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Investigation of Electromyographic Activity of Pelvic Floor Muscles in Different Body Positions to Prevent Urinary Incontinence

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

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Background: This study aimed to determine whether trunk stability muscles co-contract with body position as a factor of pelvic floor muscle (PFM) activity.

Material/Methods: Sixty-one healthy adults without pelvic floor dysfunction were examined for pelvic floor and trunk stability muscle activity in 4 body positions (ankle dorsiflexion and plantar flexion in standing position, and ankle dorsiflexion and plantar flexion in long sitting position). The activities of the PFMs via anal/vaginal probes, internal oblique (IO), multifidus (MF), tibialis anterior, and gastrocnemius muscles were measured by surface electromyography. Three-dimensional motion analysis measured the movement of the pelvis in real time according to the change in body position.

Results: There was a significant increase in PFM activity from the ankle neutral position while standing for both ankle dorsiflexion and plantar flexion in standing position ($p<0.05$). In maximal contraction of PFM in the standing position, IO and MF were found to co-activate ($p<0.05$).

Conclusions: In standing position, the ankle dorsiflexion and plantar flexion positions activated PFMs, which was found to co-activate with trunk stability muscles. Pelvic floor training programs based on the results of this study may be helpful in patients with incontinence.

MeSH Keywords: **Electromyography • Imaging, Three-Dimensional • Pelvic Floor • Posture • Urinary Incontinence**

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Background

Urinary incontinence is the unintentional leakage of urine regardless of an individual's will [1]. Urinary incontinence is an extremely common problem of the urinary system and develops more often in women than in men, and approximately 40% of women develop incontinence [2]. The occurrence of urinary incontinence also increases with age [3]. Urinary incontinence is not a life-threatening condition even if left untreated. However, it is a serious condition that affects the quality of life, restricts physical and social activities, and impairs self-esteem [1,2].

Stress urinary incontinence is caused by the relaxation of the pelvic floor muscles (PFMs) supporting the bladder neck and urethra, and urine initially leaks when an individual is in the standing position due to the effect of gravity on the PFMs [4,5]. Body position and pelvic posture affects PFM activity [4,6]. Patients with urinary incontinence need to understand that physical posture during exercise and in daily life can affect urinary incontinence. Several studies have investigated the relationship between pelvic posture and PFM activation [7–9].

In standing position, the ankle position is related to the inclination of the pelvis and activation of the PFM [10]. In a study comparing the activation of PFM with ankle position in the standing position, dorsiflexion (DF) activated the PFM more than plantar flexion (PF) or neutral position [6,7,9]. When the pelvis is tilted anteriorly by ankle DF, the coccyx is rotated posteriorly, and the PFMs are activated because the muscle fibers are elongated to extend the PFMs [6,11].

According to the above observations, when the ankle is in PF, the pelvis is tilted posteriorly, and the coccyx moves forward to shorten the muscle fiber. However, there is no pelvic movement during PF [12]. Even without pelvic movement, PFMs are activated during PF rather than during neutral position of the ankle [12]. This fails to explain PFM contraction with pelvic tilt and coccyx movement alone.

PF of the ankle in the standing position reduces the area of the base of support (BOS) more than DF. As BOS decreases, the trunk stability muscles are tensed to maintain balance [13,14]. The trunk stability muscles are important for strength and stabilization of the trunk core and are co-activated in harmony with the PFM [15]. Thus, the activity of PFMs may be related to BOS changes and pelvic displacements.

Most previous studies have measured PFM function in a fixed position [9,16]. However, in daily life, physical posture is a continuous movement; hence, real-time simultaneous analysis while moving will be more accurate [12].

This study aimed to confirm the activation of PFM according to different body positions by real-time simultaneous analysis using motion analysis and electromyography (EMG) and to determine whether the PFM and trunk stability muscles co-contracted.

Material and Methods

Subjects

The subjects in the study were 28–55 years old and had no pelvic floor dysfunction. We excluded subjects who were currently pregnant or menstruating, gave birth within the last 12 months, had musculoskeletal or neurologic abnormalities, underwent multiple vaginal surgeries, or were unable to exercise due to mental problems or lack of understanding. The 61 healthy adults (28 men, 33 women) recruited had an average age of 41.12 years, height of 164.59 cm, weight of 62.85 kg, and body mass index of 23.14 (Table 1). Detailed information about the purpose and procedure of the study was provided to all subjects, and they provided written informed consent prior to participation in accordance with the ethics principles of the Declaration of Helsinki.

Procedure

This study had an observational, cross-sectional, within-subject, comparative measures design.

Table 1. General characteristics of subjects.

	Male n=28	Female n=33	Total N=61
Age (year)	37.86±5.32	43.04±7.37	41.12±6.89
Height (cm)	172.04±3.76	159.45±5.37	164.59±7.67
Weight (kg)	73.84±5.45	55.55±4.52	62.85±9.83
BMI (kg/m^2)	24.99±2.17	21.95±2.60	23.14±2.81
Childbirth (yes/no)		15/18	

Values are presented as n (%) or mean±standard deviation. BMI – body mass index.

In the 4-posture analysis (2 body positions and 2 ankle positions), pelvic floor and postural muscle activities were recorded using surface EMG (sEMG), and body movements were recorded using motion analysis. The 2 body positions consisted of standing and long sitting positions, and the 2 ankle positions consisted of DF and PF. Three trials were recorded for each position, and the order of positions was randomized for each subject.

Subjects were allowed to maintain their correct posture while keeping their trunk from swinging back and forth, except for the natural pelvic tilt caused by the ankle position. Subjects were asked to look directly forward, breathing normally without moving or speaking. The sitting position allowed the subjects to sit upright on the floor without back support, with their hips in neutral position and their legs extended forward. Subjects were asked to sit upright.

The test was conducted in a separate private room. Subjects were asked to empty their bladder to standardize the amount of urine. Before the measurement, an anal or vaginal probe was properly inserted and then was fixed with medical tape. The subjects were able to contract the PFMs. All subjects were trained before the experiment with PFM movements with perineal movement in cephalad direction during pelvic floor contraction and caudal movement during relaxation.

Maximal voluntary isometric contraction (MVIC) of the PFMs was performed in the standing position with the ankle in the neutral position to act as a reference. MVIC of the PFMs for 5 s and rest for 5 s (resting sEMG activity) was measured as the baseline value. Subsequently, the pelvic floor and postural muscle activities in the 4 body positions were recorded.

Measurements

Pelvic floor and postural muscle activities were measured using sEMG, a noninvasive method. PFM activity was measured using an anal/vaginal probe. As the probe was in contact with the lateral vaginal/anal lining, the reference and measurement electrodes were arranged at preset intervals. Pairs of silver/silver chloride electrodes (1.5 cm center to center, Therapeutics Unlimited) were attached to the internal oblique (IO), multifidus (MF), tibialis anterior (TA), and gastrocnemius (GCM) muscles to monitor postural muscle activity. The electrode attachment position of the IO is the midpoint between the pubic tubercle in the anterior superior iliac spine, and the MF is 3 cm outward from the L5 spinous process on the line from the end of the iliac pole to the space between L1 and L2. The electrode attachment position of TA is the proximal third of the line between the end of the fibula and ankle bone. The electrode attachment position of the GCM is 1/3 of the distance below the leg, between the head of the fibula and calcaneus. To minimize the error caused by skin impedance, the electrode attachment areas in the subjects were shaved and disinfected with alcohol. The electrode was attached parallel to the direction of the muscle fibers. The signal from the electrode was acquired via EMG and stored in the computer using software (MyoResearch XP Master Edition, Noraxon, Inc., USA). The EMG signal was sampled at 1000 Hz and 60 Hz low-pass filtered using a 10–250 Hz bandpass filter to calculate the root mean square value.

The Qualisys Motion Capture System (Qualisys, Gothenburg, Sweden) was used to analyze three-dimensional motion of the pelvis according to body position changes in real time. Biomechanical measurements collected by 8 infrared cameras (Miqus M3 series, Qualisys AB, Sweden) were sent to the QTM software (Qualisys, Gothenburg, Sweden) for storage.

The reflex markers were located in the bilateral anterior superior iliac spine, posterior superior iliac spine, greater trochanter, medial/lateral epicondyle or the femur, medial malleolus, lateral malleolus, and first and fifth toe joints. Cluster markers were attached to the bilateral thigh and middle of the lower thigh. Collected kinematic data were analyzed using the Visual3D motion analysis program (C-Motion, Rockville, MD, USA).

Statistical analysis

Data analysis was conducted using SPSS version 20.0 (SPSS, Inc., Chicago, USA). Descriptive statistics of the general characteristics included means and standard deviations for all variables. The differences in the muscle activation data according to different body positions were analyzed using one-way repeated analysis of variance, and the Scheffe test was performed for post hoc analysis. The statistical threshold was set at a P-value <0.05.

Results

Muscle activities of the PFM, TA, GCM, MF, and IO in 4 body positions (DF in standing, PF in standing, DF in sitting, and PF in sitting positions) are shown in Figure 1. Compared to ankle neutral in standing position, the MF and IO significantly increased muscle activity in standing position ($p<0.05$) but not in sitting position. The activity of PFM increased in order of ankle neutral in standing position (men, 12.16 MVIC%; women, 10.93 MVIC%; average 11.55 MVIC%), PF in sitting position (men, 13.23 MVIC%; women, 9.88 MVIC%; average 11.56 MVIC%), DF in sitting position (men, 12.32 MVIC%; women, 11.04 MVIC%; average, 11.68 MVIC%), PF in standing position (men, 23.28 MVIC%; women, 25.54 MVIC%; average, 24.41 MVIC%), and DF in standing position (men, 39.46 MVIC%; women, 45.65 MVIC%; average, 42.56 MVIC%). When comparing PFM activation in

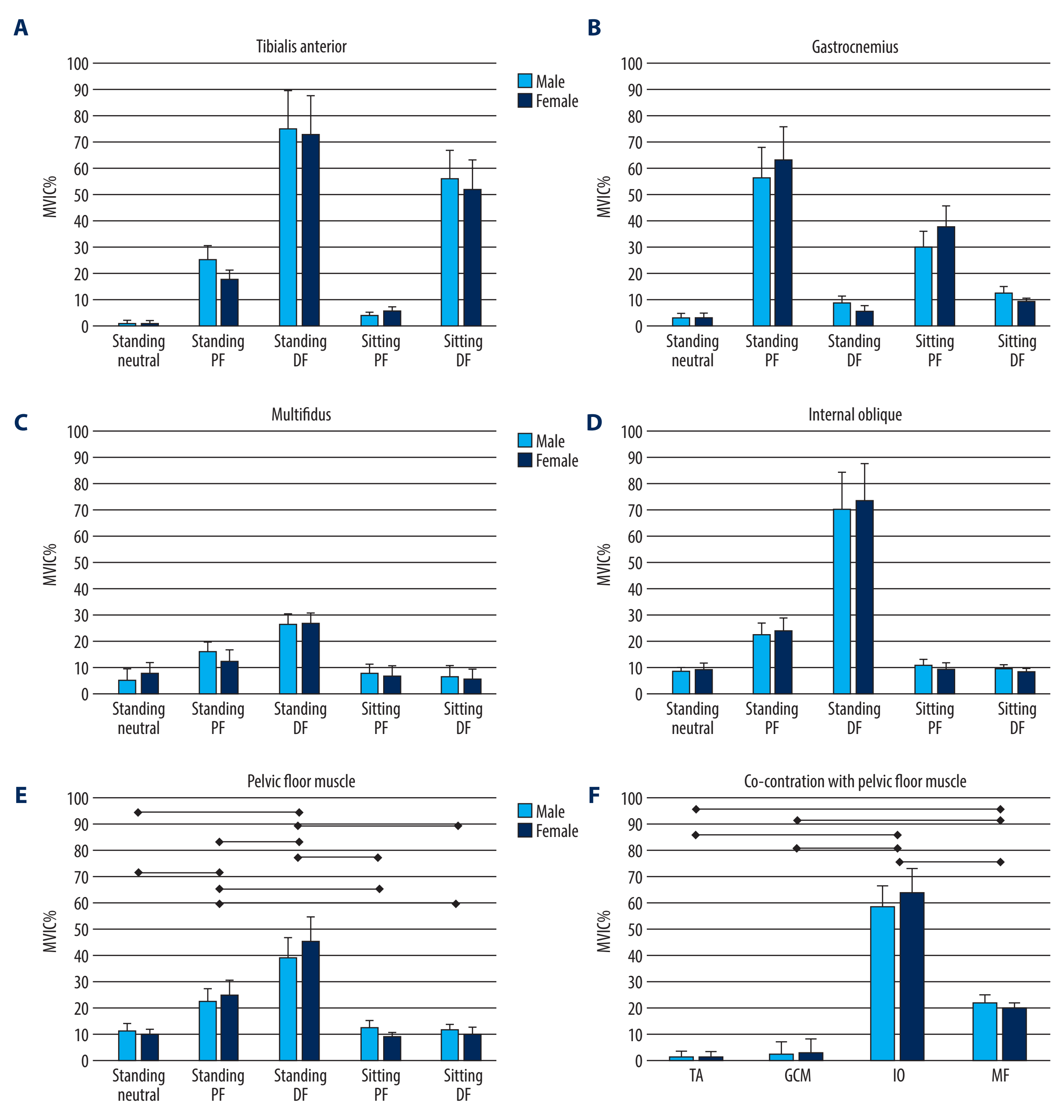

Figure 1. Muscle activity in body positions (**A–E**) and muscle co-contraction activity with the pelvic floor muscle (**F**). Horizontal lines indicate significant differences from one-wey ANOVA, followed by Scheffe's post hoc analysis. MVIC% – percentage of maximal voluntary isometric contraction; PF – ankle plantar flexion; DF – ankle dorsiflexion; TA – tibialis anterior; GCM – gastrocnemius; IO – internal oblique; MF – multifidus

each body position, activation in DF in standing position and those in other body positions were significantly different, and activation in PF in standing position was also significantly different from those in other body positions (p<0.05). PFM activation in DF and PF in sitting position was significantly different from DF and PF in standing position (p<0.05). In maximal contraction of the PFM in the standing position, among the 4 muscles, IO (men, 57.65 MVIC%; women, 63.43 MVIC%; average, 60.54 MVIC%) and MF (men, 22.20 MVIC%; women, 20.34 MVIC%; average, 21.27 MVIC%) were found to be co-activated, while TA and GCM were not activated.

Figure 2 shows the maximum angle change in the ankle and pelvis with different body positions. The maximum change of pelvic angle according to the ankle movement in the standing position was 12.82° in DF and 2.12° in PF. However, in sitting

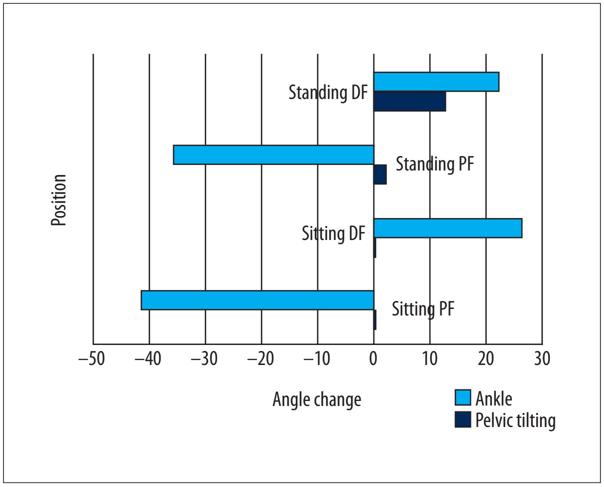

Figure 2. Maximum angle changes in the ankle and pelvis with different body positions. PF – ankle plantar flexion; DF – ankle dorsiflexion.

position, there was no change in the pelvic angle according to the ankle movement.

Discussion

Urinary incontinence is a major health problem, and most patients with symptoms have weak pelvic muscles. The position of the body has a significant effect on PFM activity [4,17]. A previous study investigated PFM activity according to changes in pelvic angle [6,7,9]. Changes in pelvic tilting have been associated with changes in ankle position; however, to date, no studies have investigated pelvic tilting angle changes and PFM activity in various body positions. Therefore, the present study investigated the effects of different body positions on PFM activity to determine if there is a higher level of muscle activity in a particular position. Moreover, we also determined whether the trunk stability muscle co-contracts with the factor that affects PFM activity.

We found that PFM activity was the highest in DF in standing position, followed by PF in standing position, PF in sitting position, and DF in sitting position. The amount of change in the pelvic tilt was also greatest in DF in standing position. We found that the pelvic tilt angle caused by the change in ankle movements in standing position was a factor influencing the PFM activity. In the standing position, the pelvis tilted up to 12.82° forward when the ankle was in DF. Previous studies also found that, when the pelvis was tilted anteriorly, the pelvic floor was elongated by posterior rotation of the coccyx to activate the PFM [6,7,18].

In previous studies, artificial fixation with the ankle in PF and standing position kept the coccyx moving forward due to the posterior tilt of the pelvis, resulting in shortening of the muscle fibers of the pelvic floor [6,18–20]. However, Lee [12] found that there was no pelvic movement while moving in real time, rather than that in the fixed ankle position; that is, when moving the ankle from neutral position to PF. The problems caused by incontinence in daily life are more likely to occur during natural movements than in fixed positions [12]. This is because urine leakage occurs due to changes in posture and pressure during continuous movement. Therefore, when checking the ankle position as a factor affecting the pelvic floor, it may be more useful to observe in real time movements rather than in fixed ankle positions.

In this study, the maximum change in the pelvic tilt angle was extremely low at 2.12° when the ankle is in PF in the standing position. The PFM activity when the ankle is in PF in the standing position was lower than that in DF but greater than that in the neutral position.

PFMs are complex muscles that form the basis of the abdominopelvic cavity [21]. Postural control muscles such as IO abdominis, transversus abdominis, and deep vertebral muscles work in harmony with the PFM [22]. Therefore, co-contraction with trunk stability muscles affects PFM activity [23].

PFM activity increases when sitting from the supine position and increases further when standing [4,24,25]. The supine position is more stable than the standing or sitting position because it has a wide BOS and lower center of gravity [26]. Antigravity posture with a high center of gravity and narrow BOS make it difficult to balance the body. In an unstable state, many trunk stability muscles are used to maintain posture and show high muscle activity [27].

The present study also showed higher PFM activity in standing position than in sitting position. In standing position, the PFM activity was greater in unstable PF and DF than in ankle neutral position. Additionally, it was confirmed that, when the PFM contracts, the IO and MF, which are trunk stability muscles, co-contract.

In a study assessing PFM activity according to various sitting positions, the PFMs and IO were activated in the order of slump supported, upright unsupported, and very tall unsupported sitting positions [28]. The more unstable the posture, the more co-active the trunk stability muscles and PFM, which supports the results of the present study.

Previous studies investigated the effect of pelvic tilt on PFMs activity [20] and synergistic muscles [19,23,24]. Ptaszkowski et al. [19], Ptaszkowski et al. [23], Halski et al. [24] studies showed higher bioelectric activity of adductor magnus, rectus abdominis, and gluteus maximus muscles at the posterior pelvic tilt than at the anterior pelvic tilt. In addition, studies by Ptaszkowski et al. [19], Ptaszkowski et al. [23], Halski et al. [24], and Ptaszkowski et al. [20] found that the posterior pelvic tilt had the greatest effect on PFMs bioelectrical activity. In the present study, the change of pelvic movement according to the ankle posture and the resulting PFMs activity were identified. In standing position, the ankle movement induced an anterior tilt of the pelvis, which led to contraction of the PFMs. In previous studies, the contraction of the PFMs at the posterior tilt of the pelvis may have been due to the co-activation of the abdominal muscles. In addition, it is thought that the abdominal muscles were not used during anterior pelvic tilt, so the PFMs activation was low. However, the present study showed different results from previous studies because the abdominal muscles were used to maintain posture even during anterior pelvic tilt.

Chmielewska et al. [29] reported that women with urinary incontinence had more difficulty in controling postural balance. Therefore, it is necessary to improve posture maintenance by strengthening core muscles in incontinence patients. In this study, the co-activation of core muscle and PFMs was confirmed, and the results were consistent with the results of previous studies.

The results of this study suggest that training to improve trunk stability muscles to induce co-contraction to strengthen PFMs would be helpful in patients with incontinence. A limitation of this study was that other variables, such as intraperitoneal pressure and breathing patterns, that could affect the activation of the PFMs and trunk stability muscles were not evaluated. Investigating the various factors affecting the PFMs and trunk stability muscles will increase the understanding of muscle activity and help establish an exercise method for urinary incontinence prevention training.

Conclusions

Factors affecting PFM activity were pelvic tilt angle and co-contraction activity of postural muscles. In the standing position, the ankle DF and PF activated PFMs, which was found to be co-activate with trunk stability muscles. Pelvic floor training programs based on the results of this study may be helpful in patients with incontinence.

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