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# Asymmetries of the Muscle Mechanical Properties of the Pelvic Floor in Nulliparous and Multiparous Women, and Men: A Cross-Sectional Study

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**Abstract:** This study aimed to identify if the muscle mechanical properties (MMPs) of both sides of pelvic floor muscles (PFMs) are symmetrical in different populations of both sexes. Between-sides comparisons of MMPs of PFMs, assessed with manual myotonometry, were performed in three groups, with 31 subjects each, composed of healthy nulliparous women (without any type of delivery or pregnancy), multiparous women (with at least two vaginal deliveries), and healthy adult men. Intra-group correlations between MMPs and age, body mass index (BMI), or clinical state of pelvic floor were also obtained. The nulliparous women and the men showed no between-sides differences in any MMP of PFMs. However, the multiparous women showed that the right side displayed less frequency (−0.65 Hz, 95% CI = −1.01, −0.20) and decrement (0.5, 95% CI = 0.11, 0.01), and more relaxation (1.00 ms, 95% CI = 0.47, 1.54) and creep (0.07 De, 95% CI = 0.03, 0.11), than the left side. Further, MMPs were related to age, sex, and BMI, also depending on the population, with the multiparous women being the only group with some between-sides asymmetries, which in this case were positive and of fair intensity for the left side of the PFMs, between BMI, and frequency and stiffness (rho Spearman coefficient: 0.365 and 0.366, respectively). The symmetry of MMPs of the PFMs could depend on the subject's condition. Multiparous women show a higher tendency to asymmetries than nulliparous women and men, which should be considered in research and clinical settings.

**Keywords:** pelvic floor disorders; manual tonometry; childbirth; tissue damage

## 1. Introduction

The pelvic floor (PF) is essential for different functions, such as pelvic girdle stability, continence, voiding, defecation, sexual function, and delivery. The PF includes a complex anatomic structure with fascial components (endopelvic fascia, ligaments, or perineal membrane), muscular components (pelvic floor muscles (PFMs) including levator ani muscles, muscles of the urogenital diaphragm, and superficial perineal muscles) [1], and neural components (both afferent and efferent nerves, visceral and somatic) [2]. Despite the skeletal and visceral differences, the histomorphology of PFM are similar between female and male individuals [3]. Most of the structures of PF are paired, and even those unpaired and medially located tend to have symmetry. However, this symmetry is not completely warranted, which is considered a strong risk factor of musculoskeletal injury [4].

Pelvic rotation in relation to the body axis, or the incorrect length of the muscles attached to the pelvic bones, could be the origin of pelvic asymmetries [5], which could disturb the functioning of PFMs. In fact, it has been reported that approximately 80% of healthy individuals have rotated body patterns that could lead to the lumbopelvic complex being more prone to asymmetry due to the fascial tension [6,7]. The pelvic asymmetries also cause changes in the tension of fascia, which disrupts PFMs contraction, and could impair the biomechanics of the spine and lower limbs [5]. However, limited information is available regarding the consequences of these asymmetries on other muscle mechanical properties (MMPs) in PFMs.

Although many factors could lead to PFDs (i.e., chronic constipation, obesity, or respiratory diseases), obstetric processes, aging, and other possible "trauma" could be more prone to modifying the mechanical behavior of PF tissues in an asymmetrical fashion at PF level, due to the deterioration of support mechanisms and the reduction in muscle function [1,8]. Thus, the action of hormones and, mainly, the PF tissue damage and their rebuild, associated with pregnancy, childbirth, and postpartum, could not be completed and symmetrical, with negative consequences for PF functions [5]. Specifically, vaginal delivery greatly impacts on PFMs [9], due to a decreased support capacity for pelvic organs, and damage to the levator ani muscles, the pudendal nerve, and visceral pelvic fascia [10]. Nevertheless, although some of the obstetric processes are not symmetrical (i.e., delivery presentations [11], episiotomy is commonly performed on the right side of the PF [12]), no information about their repercussions on the MMPs of each side of the PFMs is available.

Aging is another of the main factors that provokes changes and deterioration of the PF, that are worse in women due to menopause [13]. The changes start around the age of 40 years, with a loss of muscle mass and strength, and at 80 years, between 30 and 50% of muscle mass was lost [14], with a special fiber II type decline, which reduces the velocity of contraction and increases the fatigability, associated with a decrease in motor neurons [15]. Furthermore, the loss of collagen I, that increases with aging, and specifically at postmenopausal period, is consistent with loss of ligament function [16]. However, information about asymmetries caused by aging in PFMs, well defined in cadavers [17], is limited and inconclusive [8].

Since PFMs function can play an essential role in pelvic girdle instability and pain [18], its assessment is essential in clinical settings. Among the evaluations, the study of some MMPs, such as muscle tone, that is, resting tension determined by resistance to passive movement, or relaxation ability [13], and symmetry, are relevant [1,19]. Muscle tone has two components: the contractile component, created by the low-frequency activation of a small number of motor units; and the viscoelastic component (tension), which is independent of neural activity and reflects the passive physical properties of the elastic tension of the muscle fiber elements and the osmotic pressure of the cells. However, there is no single accepted or standardized way of measuring muscle tone, and there are no normative values [19]. Stiffness, defined as the resistance to deformation, is also relevant for PFMs assessment [20]. Passive elastic stiffness is defined as the ratio of the change in the passive resistance or passive force to the change in the length displacement [21]. The term should only be used if stiffness is measured quantitatively, with instruments such as dynamometry or myotonometry [19].

Commonly, the muscle activity assessment of PFMs does not consider lateral asymmetries [22,23], as occurs with dynamometry and EMG. Regarding stiffness, this situation remains. Although palpation is used as a readily available and low-cost method of assessing muscle stiffness, it should be used with caution, since it is not completely validated [24]. However, other new technologies allow the evaluation of each side of the PF in a separate fashion [25], which could bring new relevant information in clinical settings. That is the case of MyotonPRO, (Myoton AS, Taillinn, Estonia) a manual myotonometric device that does not require such high levels of expertise as other assessment tools, such as ultrasound imaging, and can be used by novices with acceptable results [26], as long as the correct measurement positions can be found [27]. Furthermore, several studies have shown sufficient accuracy and precision of manual myotonometric assessment with MyotonPRO in different tissues and regions [28–32], including PFMs [25,33].

In summary, since pelvic asymmetries have been identified as a source of PFDs, the description of the between-sides asymmetries of the MMPs of the PFMs could be clinically relevant. Their determination in clinical setting would add relevance to this new assessment. Thus, the objective of this study was to identify if MMPs of both sides of PFMs are symmetrical in different populations (i.e., nulliparous women, multiparous women, and healthy men). It was hypothesized that different populations show different patterns of between-sides asymmetries of the MMPs of the PFMs, according to specific characteristics, such as sex, age or number of deliveries.

## 2. Materials and Methods

### *2.1. Study Design*

An observational, cross-sectional study of cases and controls with a non-probabilistic sampling of consecutive cases was conducted between March 2019 and May 2022. The strengthening the reporting of observational studies in epidemiology (STROBE) method was used. The Research Ethics Committee of Córdoba approved this project (registration number 4074, 20 December 2018 approved). All participants signed the informed consent form.

### *2.2. Subjects*

Three groups were included, each consisting of 31 subjects aged between 18 and 65 years, all recruited via social media and flyers posted on the university campus. The nulliparous group inclusion criteria were: healthy adult women; without any type of delivery or pregnancy. The multiparous group inclusion criteria were: women; with at least 2 vaginal deliveries, considering childbirth a possible source of asymmetries of PF. The men group inclusion criterion was: healthy adult men. Exclusion criteria for all groups were: history of surgery at lumbopelvic level; engagement in regular physical training (only recreationally active); experience of any spinal pain in the 6 months before enrolment in the study [34]; presence of scoliosis [35]; body mass index (BMI) > 30 kg/m$^2$. Furthermore, neither the nulliparous women nor the men could present any type of incontinence.

To identify a moderate effect size (Cohen d index = 0.7) based on a minimum detectable change of 0.86 and a pooled standard deviation of 1.23 for frequency, as previously reported [25], an error type I of 0.05 and 0.90 of power, 25 women/men per group were necessary (G*power 3.1.9.2, *t*-test for difference between two dependent measures). The final sample size was increased 20% in each group for possible data loss.

### *2.3. Assessments and Procedures*

Sociodemographic and clinical data of the three groups were collected. For multiparous women, the Spanish versions of the Pelvic Floor Distress Inventory (PFDI-20) and Pelvic Floor Impact Questionnaire (PFIQ-7) were applied to assess the PF clinical state. PFDI-20 has 20 questions divided into three domains: Pelvic Organ Prolapse Distress Inventory (POPDI-6) for symptoms of genital prolapse (questions 1 to 6); Colorectal–Anal Distress Inventory (CRADI-8) for colorectal-anal symptoms (questions 7 to 14); and Urinary Distress Inventory (UDI-6) for urinary symptoms (questions 15 to 20). Each question determines four levels of dysfunction: not at all, somewhat, moderately, or quite a bit. The score for each domain ranges from 0 points (minimum dysfunction) to 100 points (maximum dysfunction). The total score is the sum of the three blocks [36,37]. The PFIQ-7 also has three domains, each one with seven questions: Urinary Impact Questionnaire (UIQ-7) for the impact of symptoms on activities, relationships, or feelings in relation to urinary prolapse; Colorectal–Anal Impact Questionnaire (CRAIQ-7) for colorectal-anal conditions; and Pelvic Organ Prolapse Impact Questionnaire (POPIQ-7) for genital conditions. Again, each of the questions can be answered at four levels of impact: not at all, somewhat, moderately, or quite a bit. The minimum score for each block is 0 points (low impact) and the maximum is 100 points (maximum impact). The total score is the sum of the three blocks with a maximum score of 300 [36,37].

Afterward, the evaluation of the MMPs of the PFMs was performed by two physical therapists, with more than one year of experience in the evaluation and treatment of PFDs, and who received six hours of training for the use of the MyotonPRO, to assess muscles of different body regions researched by our team [38,39], including the PFMs [25]. Measurements were taken with the participants in a supine position on a table, with the knees flexed and the soles of the feet on the table, to ensure that both lower limbs were symmetrical and relaxed during the measurement. Immediately after a maximal voluntary contraction, and once the muscle was in a relaxed state (verbal command: *Please, tighten the pelvic floor muscles as if you are holding in your urine. Then let go*), the measurement site was located by visual observation and palpation in the largest area of muscle bulk during contraction on both sides of the perineal body (PB) [25]. This area, also referred to as the central tendon of the perineum, was chosen as the optimal location for obtaining accurate measurements of the external perineal muscles, since it contains the most contractile portion of the perineal muscles [40]. A marker was placed on the skin to ensure that the measurements were taken at the same site [33]. For the men evaluation, they were asked to keep the sexual organs away from the region of the evaluation, without generating tensions in the PB. A MyotonPRO (Myoton AS, Tallinn, Estonia) was used to record the MMPs on the PF according to the manufacturer's instructions. The recording was performed during five seconds of apnea after exhalation, to reduce the abdominal influence on the test [31]. The 100 mm-long probe was placed on the measurement location, perpendicular to the surface of the skin [31,41]. The average value of five mechanical pulses was used for the analysis. The coefficient of variation among the mechanical impulses automatically exerted with the probe (pulse of 15 ms and 0.40 N of mechanical force) of each set of assessments was lower than 3%. An online tool (www.randomization.com, accessed on 2 February 2019) was used to randomize the order of the evaluations (right/left). The reliability of the MyotonPRO determinations is well documented in different parts of the body and structures [27], including PFM in subjects with and without disease [25,33].

The MMPs are expressed as follows: muscle tension or tone in resting state (Hz), defined by frequency; stiffness (N/m), which reflects the ability of the muscle to resist contraction or external force that deforms its initial shape; logarithmic decrement in the amplitude of oscillation, which has no unit (Ø), and describes the ability of the tissue to restore its shape after deformation, characterizing the inverse of the elasticity (the lower the decrement value, the greater elasticity) [42]; the relaxation time of stress (ms), which is the recovery time for the muscle to return to its normal state after deformation; and the creep (Deborah number), which is the property of progressive deformation while applying constant stress, and reflects the fluidity of the tissue. Relaxation and creep characterize viscoelastic properties [43].

To identify the possible presence of pain during the evaluation, a visual analogue scale (VAS) was used at the end of the protocol. The whole protocol did not last more than 20 min per individual.

### 2.4. Statistical Analysis

Categorical variables were analyzed as frequencies and percentages. Continuous data were described by mean, standard deviation, and 95% confidence interval (95%CI). The Kolmogorov–Smirnov test showed normal distribution for MMPs ($p > 0.05$), while BMI and questionnaires results were not normally distributed. These variables were described as median and interquartile ranges.

Age and BMI of the groups were compared with a one-way ANOVA and Tukey's test for post hoc analyses, and with a Kruskal–Wallis test and Dunn's test for post hoc analyses, respectively. For each group, to compare the MMPs of both sides, paired Student *t*-tests were applied. Furthermore, to identify intra-group associations among the MMPs and sociodemographic data, and clinical features for the multiparous group, Pearson r or Spearman rho coefficients were calculated. Correlations were considered as negligible (0.0 to 0.19), fair (0.20 to 0.39), moderate (0.40 to 0.69), strong (0.70 to 0.89) or almost perfect (0.0 to 1.00) [44].

The level of significance was set at 0.05 for all tests, and the IBM-SPSS software, version 25 (Armonk, NY, USA) was used for the statistical analysis.

## 3. Results

### 3.1. Sociodemographic and Clinical Data

Thirty-one subjects composed each study group, all right-handed. The age showed significant differences among the three groups ($p < 0.001$), with nulliparous women being the youngest (23.9 ± 6.3 years), men being the oldest, but with the highest variability (49.4 ± 8.8 years), and multiparous showing a mean age and variability among the other groups (36.8 ± 15.8 years). The BMI also showed differences among the three groups ($p < 0.001$), with nulliparous women and men showing normal values (21.2(3.03) kg/m$^2$ and 23.4(3.2) kg/m$^2$, respectively), and multiparous women with overweight and the highest variability 25.5(5.1) kg/m$^2$ (Table 1).

**Table 1.** Sociodemographic and clinical data of the study groups.

| | Nulliparous Group ($n$ = 31) | Multiparous Group ($n$ = 31) | Men Group ($n$ = 31) | $p$-Value |
|---|---|---|---|---|
| Age (years) | 23.9 ± 6.3 | 49.4 ± 8.8 | 36.8 ± 15.8 | <0.001 † |
| BMI (kg/m$^2$) | 21.2 (3.03) | 25.5 (5.1) | 23.4(3.2) | <0.001 † |
| Vaginal deliveries (frequency) | | **2**: 25; **3**: 6 | | |
| Pregnancies (frequency) | | **2**: 20; **3**: 8; **4**: 0; **5**: 2; **6**: 1 | | |
| Any instrumental delivery (frequency) | | **Yes**: 7; **No**: 24 | | |
| Any episiotomy (frequency) | | **Yes**: 23; **No**: 8 | | |
| Laceration (frequency) | | **Yes**: 5; **No**: 26 | | |
| Epidural analgesia (frequency) | | **Yes**: 19; **No**: 12 | | |
| Types of UI (frequency) | | **No UI**: 10; **SUI**: 10; **UUI**: 7; **MUI**: 4 | | |
| Menopause (frequency) | | **Yes**: 16; **No**: 15 | | |
| PFDI-20 | | 38.0 (61.7) | | |
| UDI-6 | | 16.7 (14.6) | | |
| CRADI-8 | | 12.5 (16.4) | | |
| POPDI-6 | | 6.3 (25.0) | | |
| PFIQ-7 | | 33.1 (58.3) | | |
| UIQ-7 | | 9.5 (23.8) | | |
| CRAIQ-7 | | 6.8 (10.7) | | |
| POPI-7 | | 10.15 (1.19) | | |

Values expressed as frequencies, means ± SD, or median (interquartile range). † Significant difference ($p < 0.05$) between the three groups. Abbreviations: BMI: body mass index; CRADI-8: Colorectal–Anal Distress Inventory; CRAIQ-7: Colorectal–Anal Impact Questionnaire; PFDI-20: Pelvic Floor Distress Inventory; PFIQ-7: Pelvic Floor Impact Questionnaire; POPDI-6: Pelvic Organ Prolapse Distress Inventory; POPIQ-7: Pelvic Organ Prolapse Impact Questionnaire; UDI-6: Urinary Distress Inventory; UIQ-7: Urinary Impact Questionnaire; UI: urinary incontinence; SUI: stress urinary incontinence; MUI: mixed urinary incontinence; UUI: urgency urinary incontinence.

Multiparous women showed two vaginal deliveries in 80.6% of cases, three being the maximum number of vaginal deliveries, and the number of pregnancies ranged from two to six. Results showed that 22% and 74.2% of the women suffered at least one instrumental delivery or episiotomy, respectively, while 16% of the women had lacerations associated with deliveries, and 61.3% received epidural analgesia for at least one delivery. Furthermore, 67.7% of the multiparous women presented UI, with 32.3% being of stress urinary incontinence (SUI), 22.6% of urgency urinary incontinence (UUI), 12.9% of mixed urinary incontinence (MUI), and 51.6% were in post-menopause state. Furthermore, PFDI-20 and PFIQ-7 showed similar median values and high variability (38.0 (61.7) and 33.1 (58.3), respectively). Other data are available in Table 1.

### 3.2. Between-Sides Comparison of MMPs of PFMs in Each Group

The nulliparous group showed no between-sides differences in any MMP of the PFMs, despite of the creep showed a tendency to statistical significance. In fact, all differences between means were low. However, the multiparous women showed that frequency (tension), decrement (inverse of elasticity), relaxation (recovery time to normal state), and creep (fluidic state) were different between-sides. That is, although several MMPs showed the highest variability data of the study groups, as occurred with frequency and stiffness, the right side displayed less tension (−0.65 Hz, 95% CI = −1.01, −0.20) and more elasticity (0.5, 95% CI = 0.11, 0.01) and viscoelastic properties, in terms of relaxation time of stress (1.00 ms, 95% CI = 0.47, 1.54) and fluidity (0.07 De, 95% CI = 0.03, 0.11), than the left side.

Finally, the men group demonstrated no between-sides differences in any MMP, with the highest variability among the three groups for decrement, relaxation, and creep, and the frequency showing a tendency of statistical significance (Table 2).

**Table 2.** Between-sides differences of MMPs of PFMs in the three groups.

| | **Nulliparous Group (*n* = 31)** | | | **Multiparous Group (*n* = 31)** | | | **Men Group (*n* = 31)** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Right** | **Left** | ***p*** | **Right** | **Left** | ***p*** | **Right** | **Left** | ***p*** |
| Frequency (Hz) | 15.11 ± 2.00 | 15.39 ± 1.85 | 0.236 | 15.77 ± 2.32 | 16.42 ± 2.55 | 0.006 † | 11.81 ± 1.08 | 12.20 ± 1.26 | 0.067 |
| Stiffness (N/m) | 229.00 ± 70.88 | 230.03 ± 57.39 | 0.896 | 254.72 ± 77.39 | 320.69 ± 64.74 | 0.197 | 141.61 ± 24.05 | 149.42 ± 22.48 | 0.086 |
| Decrement (Ø) | 1.02 ± 0.20 | 1.01 ± 0.19 | 0.890 | 1.10 ± 0.16 | 1.15 ± 0.18 | 0.045 † | 0.93 ± 0.21 | 0.94 ± 0.20 | 0.472 |
| Relaxation (ms) | 17.76 ± 2.77 | 17.26 ± 2.41 | 0.150 | 17.42 ± 3.02 | 16.41 ± 2.73 | 0.001 † | 25.19 ± 4.37 | 24.73 ± 4.09 | 0.319 |
| Creep (De) | 0.95 ± 0.10 | 0.93 ± 0.09 | 0.061 | 0.98 ± 0.13 | 0.91 ± 0.11 | 0.001 † | 1.27 ± 0.33 | 1.28 ± 0.32 | 0.687 |

Values expressed as frequencies, means ± SD, or median (interquartile range). † Significant difference ($p < 0.05$) between the three groups.

### 3.3. Intra-Group Correlations between MMPs of PFMs and Sociodemographic and Clinical Data

Only the men showed significant correlations between age and MMPs of both sides of PFMs, ranging from fair (decrement) to strong (relaxation and creep) intensity when positive, and moderate (frequency) when negative. Regarding the BMI, the three groups demonstrated a different trend of correlations. Thus, fair to moderate positive associations were found with relaxation and creep of both sides in the nulliparous women. That is, the higher BMI, the higher relaxation time, and fluidity. For multiparous women, decrement was related to BMI on both sides (right: rho = 0.467; left: rho = 0.505), but only the left side showed associations with frequency (rho = 0.365) and stiffness (rho = 0.366), in all cases positively, that is, the higher BMI, the higher decrement, frequency, and stiffness. Finally, frequency, in negative fashion, and relaxation and creep, in positive fashion, on both sides were moderately correlated ($|0.415| < \text{rho} < |0.532|$) in men. Thus, the higher BMI, the lower tension and the higher relaxation and fluidity.

Regarding the questionnaires applied to the multiparous group, scant correlations with the MMPs of both sides were identified. In fact, total scores did not show correlations, and only POPDI-6, in fair intensity, and POPI-7, in moderate intensity, were related to decrement of both sides (Table 3).

**Table 3.** Correlations between MMPs of PFMs of both sides, and age and BMI of the three groups, and PF questionnaires of multiparous women.

| | Frequency | | Stiffness | | Decrement | | Relaxation | | Creep | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Right** | **Left** | **Right** | **Left** | **Right** | **Left** | **Right** | **Left** | **Right** | **Left** |
| **Age** | | | | | | | | | | |
| Nulliparous group | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Multiparous group | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Men group | −0.658 †† | −0.466 † | NS | NS | 0.357 † | 0.368 † | 0.823 †† | 0.756 †† | 0.803 †† | 0.766 †† |
| **BMI** | | | | | | | | | | |
| Nulliparous group | NS | NS | NS | NS | NS | NS | 0.378 † | 0.413 † | 0.359 † | 0.438 † |
| Multiparous group | NS | 0.365 † | NS | 0.366 † | 0.467 † | 0.505 † | NS | NS | NS | NS |
| Men group | −0.494 † | −0.415 † | NS | NS | NS | NS | 0.532 † | 0.494 † | 0.488 † | 0.481 † |
| **PDFI-20** | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| UDI-6 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| CRADI-8 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| POPDI-6 | NS | NS | NS | NS | 0.384 † | 0.391 † | NS | NS | NS | NS |
| **PFIQ-7** | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| UIQ-7 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| CRAIQ-7 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| POPI-7 | NS | NS | NS | NS | 0.488 † | 0.509 † | NS | NS | NS | NS |

Values expressed as Pearson r or Spearman rho coefficients, *p*-value. † $p < 0.05$; †† $p < 0.01$. Abbreviations: BMI: body mass index; PFDI: Pelvic Floor Distress Inventory; PFIQ: Pelvic Floor Impact Questionnaire; NS: not significant.

## 4. Discussion

The current results showed that the between-sides symmetry of MMPs of PFMs, that is present in healthy nulliparous women and healthy men, can be altered in certain populations, such as multiparous women. Furthermore, the between-sides symmetry of the associations between MMPs of PFMs and age and BMI also depends on the target populations. Thus, while nulliparous women and men showed positive relations between BMI and relaxation time of stress and fluidity in both sides, the multiparous showed positive relations with tension and stiffness of the left side, and negative with the elasticity of both sides. The values of distress and impact due to PFDs of the multiparous group were similar to control groups of previous research and lower than those with PFDs [45,46], probably because the multiparous women were not seeking treatment for PFDs at the time of the study, and were scantly correlated with MMPs. Finally, no subject reported pain or any discomfort due to the evaluations, demonstrating that the protocol is innocuous and useful in clinical settings.

### *4.1. Between-Sides Asymmetries of MMPs of PFMs*

Very limited information is available regarding the asymmetries of tissues in PFMs. Specifically, although the reliability of the assessment of MMPs at both sides of the PFMs was considered as good to very good, the left side of the women with UI showed more differences in reliability determinations than the right side, and even more than both sides of healthy women [25]. The same pattern was found for the stiffness of PFMs of women with vulvodynia, where higher between-sides differences were identified, when compared to healthy women [33]. This lower reliability in stiffness assessment could partially explain the absence of between-sides differences found in the current study for this variable in multiparous women, being the only MMPs without statistical differences, despite the difference in means was higher than the MDC established for this measurement in women with and without UI [25].

In line with the results in multiparous women, between-sides differences in MMPs were reported in asymmetrical disorders. For example, higher tone and stiffness and low relaxation time of stress and creep were found in the concave side of the spine in adolescent idiopathic scoliosis [35,47], a clearly asymmetrical disorder. Moreover, the lumbar paravertebral muscle stiffness is higher on the painful side when compared with the non-painful side in chronic low back pain in adults [48] and elderly individuals [49]. Furthermore, surgery provokes asymmetries of MMPs in non-contractile structures, as occurs with the Achilles tendon rupture, that shows higher stiffness after repair [50]. Consequently, it could be concluded that the determination of MMPs with manual myotonometry has potential to detect pathological asymmetries in muscle tissues.

Some factors could be considered as sources of the asymmetries of MMPs of PFMs, as the presence of: disorders, such as UI [25], which was present in more than 60% of the multiparous women; different types of deliveries [11], as occurred in the studied group in terms of instrumental delivery and lacerations; episiotomies [12], that were also present in three-quarters of the multiparous women; and other obstetric scars and lesions [51,52]. Although it cannot be affirmed with precision which of these lesions or tissue changes affected one side more than the other, the multiparous women showed more tension and less elasticity and viscoelastic properties on the left side of the PFMs. As a consequence of this tendency of asymmetry of PFMs, it should be pointed that muscles on one side may contract in the form of unnatural lengthening and on the opposite side, in unnatural shortening, which is undesirable for effective contractions and force production [34,53].

On the contrary, the MMPs were symmetrical in right-handed healthy nulliparous women and men, as demonstrated in the lower limb muscles of older males [26], and athletes. Thus, no bilateral differences were found in the stiffness of lower limb muscles or patellar tendon in subjects that practice a sport linked to unilateral predominance, such as badminton [54]. For unhealthy states, no between-sides differences were reported in, a priori, non-asymmetrical diseases. Thus, at the spinal level, several studies did not find between-sides differences in MMPs in lumbar [31,32,55] and cervical [31,32] paravertebral muscles of spinal mechanics and rheumatic diseases and healthy subjects. Regarding PFMs, no between-sides differences were found at post-partum period after a vaginal delivery in a sample of 12 women with 25% of assisted vaginal deliveries and 33% of episiotomies [39].

In summary, healthy subjects, even when practicing asymmetric sport, and unhealthy subjects that suffer symmetric diseases, show symmetric MMPs in several body regions. However, when possible asymmetrical alterations are involved, between-sides MMPs differences can be found.

### *4.2. Intra-Group Correlations Patterns between MMPS of PFMs, and Age, BMI and Clinical Status*

The pattern of correlations of MMPs with age and BMI reinforced the specificity of the symmetry pattern according to each group, with the multiparous group again being the only group that showed some correlations on only one side. This pattern was found for the direct relation between BMI, that showed overweight in mean values, and tension and stiffness in the left side of PFMs (i.e., higher rigidity and higher BMI are linked, as previously reported [56]), which could be in line with the described between-sides differences.

Regarding the symmetric correlations of both sides, relevant differences were found among the trends of the groups. Thus, only men showed associations between age and MMPs of PFMs, with older subjects showing lower tension and higher viscoelasticity. The relationships between sex and aging and MMPs are well documented. In fact, in healthy subjects, the tension and elasticity of upper limb muscles are greater in men than in women, whereas the relaxation time of stress is greater in women than in men. Furthermore, greater muscle stiffness is found in subjects over 50 years old, and less muscle elasticity in the same muscles in more than 70 years old subjects [57], which is contrary to the relation between age and MMPs identified in the men of the current study, maybe due to the different anatomic locations. Thus, independent of the type of relations, these results supports the idea that age and sex differently impact MMPs of musculoskeletal muscles [58].

BMI also showed a heterogenous pattern of correlations with MMPs of both sides among groups. The men showed lower tension and higher viscoelasticity when BMI increases, which was not found in nulliparous women, and was contrary to other results observed in limb muscles of healthy subjects [56], again may be due to the different anatomic locations and the differences between sexes.

Finally, for multiparous women, only the domains of both questionnaires of PF that assess organ prolapse showed associations with some MMP, in this case, the decrement. The relation between vaginal deliveries and organ prolapse, and consequently the tissue damages, has been described [59]. Thus, higher stiffness of the vaginal wall is associated with organ prolapse [60], due to lower protein expression of collagen III in the vaginal wall [61], which could be related to the lower values of elasticity presented on both sides of the current study.

### *4.3. Clinically Relevance of the Assessment of MMPs in PF*

As described, the assessment of MMPs is relevant in different fields, and specifically in PFMs, since the increase in the stiffness of the pelvic ring is relevant in women with pelvic pain [20]. Moreover, and in line with the current results in women, different factors, such as the number of vaginal births, age at first pregnancy, history of episiotomy, and menopause, that are clearly associated with PFDs, should be considered when assessing MMPs of PF [62].

Although the current study is focused on assessment, it should be pointed out that the PFMs asymmetries are reversible with the application of specific exercises [34], which could reveal new and more specific treatment strategies in PFDs. Finally, due to the innocuousness and the short time required for the assessment protocol, it can be concluded that the determination of MMPs of PFMs with a manual myotonometer could be applied routinely in clinical settings.

### *4.4. Strengths and Limitations of the Study*

To the best of our knowledge, the current study is the first to analyze between-sides asymmetries of PFMs in specific populations using a manual myotonometer. Furthermore, it is the first in assessing MMPs of PFMs in men. These aspects, added to the innocuousness of the assessment protocol can be considered strengths of this study.

Nevertheless, some limitations should be recognized. The study design did not allow us to establish cause–effect relationships, and it cannot be concluded that parity is a cause of MMPs asymmetries. The phase of the menstrual cycle was not controlled in women groups, which could be relevant in clinical evaluation [63]. The multiparous group was heterogenous, including women with two to six pregnancies, with and without any type of UI, instrumental delivery, laceration, and menopause, which could lead to different clinical behaviors. Furthermore, other factors, such as the duration of birth, the use of oxytocic agents at birth, or the weight of the baby at birth, were not controlled, which could have influenced the results. All evaluations were performed in the same lying position, which increases the consistency of the results, but different positions could determine different results and interpretations [64]. Likewise, all MMPs measurements were performed at the same location, that is the PB, and other locations could also assess other structures. However, the PB is considered a good location, since is the key point of anchorage for the contraction of different muscles, such as the bulbocavernosus, the superficial transversus, part of the levator muscles, the external anal sphincter, and other fibromuscular tissues, among which is the rectovaginal septum. Further, the deep transverse muscle of the perineum, which stabilizes the central body of the perineum laterally, is also inserted on it. The external anal sphincter also acts as a tensor of the PB and is the main point of insertion of the longitudinal muscle of the anus [40]. Therefore, the results cannot be generalizable for other diseases, age stages, and populations, and specific considerations regarding between-sides asymmetries should be considered, depending on each objective in future studies.

## 5. Conclusions

The symmetry of MMPs could depend on the subject's condition at PF level. Multiparous women with different number of deliveries and levels of UI show higher tendency to asymmetries than nulliparous women and men. Multiparous women show a higher tendency towards asymmetries than nulliparous women and men, which should be considered in research and clinical settings. Further, MMPs are related to aging, sex and BMI, also depending on the target populations and the anatomic location. Thus, MMPs are associated with aging only in men, while nulliparous women and men show positive relations between BMI and viscoelasticity in both sides of PFMs, and the multiparous women show positive relations with tension and stiffness only in the left side.

Since the symmetry of MMPs show clinical interest and depends on the studied population, clinical assessments and future research on MMPs of PFMs should consider previous PFDs, age stages and sex.

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