces secondary to PFM contraction to improve stress incontinence.

A recent study identified greater PFM activity in the HS and the passive DF positions than in passive PF positions, which was primarily related to pelvic tilt position changes.<sup>13</sup> We found no significant differences in PFM activity between DF and PF, although significant differences were noted for active ankle postures. These differences may be secondary to muscle co-activation or to the small sample size in our study, which limited the foot size range. This could serve as a possible factor in ankle flexion because the measured angles might be greater with shorter feet. This would result in an overestimation of differences.

Median PFM activity for active and passive ankle positions was between 18.0 and 18.25  $\mu$ V. No statistically significant differences existed between PFM

activity when active and passive ankle positions were separated into DF and PF postures, and compared with each other.

Some groups have focused on the co-activation of muscles under isometric contraction, particularly co-activation between PFMs and other muscles.<sup>15</sup> Future studies should include a greater number of individuals, and effects in continent and incontinent women. Our results reveal that the PFAU posture resulted in greater PFM activity. This could be secondary to muscle group co-activation. This posture was only measured while individuals were in active ankle positions and we did not measure PFM activity when individuals raised their arms in passive ankle positions. This should be evaluated in further studies. Our results also suggest that PFAU, which increased PFM activity and potentially contraction force, could be incorporated with traditional Kegel exercises as part of exercise therapy for SUI, which might improve the efficacy of Kegel exercises.

## CONCLUSIONS

Different muscles are involved in pelvic muscle contraction in conjunction with active or passive ankle positions and different arm positions. This results in different effects on PFM activity. Few groups have evaluated the relationship between ankle position and PFM activity. Our data reveal that active ankle positions increased PFM activity during PFM exercises. This is important clinically because of the potential improvement in exercise efficacy in incontinent individuals. Further research is required to elucidate the underlying mechanisms of these changes. We found no differences in PFM activity between DF and PF postures, which differs from findings in previously reported studies.<sup>13</sup> Additional studies are required to identify the effects of passive and active ankle positions on pelvic tilt. Better understanding of such differences would facilitate the development of effective PFM exercises for SUI in women.

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