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To cite this article: Iman Akef Khowailed , Heather Disney & Haneul Lee (2020) Gender-specific differences of normative values of pelvic floor muscle function in healthy adults population: an observational analytical study, Women & Health, 60:10, 1185-1195, DOI: [10.1080/03630242.2020.1807449](https://doi.org/10.1080/03630242.2020.1807449)

To link to this article: <https://doi.org/10.1080/03630242.2020.1807449>



Published online: 28 Aug 2020.



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Gender-specific differences of normative values of pelvic floor muscle function in healthy adults population: an observational analytical study

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ABSTRACT

Females and males differ significantly in gross anatomy and physiology of the pelvic floor muscle, and these differences are commonly discussed in the scientific literature. However, less attention is dedicated to investigating the normative values of pelvic floor muscle (PFM) function between females and males. Our study aims to describe the normal reference values of PFM function in females and males of a healthy adult population using transabdominal ultrasound (TAUS). A total of 200 healthy adults, including 71 males and 129 females consented to participate in this study. Bladder base displacement was measured using a sagittal curved linear array 2–5 MHz transducer over the suprapubic region. The amount of bladder base movement on ultrasound was measured in all subjects from freeze frame ultrasound images and considered as an indicator of PFM function. The average age of subjects was (26.1 ± 2.6 years), (24.4 ± 3.7 BMI). Statistical analysis revealed a significant difference in transabdominal ultrasound measurement for PFM function ($p = .00000$). The bladder base displacement was significantly greater in males compared to females (0.65 ± 0.42 vs. 0.38 ± 0.35 , $p < .001$, 95% CI: 0.16–0.38). The present study provides evidence of a gender-related PFM functional differences creating a baseline for the clinic to establish the normal percentile values of PFM function.

ARTICLE HISTORY

Received 16 January 2020

Revised 18 July 2020

Accepted 1 August 2020

KEYWORDS

Bladder base; gender-specific differences; normal reference values; pelvic floor muscles function; ultrasonography

Introduction

Female pelvic floor dysfunction is a common disease which has become one of the five common chronic diseases threatening women's health (Gachon et al. 2019). As the supporting structures, pelvic floor muscle is critical to support the pelvic organs, maintain continence, and prevent prolapse. The quantitative evaluation of pelvic floor muscle (PFM) function is of great value for the diagnosis and treatment of female pelvic floor dysfunction (Gachon et al. 2019). The weighted prevalence rate of one or more pelvic floor disorders (PFDs) has been reported to be as high as 25.0%, including 17.1% of women with moderate-to-severe urinary incontinence, 9.4% with fecal incontinence, and 2.9% with prolapse (Wu et al. 2014).

Caring for women with PFDs is an increasingly important component of women's health care (Jundt, Peschers, and Kentenich 2015). The demographics and the prevalence of pelvic floor dysfunction are well understood but there are no data on the normative values of PFM function and the preventive measures needed to serve this population (Jundt, Peschers, and Kentenich 2015). The increased life expectancy, the importance of the prevention in younger age, and the role of the pelvic floor dysfunction not only in the disease of the third age, but also in the childbearing age, as the influence on the type of

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delivery, underline the importance of the evaluation of the PFM function (Vellucci et al. 2018). PFM weakness is one of the most important factors in the etiology of PFDs and definitely contributes to the occurrence of some or all types of PFDs (Jundt, Peschers, and Kentenich 2015).

Sex differentiation plays a key role in PFM function (Abelson et al. 2018). The discrepancy in PFM function between sexes has been attributed to multiple factors including differences in anatomical, hormonal, biomechanical, and neuromuscular characteristics. Literature has revealed that the neuroimaging studies of PFM function in normal subjects showed men had strong and bilateral activation patterns in the periaqueductal gray (PAG) during contraction and relaxation of the pelvic floor (Athwal et al. 2001; Griffiths et al. 2005; Seseke et al. 2008). The activation levels in men during contraction of PFM were stronger than during relaxation, whereas women did not show these different levels (Seseke et al. 2008).

Evidence has also shown that men and women recruit different neural networks or show different levels of activation during pelvic floor contraction and relaxation. This could be caused by the different genitourinary system anatomies in men and women as well as the different micturition habits. The presence of the prostate and the longer male urethra might have an influence on activated sites and activation level (Seseke et al. 2008).

The evaluation of pelvic floor is generally clinical, but in the last two decades, the use of ultrasound has become a mainstream diagnostic tool in the investigation of female pelvic organ prolapse, urinary and fecal incontinence and defecation disorders, providing an immediate objective confirmation of findings obtained on clinical examination and filling some of the gaps of the urogynecological exam (Vellucci et al. 2018). Clinical measurement of PFM activity commonly involves techniques that are both physically and psychologically invasive. Assessment of PFM function has commonly included clinical observation, digital palpation, electromyography, manometry, dynamometry, magnetic resonance imaging, and vaginal cones (Dufour et al. 2018).

TAUS has been shown to be a valid and reliable tool to assess PFM function. This tool has been used as an evaluative technique to visualize PFM function by observing movement at the base of the bladder (Barton et al. 2015). Multiple studies support the validity of TAUS to demonstrate PFM activation by viewing displacement of the bladder (Sherburn et al. 2005).

Successful management of PFDs hinges on retraining PFM recruitment and recently TAUS has been used to visualize the dynamic muscle activity and the management of PFD. Furthermore, no data exists for the normative data of PFM function in females and males using TAUS. Thus, the purpose of this study is to observe normative values of PFM function in females and males in a healthy population using TAUS.

Methods

Subjects

A total of 200 healthy adults, including 71 males and 129 females participated in this observational analytical study. The subject population in this study was a sample of convenience made up of healthy adults with no history of PFDs. Subjects were recruited from the university of saint Augustine, San Marcos Campus, California. Subject were included in the study if they were healthy females or males aged 20–45. Exclusion criteria were (a) previous pregnancy, (b) previous pelvic surgery, (c) pelvic prolapse, (d) spinal surgery, (e) prostate cancer, (f) urinary tract infection, (g) breast feeding, (h) urinary incontinence, (i) radiation therapy, and (j) pelvic pain. Subjects were screened and were free of any PFDs. Physical activity questionnaire was also administered to assess the physical activity intensity levels and it was converted to MET value for analysis. All participants gave their written informed consent prior to entering the study. All procedures and protocols were approved by Institutional Review Board of the university.

Self-reported physical activity

Self-reported physical activity (PA) was taken using the international physical activity questionnaire (IPAQ). IPAQ is an instrument designed primarily for PA among adult population. The participants were asked to report the three intensity-specific PA indices combine information on the duration of activities that included walking, moderate, and vigorous during a full week. All continues scores of PA level are expressed in MET-minutes/week. The “walking activity index” reflect total walking activity for the week. A PA level of walking intensity was assigned a MET value of 3.3. The “moderate PA index,” reflects total moderate activity for the week. A PA level of moderate intensity was assigned a MET value of 4.0. A “vigorous activity index” was created by time spent in vigorous activity (MET = 8.0). A “total PA index” was calculated by summing walking, moderate activity, and vigorous activity indices to provide an integrated summary of PA and energy expenditure (Biernat et al. 2008).

Ultrasound measurement

The description of TAUS measurement procedure is described as follows: A diagnostic ultrasound imaging unit set in B-mode (Next Generation LOGIQ e ultrasound; General Electrics, Fairfield, CT, USA) with a 3.5 MHz curved (convex) array transducer was used for TAUS measurement of PFM function. We followed the procedure described by Sherburn et al. (2005) and others (Bo, Sherburn, and Allen 2003; Kelly et al. 2007; Thompson et al. 2007, 2005) to measure the PFM contraction. A standardized bladder filling protocol was used prior to imaging to ensure that subjects had sufficient fluid in their bladders to allow clear imaging of the base of the bladder. The subjects were asked to fill their bladder by consuming 600–750 ml of water one hour prior to testing, without voiding until after the ultrasound assessment. The participants were tested in a crook-lying supine position with one pillow underneath the head. The hips and knees flexed to 60 degrees and lumbar spine was positioned in neutral (Figure 1). The ultrasound transducer was placed transversely in the midline on the suprapubic region and angled in a posterior/caudal direction. The angle of the transducer was adjusted in each participant to obtain the clearest image of the inferior–posterior aspect of the bladder. This angle varied depending on the fullness of participants’ bladders and was approximately between 15 and 30 degrees.

The bladder base displacement was measured using a sagittal curved linear array 2–5 MHz transducer over the suprapubic region. The amount of bladder base movement on ultrasound was measured in all subjects and considered as an indicator of PFM function. Pelvic floor muscle contraction was explained, and displacement was measured three times including the direction of movement/displacement from freeze frame ultrasound images. Two investigators with at least five years of experience in using TAUS measurement completed the ultrasound measurement. A marker was placed on the image of the central portion of the bladder base at the junction of the hyperhypoechoic structures for a baseline measurement. The participants were asked to perform a three voluntary PFM contraction for 10 s each; and each image was captured at the point of maximal displacement and again marked. Displacement was measured as the distance between the two points marked in millimeter (mm) (Figure 2a,b). Subjects held the contraction no more than 10 seconds. If the bladder base was found to descend during PFM contraction, the displacement was given a negative value. The ultrasound transducer was not moved during the testing procedure and remained constant between rest and maximal contraction. Three PFM contractions were taken and the mean of three measurements was used for statistical analysis.

In this study, we followed the procedure described by Thompson et al. (Kelly et al. 2007) to analyze the difference in direction of the bladder base movement during PFM contraction. All testing procedure was performed in the research lab.

Data analysis

G power 3.0.1 was used to determine sample size. The study was designed to have 80% power to detect a clinical meaningful difference of the bladder base displacement by cutoff value (quartiles) using an



Figure 1. Set up for the ultrasound measurement.

effect size of 0.25, using a one-way ANOVA with a significance level of 0.05. As sample size of 180 participants were needed. Assuming 10% mortality rate we calculated that 200 participants were recruited.

Statistical analysis

The descriptive analysis was developed by calculating the means and standard deviations for quantitative variables. The normality of the variables was assessed by the Kolmogorov-Smirnov test. The

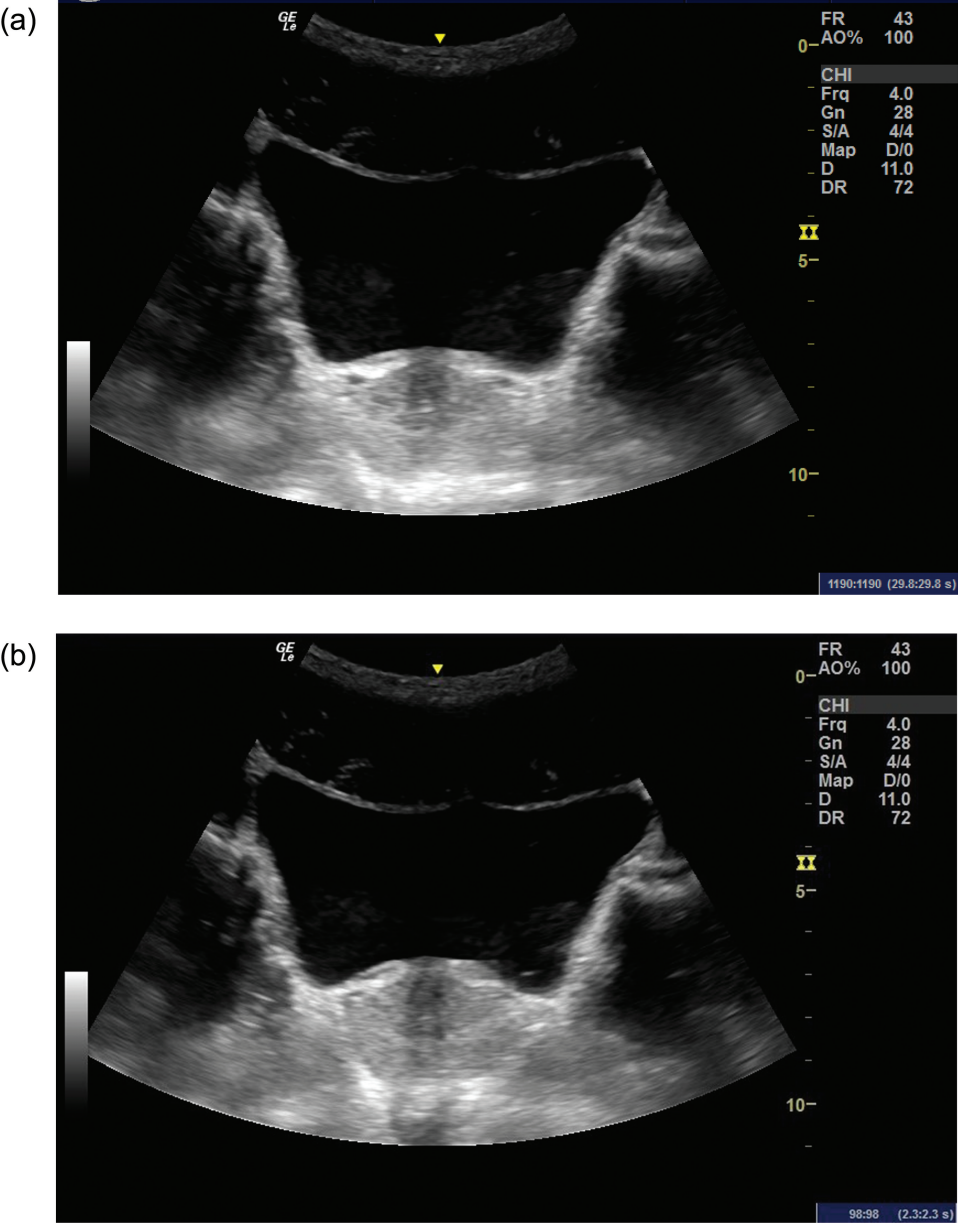


Figure 2. (a) Bladder base during resting position. (b) Bladder base displacement during pelvic floor muscle contraction.

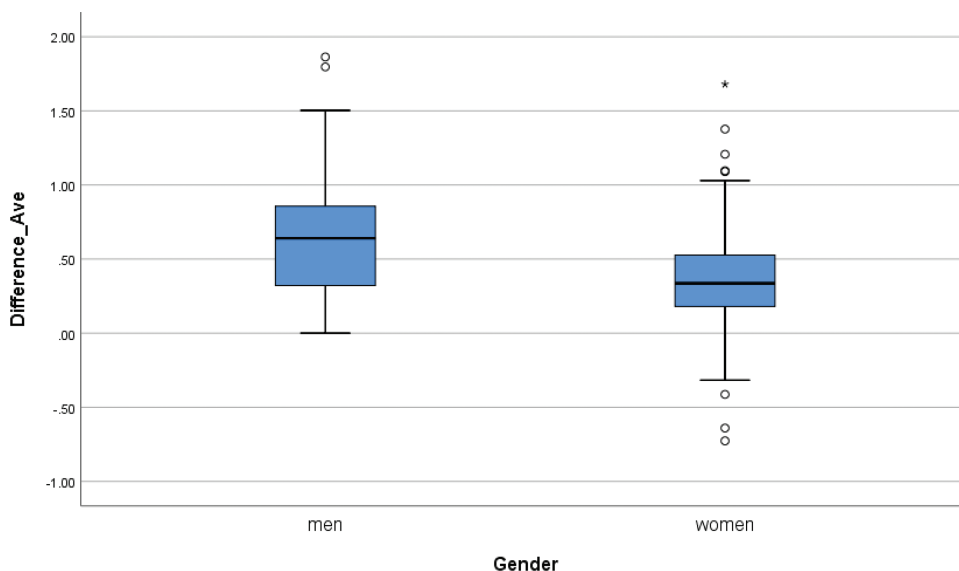
bladder base displacement between men and women was assessed by an independent t-test, and one-way ANOVA was conducted to see the difference in age, weight, height, BMI, and total PA by cut off values of bladder base displacement in men and women. The Pearson correlation coefficient was calculated to test the association between the variables. The level of significance set at $\alpha = .05$.

Results

Two hundred healthy adults (128 females and 71 males) with a mean age of 26.0 ± 2.6 years (range 21–40 years) were included in the study. The demographics of participants are displayed in Table 1.

Table 1. General characteristics of participants.

	Total (<i>n</i> = 199)	Female (<i>n</i> = 128)	Male (<i>n</i> = 71)
Age	26.04 ± 2.56	25.81 ± 2.87	26.45 ± 1.87
Height (cm)	168.16 ± 10.59	162.99 ± 8.13	177.48 ± 7.76
Weight (kg)	69.64 ± 13.13	63.98 ± 9.86	79.84 ± 12.14
BMI (kg/m ²)	24.56 ± 3.67	24.15 ± 3.87	25.29 ± 3.17
Total PA (METs)	697.88 ± 558.89	661.42 ± 467.24	763.61 ± 693.29

**Figure 3.** Average bladder base displacement of men and women.

The mean bladder base displacement of the participants was 0.45 ± 0.31 mm, and the bladder base displacement was significantly greater in male participants compared to female participants (0.61 ± 0.34 vs. 0.35 ± 0.25 , $p < .001$, 95% CI: 0.16–0.35) as shown in Figure 3.

Among all participants 10 women (7.8%) failed to demonstrate a correct PFM contraction while no men failed it. The results of the Chi-square test showed significant difference ($p = .015$) in the number of individuals with PFM contraction fails between men and women. Our results showed that bladder base displacement in males were the following: 0.61 ± 0.34 , the cut off points were 0.3, 0.64, and 0.86 for the percentile 25, 50, and 75, respectively as seen in Figure 4. The distribution of four categories was very weak from 0 to 0.3 mm bladder base displacement, in the weak category from 0.3 mm to 0.64 mm bladder base displacement, in the strong category from 0.64 mm to 0.86 mm bladder base displacement, and in the very strong category above 0.5 mm bladder base displacement. While bladder base displacement in females were the following: 0.35 ± 0.25 , the cut off points were 0.18, 0.33, and 0.53 for the percentile 25, 50, and 75, respectively (Figure 5). The distribution of four categories was very weak from 0 mm to 0.18 mm bladder base displacement, in the weak category from 0.18 mm to 0.33 mm bladder base displacement, in the strong category from 0.33 mm to 0.53 mm bladder base displacement, and in the very strong category above 0.53 mm bladder base displacement.

Analysis of the Pearson's correlation among age, BMI, total PA, and average bladder base displacement by gender did not show any significant relationship ($p > .05$) as displayed in Table 2.

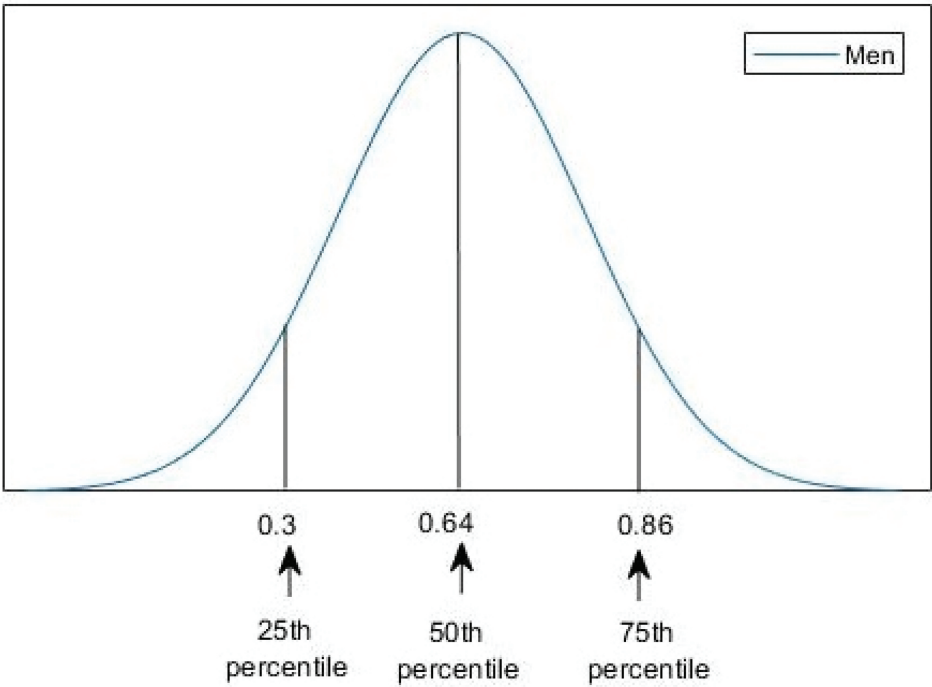


Figure 4. Normative pelvic floor muscle parameter in men.

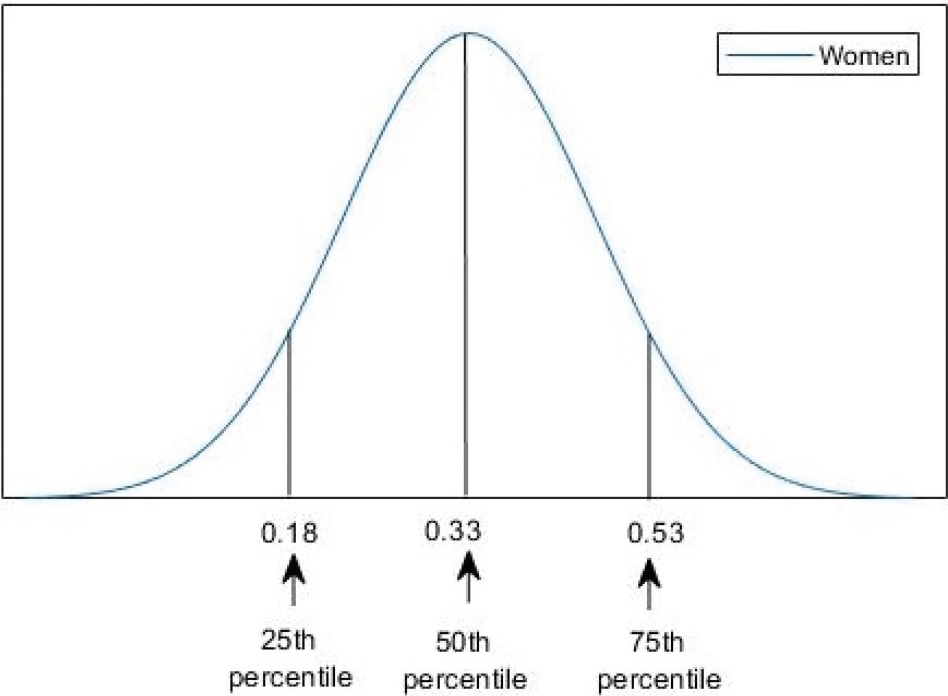


Figure 5. Normative pelvic floor muscle parameter in women.

Table 2. Difference of age, height, weight, BMI, and total PA according to cut off category by gender.

		Age (yrs)	Height (cm)	Weight (kg)	BMI	Total PA(METs)
Female						
Very weak (0–0.18)	n 30	26.93 ± 4.44	162.72 ± 7.20	61.73 ± 8.57	23.44 ± 3.95	717.10 ± 436.15
Weak (0.18–0.33)	33	25.27 ± 1.74	161.17 ± 9.86	63.72 ± 9.89	24.69 ± 4.50	701.30 ± 553.34
Strong (0.33–0.53)	34	25.47 ± 2.27	164.73 ± 9.04	66.46 ± 8.87	24.55 ± 3.10	627.04 ± 436.96
Very strong (Above 0.53)	31	25.68 ± 2.26	163.28 ± 5.36	63.69 ± 11.72	23.83 ± 3.87	602.79 ± 440.39
Average	128	25.81 ± 2.87	162.99 ± 8.13	63.98 ± 9.86	24.15 ± 3.87	661.42 ± 467.24
	F(p)	2.161(.096)	1.092(.355)	1.263(.290)	.742(.529)	.440(.725)
Male						
Very weak (0–0.3)	n 18	26.44 ± 1.54	176.81 ± 6.47	80.41 ± 10.04	25.75 ± 3.25	884.89 ± 736.76
Weak (0.3–0.64)	18	26.61 ± 2.38	175.68 ± 7.14	79.03 ± 12.48	25.54 ± 3.44	689.74 ± 829.46
Strong (0.64–0.86)	18	26.22 ± 1.83	179.35 ± 8.89	80.86 ± 13.60	25.01 ± 2.87	575.99 ± 419.89
Very strong (Above 0.86)	17	26.53 ± 1.74	178.10 ± 8.50	79.00 ± 13.14	24.85 ± 3.27	912.06 ± 722.52
Average	71	26.45 ± 1.87	177.48 ± 7.76	79.84 ± 12.14	25.29 ± 3.17	763.61 ± 693.28
	F(p)	.139(.936)	.743(.530)	.106(.957)	.308(.819)	.949(.422)

Discussion

This observational analytical study is the first to reveal gender specific differences of the pelvic floor muscle function in healthy adult population. It also provides a stratification model for the PFM function in a normal distribution of a large sample of a healthy population. The study findings allow a reference baseline data to have an objective method for a clinical measure and establish appropriate plan of care. This stratification model will help to identify patients who are at risk for developing PFDs.

Pelvic floor dysfunction is a common disease in middle-aged and elderly women with pelvic floor organ shifting and dysfunction due to the progressive decline of biomechanical properties of pelvic floor support tissue. Despite the obvious fact that these problems are structural failures, it is only recently that researchers have begun functional analyzes to evaluate the mechanisms of normal support and failure. Many randomized controlled trials and systematic reviews have shown that PFM training is effective for treating PFDs, with success rates between 44% and 80% among adult females (Dornowski et al. 2018). However, there is little evidence on normative values using non-invasive tools to assess PFM function.

The discrepancy in pelvic floor muscle function between sexes has been attributed to multiple factors including differences in anatomical, hormonal, biomechanical, and neuromuscular characteristics. The results of our study revealed that pelvic floor muscle function exhibits sexual dimorphism. Our results showed that male subjects had a greater bladder base displacement compared to their female's counterpart. We speculate that the observed differences in pelvic floor muscle function is related to the hormonal differences and it might have implication on the higher risk of PFD seen in women. While we are unable to find another published study that evaluated the effect of gender on PFM function in healthy adult population, our findings are surprisingly supported with those demonstrated in neuroimaging studies.

Moreover Kern et al. indicate that there are significant differences in recruitment of the insular cortex during external anal sphincter contraction between male and female subjects (Kern et al. 2004). Gender differences in cortical processing of intestinal visceral sensations have been reported previously (Berman et al. 2000; Kern et al. 2001) as well. The findings of their study support the notion of gender differences with regard to voluntary contraction of PFM and indicate a broader spectrum of differences than previously thought regarding cortical control of intestinal function between males and females (Berman et al. 2000).

Also, animal studies showed that the levator ani (LA) muscle of the developing rat fetus exhibits sexual dimorphism (Tobin and Joubert 1991). The investigators found that female LA muscles contained significantly fewer motorunits (MU) (153 versus 350) and each unit had comparatively smaller cross-sectional areas ($89.2 \mu\text{m}^2$ versus $120.8 \mu\text{m}^2$). Conversely, the number of motor units in males increased rapidly to 2726 by postnatal day 6, while in females, the number of MUs only increased modestly to 355. The authors posit that exposure to testosterone is responsible for this differential LA muscle development (Tobin and Joubert 1991).

Moreover, Niel et al. found that the number of satellite cells in the neonatal rat LA muscle was increased in males compared to females (Niel et al. 2008). The authors conclude that the sex differences found in the developing rat LA are attributed to sexual dimorphism in satellite cells, which may be androgen-sensitive (Niel et al. 2008). In contrast, Jundt et al. analyzed the pelvic floor muscles of young, healthy, female, and male cadavers. Due to small sample size, no quantitative analyses were performed, but no histomorphological differences between female and male specimens were reported (Jundt et al. 2005).

The animal studies mentioned above are in concordance with another study that investigated sex differences in the LA muscle of human fetuses (Fritsch and Frohlich 1994). The later study shows that at the same point in development, the male LA muscle constitutes a thick muscular layer, while in the female, the LA muscle is thin and its bundles are integrated with connective tissue (Fritsch and Frohlich 1994). In agreement with our hypothesis, Chevalier, Fernandez-Lao, and Cuesta-Vargas (2014) revealed that incontinence is typically seen in patients with pelvic floor weakness. By using this classification system, we may be able to identify those patients prior to developing incontinence.

This paper adds important findings in terms of establishing cut off points for females and males subjects according to the strength of the PFM function. This stratification model can help with regular pelvic floor assessment, establishing preventive measures, exercise program, and monitoring progress. Appropriate assessment of PFM function is crucial when prescribing an exercise program, adapting to patient needs, determining the correct exercise load, and reassessing the effectiveness of the exercise program. Understanding how to correctly perform PFM contraction and giving real-time feedback to the patient using TAUS during an exercise session could be helpful for patients who are reluctant to receive an internal examination as well as for a continence physiotherapist (Tosun et al. 2016).

While the observation of movement in the anterior direction, toward symphysis pubis, would logically be considered correct PFM, ten females failed to recruit and demonstrated posterior movement. Since we did not measure the various forces acting in the pelvis it cannot be concluded that subjects demonstrating a posterior direction of PFM were incorrectly recruiting or not relaxing the PFM appropriately. Increases in intrabdominal pressure such as seen with the Valsalva maneuver, and efforts to sustain a contraction of long duration increase the likelihood of downward/posterior PF movement (Bower, Chase, and Stillman 2006). It is acknowledged that the magnitude of PFM displacement seen on ultrasound could have been influenced by factors such as transducer positioning, operator pressure and orientation, subject topographical anatomy, and subject body mass.

There are several limitations of the current study. Firstly, the movement of the transducer during TAUS can cause measurement errors. However, the examiner held the ultrasound transducer firmly against the abdominal wall to control and restrict excessive movement. Secondly, the lack of a fixed bony reference point can make TAUS less reliable than transperineal ultrasonography because the measurement of the bladder base elevation with TAUS is expressed to a movable starting point.

Future research into PFDs assessment might include girth and diaphragm measures, and video recording of trunk and abdominal musculature to allow the identification and quantification of force. Future research should also address the use of shear wave elastography-based on acoustic radiation force, which can provide shear modulus that directly reflects the biomechanical properties of the pelvic floor muscle itself. Future research should also include large number of subjects to include different age groups and different ethnicities to establish a proper normal ranges of bladder base displacement to assess normal PFM function.

Conclusion

This present study revealed that pelvic floor muscle function exhibits sexual dimorphism. Men had a greater bladder base displacement compared to their female's counterpart. A consequence of differences in bladder base displacement may have implication on the higher risk of PFD seen in women.

Disclosure statement

The author declares no conflict of interest.

Funding

This work was supported by the National Research Foundation of Korea [2017R1C1B5017867] & NRF-2020R1F1A1075613..

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