Influence of adequate pelvic floor muscle contraction on the movement of the coccyx during pelvic floor muscle training

Akiko Fujisaki, MD, PhD1)*, Miwa Shigeta, PT, MSc2), Misa Shimoinaba, MD1), Yasukuni Yoshimura, MD, PhD1)

1) Department of Urology, Yotsuya Medical Cube: 7-7 Nibancho, Chiyoda-ku, Tokyo 102-0084, Japan
2) Yokohama Motomachi Women’s Clinic LUNA, Japan

Abstract. [Purpose] Pelvic floor muscle training is a first-line therapy for female stress urinary incontinence. Previous studies have suggested that the coccyx tip moves ventrally and cranially during pelvic floor muscle contraction. The study aimed to elucidate the influence of adequate pelvic floor muscle contraction on coccyx movement. [Subjects and Methods] Sixty-three females (57 patients with stress urinary incontinence and additional 6 healthy volunteers) were enrolled. Using magnetic resonance imaging, coccyx movement was evaluated during pelvic floor muscle contraction and strain. An adequate contraction was defined as a contraction with good Oxford grading scale [≥3] and without inadequate muscle substitution patterns. [Results] Inadequate muscle substitution patterns were observed in 33 participants (52.4%). No significant difference was observed in the movement of the coccyx tip in the ventrodorsal direction between females with and without inadequate muscle substitution patterns. However, a significant increase in the movement of the coccyx tip in the cranial direction was detected in the group without inadequate muscle substitution patterns. Compared to participants with inadequate pelvic floor muscle contraction, those who had adequate pelvic floor muscle contraction exhibited significantly increased cranial movement of the coccyx. [Conclusion] Adequate pelvic floor muscle contraction can produce cranial movement of the coccyx tip.

Key words: Coccyx, Pelvic floor muscle training, Stress urinary incontinence

INTRODUCTION

Stress urinary incontinence (SUI) is defined as involuntary leakage from the urethra, synchronous with exertion/effort, sneezing, or coughing1). It has been reported that female gender is associated with high morbidity of SUI2–4), and 8.7% of all adult females suffer from SUI5). SUI can render a greater mental health burden6). In Japan, it has been reported that 22.4% of all adult females, aged ≥40 years, experience SUI at least once a week, suggesting that SUI affects their daily life6).

Pelvic floor muscle training (PFMT) was introduced over 50 years ago7), and is a first-line therapy for females with stress urinary incontinence as recommended by the guidelines of the European Association of Urology and the Japanese Urological Association8, 9). According to many PFMT programs, the correct method to voluntarily contract the pelvic floor muscle (PFM) should be taught by physiotherapists, specialist nurses, or physicians in the first place10). When females perform PFMT, it is important to ensure that they contract the PFM correctly, concentrate their attention on the appropriate muscles, and perform the PFM contraction precisely as instructed, that is, without inadequate muscle substitution patterns, such as the use of the outer abdominal, erector spinae, femoral, hip adductor, or gluteal muscles instead of the PFM. However, according to a previous study, 25% of females are unable to perform an isolated pelvic floor muscle contraction following written or
Some patients may find it difficult to ensure performance of this home exercise precisely as instructed. When the females were unable to contract the PFM, a specialist taught them how to do so using vaginal, rectal or physical examination\(^\text{10, 12}\). Moreover, proper contraction can be assessed by biofeedback teaching tools, such as electromyography\(^\text{10, 12}\). However, females need to choose the right time and place in using these instruments. If the optimal way to perceive the correct PFM contraction without using these tools is discovered and taught, females can perform better PFMT at any time and any place. Previous studies have suggested that the tip of the coccyx moves ventrally and cranially at the time of PFM contraction\(^\text{13–15}\). Thus, the palpation of the movement of the coccyx during PFM contraction might be helpful for females performing PFMT to perceive the correct PFM contraction. The association between PFM contraction and movement of the coccyx has been reported by a few studies to date\(^\text{13–15}\); however, not such studies have included the relationship between movement of the coccyx and Modified Oxford grading scale (OS) or inadequate muscle substitution patterns. The OS measures PFM strength by vaginal palpation\(^\text{16}\).

Therefore, the objective of the present study was to clarify the influence of adequate PFM contraction and other inadequate muscle substitution patterns on the movement of the coccyx during PFMT.

**SUBJECTS AND METHODS**

A total of 63 females (57 patients with SUI and additional 6 healthy volunteers) were enrolled in the present study. To make the study dataset more generalizable, healthy volunteers were also included. The patients visited Yotsuya Medical Cube (Tokyo, Japan) and had a chief complaint of SUI, received PFMT instructions, and underwent cine magnetic resonance imaging (MRI) analysis. For the diagnosis of SUI, cine MRI is used at the time of strain, instead of chain-cystourethrography. Furthermore, MRI was used to confirm the movement of the coccyx during PFM contraction attempts. The OS and the presence/absence of the inadequate muscle substitution patterns were evaluated by specialist nurses or physicians\(^\text{16}\). Among patients with SUI, clinical data were transcribed from the charts at the first PFMT instruction. Healthy nurse volunteers were involved. Of them, three nurses had previous experience as a PFMT instructor, and three did not. PFM contraction in healthy volunteers was also examined with cine MRI, and the OS as well as the presence/absence of the inadequate muscle substitution patterns were used for evaluation. All participants were not taught correct PFM contraction at the time of evaluation. Appropriate informed consent was obtained from all participants. This study was approved by the Ethics Committee of Yotsuya Medical Cube (registration number: YMCIRB-CR1501001).

The OS measures PFM strength by vaginal palpation\(^\text{16}\). Palpation of the PFM on voluntary contraction is employed to obtain a grading from zero (no contraction detected) to five (a strong contraction detected). Both sides are graded, respectively, with intermediate grades (1–2 is written as 1.5) permitted, resulting in an 11-grade scale\(^\text{17}\). An inadequate muscle substitution pattern was defined as the simultaneous contraction of the gluteus maximus, outer abdominal, erector spinae, femoral, and hip adductor muscles during attempted PFM contraction. Participants were assigned to the following two groups: the (1) with-adequate-contraction group (good OS (≥3) and without inadequate muscle substitution patterns) and the (2) without-adequate-contraction group (all other participants).

On sagittal MRI images, the movement of the tip of the coccyx both at rest and during attempted contraction of the PFM was assessed. In addition, the joints moving between the sacrum and the coccyx tip during the attempted PFM contraction and strain were identified. Cartesian coordinates with the sacrococcygeal-inferior pubic point (SCIPP) line on the sagittal image of MRI were used for measurements. The X-axis is the SCIPP line and the origin is the inferior pubic point. The line perpendicular to the SCIPP line through the inferior pubic point is the Y-axis\(^\text{18}\). The positive direction of the X axis is the dorsal direction. The positive direction of the Y axis is the cranial direction. The tip of the coccyx location is given as an XY coordinate. The location of the tip of the coccyx was determined by two urologists, and the coordinates were determined by calculating the median of two. MRI examinations were performed using the Signa Excite HDxt 1.5T system (v23; GE Healthcare, Milwaukee, WI, USA) with an eight-channel Cardiac coil. 2D FIESTA was subsequently used for cine MRI imaging. Imaging parameters of the 2D FIESTA were as follows: TE minimum, full, FA, 60°, BW, 100 kHz, FOV, 24 cm, slice, 10.0 mm, spacing, 0, matrix frequency, 224, phase, 160, and time, 1.0 sec (Fig. 1).

Continuous variables were presented as medians, because the studied variables were not normally distributed. Fisher’s exact test was used to compare the occurrence of inadequate muscle substitution patterns between participants with and without good OS. The Mann-Whitney U test was used to compare the movement of the tip of the coccyx between participants with and without inadequate muscle substitution patterns. A correlation analysis was conducted to investigate the potential association between the movement of the tip of the coccyx and OS. The Mann-Whitney U test and Fisher’s exact test were used to identify factors associated with adequate contraction. Statistical analysis was performed using IBM SPSS Statistics v21 (IBM SPSS, Armonk, NY, USA).

**RESULTS**

Movement of the coccyx was observed in all participants. The participants’ median age, body mass index (BMI), height, and parity were 50 (range, 30–81) years old, 21.5 (range, 16.1–40.3) kg/m\(^2\), 157 (range, 144–170) cm, and 2 (range, 0–3), respectively. The median OS was 2.0 (range, 0.0–5.0). Inadequate muscle substitution patterns were observed in 33 partici-
Fourteen of the 63 participants have good OS, and the other 49 participants do not have good OS. Inadequate muscle substitution patterns were observed in 1 participant (7.1%) with and 32 patients (65.3%) without good OS; this difference was significant (p<0.01).

Among all participants, the rate of joint mobility between the sacrum and the coccyx tip during the attempted PFM contraction and strain on sagittal MRI was 81.0%.

No significant difference was observed in the movement of the tip of the coccyx in the direction of the X-axis (p=0.43) when comparing participants with and without inadequate muscle substitution patterns. Median movements of the tip of the coccyx in the direction of the X-axis were as follows: −0.3 (range, −5.75 to 4.75) (without inadequate muscle substitution patterns group), and −1.15 (range, −5.0 to 4.05) (with inadequate muscle substitution patterns group). No significant correlation was found between OS and the movement of the tip of the coccyx in the direction of the X-axis (r=0.96, rs=0.01). However, depending on the presence or absence of inadequate muscle substitution patterns, a significant difference was observed in the movements of the tip of the coccyx in the direction of the Y-axis (p=0.01). The median movements of the tip of the coccyx in the direction of the Y-axis were as follows: +1.5 (range, −2.9 to 7.1) (without inadequate muscle substitution group), and −0.1 (range, −6.8 to 4.7) (with inadequate muscle substitution group). Furthermore, a significant correlation was detected between OS and the movement of the tip of the coccyx in the direction of the Y axis (p<0.01, rs=0.42).

Subsequently, the with-adequate-contraction and without-adequate-contraction groups were compared. There was no significant difference in age, height, BMI, parity, joint mobility between the sacrum and the coccyx tip, and movement of the tip of the coccyx in the direction of the X-axis. However, there was a significant difference in the movement of the tip of the coccyx in the direction of the Y-axis. The tip of the coccyx shifted more toward the positive direction (i.e., the cranial side) in the with-adequate-contraction group than in the without-adequate-contraction group (Table 1).

**DISCUSSION**

In agreement with previous studies, movement of the coccyx at the time of PFM contraction was observed in the present study. Notably, this study is the first to demonstrate the movement of coccyx in relation to OS, inadequate muscle substitution patterns, and adequate PFM contraction.

According to many PFMT programs, the correct voluntary PFM contractions should be taught by physiotherapists, specialist nurses, or physicians in the first place. It is important that patients with SUI learn the correct voluntary PFM contractions in PFMT programs. It was reported that palpation of the coccyx identified PFM contraction, thus, the results of this study may serve as a guidance tool regarding the learning of adequate PFM contraction by females. In the present study, the movement of the tip of the coccyx in the with-adequate-contraction group shifted more cranial side (i.e., the...
positive direction on the Y-axis in this study) compared to that in the without-adequate-contraction group. This suggests that, when teaching patients with SUI unable to contract the PFM appropriately, we may be able to assist them in producing an appropriate contraction of the PFM without inadequate muscle substitution patterns by providing them with a verbal cue such as contract “in such a way as to make the tip of the coccyx move toward the cranial side.” In addition, it is difficult for patients with SUI to receive direct PFMT instruction by healthcare professionals every day. Therefore, touching the tip of the coccyx over their clothes when they perform home PFMT during their free time in daily life may be an easy way to confirm an adequate PFM contraction for the patients themselves. However, further study is needed to assess the effectiveness of PFMT instruction by palpation of the coccyx.

When patients receive examination or treatment covered by health insurance in Japan, they are only liable to pay 10–30% of the medical expenses. However, since PFMT instruction is not covered by health insurance, patients are required to pay all related expenses. In Japan, the average cost of pelvic floor muscle exercise is US$ 45, which is higher than other medical treatments. Therefore, PFMT instruction is not yet widespread in Japan with few trained instructors. Although PFMT is presented in the treatment guidelines as the first treatment option for SUI, Japanese patients with SUI can receive PFMT instruction at only a few female urology facilities and cannot get feedback by healthcare professionals frequently. High-quality home PFMT is more important for Japanese patients. Thus, tactile perception of the movement of the coccyx may be helpful for identifying adequate pelvic floor muscle contractions in the home setting.

In the present study, the movement of the tip of the coccyx in the without-adequate-contraction group shifted to the negative direction on the Y-axis (i.e., toward the caudal side) compared with that in the with-adequate-contraction group. It can be inferred that the coccyx tip movement toward the caudal side may be explained by the fact that the erector spinae, multifidus, and the hamstring muscles contracted as the inadequate muscle substitution patterns and induced the rotation of the sacrum (forward flexion of the sacrum, i.e., backward movement of the coccyx). Joint mobility between the sacrum and the coccyx tip during PFM contraction and/or strain was examined on sagittal MRI, and demonstrated that 19.0% of the joints did not move. This suggests that the movement of the coccyx tip is not only affected by joint mobility observed on sagittal MRI, but is also associated with the aforementioned sacral nutation that may induce the coccyx tip shift regardless of the movement of these joints.

There are some limitations of this study. Firstly, this study is not a general population survey. Secondly, as sagittal MRI images alone were used for evaluation, as well as the SCIPP line as a reference, it was difficult to evaluate the movement of the entire sacrum, including nutation and counternutation. Thirdly, interobserver errors in the evaluation of the OS and inadequate muscle substitution patterns were not assessed. Fourthly, our study was cross-sectional in nature. Further prospective study is warranted to evaluate the PFMT program with the movement of the coccyx tip.

The movement of the tip of the coccyx in those with adequate contraction shifted in the positive direction on the Y-axis (i.e., toward the cranial side) as compared with that in those without adequate contraction. There is a possibility that the result of this study may be useful as an objective assessment of effective PFMT.

**Presentation at meetings**
The abstract was presented at the 2015 annual meeting of the International Urogynecological Association, Nice, France.

**Conflict of interest**
The authors declare that they have no competing interests.

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### Table 1. Factors related to adequate PFM contraction

|                          | With adequate contraction | Without adequate contraction | p-value |
|--------------------------|---------------------------|-----------------------------|---------|
| Age (years)              | 51 (30–74)                | 49.5 (36–81)                | 0.95    |
| Height (cm)              | 157 (144–169)             | 157 (147–170)               | 0.75    |
| BMI (kg/m²)              | 20.3 (16.1–33.8)          | 21.6 (17.8–40.3)            | 0.27    |
| Parity                   | 2 (0–3)                   | 2 (0–3)                     | 0.38    |
| Joint movability between the sacrum and coccyx tip | Yes: 12 (92.3) | Yes: 39 (78.0) | 0.43 |
| No: 1 (7.7)              | No: 11 (22.0)             |                             |         |
| Movement of the tip of the coccyx in the direction of the X-axis (mm) | −0.25 (−5.75 to 4.75) | −1.1 (−5.0 to 4.05) | 0.49 |
| Movement of the tip of the coccyx in the direction of the Y-axis (mm) | +1.9 (0.5 to 7.1) | +0.5 (−6.8 to 6.3) | <0.01 |

Data are shown as medians (ranges) or n (%) and were analyzed using the Mann-Whitney U test or Fisher’s exact test.

PFM: pelvic floor muscle; BMI: body mass index.
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