Pelvic-floor function, dysfunction, and treatment

European Journal of Obstetrics & Gynecology and Reproductive Biology

The pelvic- floor function, dysfunction, and treatment

--Manuscript Draft--

Manuscript Number:	
Article Type:	Review Article
Section/Category:	Urogynaecology
Keywords:	bladder pain syndrome, chronic pelvic pain syndrome, Integral Theory, irritable bowel syndrome, LUTS, overactive bladder, pain, pelvic floor
Corresponding Author:	Jörgen Quaghebeur, PhD University of Antwerp: Universiteit Antwerpen Edegem, BELGIUM
First Author:	Jörgen Quaghebeur, PhD
Order of Authors:	Jörgen Quaghebeur, PhD
	Peter Petros, PhD. MD
	Jean-Jacques Wyndaele, PhD. MD
	Stefan De Wachter, PhD. MD
Abstract:	The pelvic floor functions as a holistic entity. The organs, bladder, bowel, smooth and striated muscles, nerves, ligaments and other connective tissues are directed cortically and reflexly from various levels of the nervous system. Such holistic integration is essential for the system's multiple functions, for example, pelvic girdle stability, continence, voiding/defecation, and sexuality. Pelvic floor dysfunction (PFD) is related to a variety of pelvic pain syndromes and organ problems of continence and evacuation. Prior to treatment, it is necessary to understand which part(s) of the system may be causing the dysfunction (s) of Chronic Pelvic Pain Syndrome (CPPS), pelvic girdle pain, sexual problems, Lower Urinary Tract Symptoms (LUTS), dysfunctional voiding, constipation, prolapse and incontinence. The interpretation of pelvic floor biomechanics is complex and involves multiple theories. Non-surgical treatment of PFD requires correct diagnosis and correctly supervised pelvic floor training. The aims of this review are to analyze pelvic function and dysfunction. Because it is a holistic and entirely anatomically based system, we have accorded significant weight to the Integral Theory's explanations of function and dysfunction.
Suggested Reviewers:	Klaus Goeschen, PhD, MD Prof, Universität Hannover: Leibniz Universitat Hannover klaus.goeschen@googlemail.com expert
	Darren Gold, PhD, MD Dr, University of New South Wales dandjgold@googlemail.com expert
Opposed Reviewers:	

Dr. Quaghebeur Jörgen
PhD. Med. Sci.
University Hospital Antwerp / Dep. Urology
Wilrijkstraat 10,
B 2650 Edegem Belgium
Phone: 32(0)38214699

Aarschot, 22/04/2021

Editorial board
European Journal of Obstetrics & Gynecology
and Reproductive Biology

Elisabethlaan 46
B 3200 Aarschot Belgium
Phone: 32(0)16567880
E-mail: jorgen.quaghebeur@telenet.be

Concerns: Cover letter

Editor,

We want to submit the article: *The Pelvic floor- function, dysfunction and treatment.*

The authors are:

- Dr. Jörgen Quaghebeur, PhD. Med. Sci.
- Prof. Dr. Peter Petros M.D.
- Prof. Dr. Jean-Jacques Wyndaele M.D.
- Prof. Dr. Stefan De Wachter M.D.

This publication explains the anatomy and biomechanics of the pelvic floor. This review shows the pelvic floor's essential role for pelvic girdle stability, continence, voiding, defaecation, sexual function and delivery. This review describes the integral pelvic floor function, dysfunction and the relation with chronic pain, the diagnosis of pelvic floor dysfunctions and pelvic floor revalidation.

Competing interests statement.
The authors declare no competing interests.

Author contributions
Dr Jörgen Quaghebeur researched data for the article and wrote the manuscript. Prof Peter Petros MD, Prof Jean-Jacques Wyndaele MD, and Prof Stefan De Wachter MD made substantial contributions to content discussions.

Kind Regards,

Quaghebeur Jörgen

The pelvic- floor function, dysfunction, and treatment.

Abstract

The pelvic floor functions as a holistic entity. The organs, bladder, bowel, smooth and striated muscles, nerves, ligaments and other connective tissues are directed cortically and reflexly from various levels of the nervous system. Such holistic integration is essential for the system's multiple functions, for example, pelvic girdle stability, continence, voiding/defecation, and sexuality. Pelvic floor dysfunction (PFD) is related to a variety of pelvic pain syndromes and organ problems of continence and evacuation. Prior to treatment, it is necessary to understand which part(s) of the system may be causing the dysfunction (s) of Chronic Pelvic Pain Syndrome (CPPS), pelvic girdle pain, sexual problems, Lower Urinary Tract Symptoms (LUTS), dysfunctional voiding, constipation, prolapse and incontinence. The interpretation of pelvic floor biomechanics is complex and involves multiple theories. Non-surgical treatment of PFD requires correct diagnosis and correctly supervised pelvic floor training.

The aims of this review are to analyze pelvic function and dysfunction. Because it is a holistic and entirely anatomically based system, we have accorded significant weight to the Integral Theory's explanations of function and dysfunction.

The pelvic- floor function, dysfunction, and treatment.

Jörgen Quaghebeur PhD[a, b], Peter Petros MD, PhD[c], Jean-Jacques Wyndaele MD, PhD[b], Stefan De Wachter MD, PhD[a, b]

[a] Department of Urology, University of Antwerp, Edegem, Belgium

[b] Faculty of Medicine and Health Sciences, University of Antwerp, Edegem, Belgium

[c] Faculty of Medicine, University of New South Wales, Kensington, Sydney, Australia

Correspondence: Jörgen Quaghebeur, Department of Urology, Faculty of Medicine and Health Sciences, University of Antwerp, Wilrijkstraat 10, B 2650 Edegem, Belgium. Phone: +3238214699 Email: jorgen.quaghebeur@telenet.be

Abstract

The pelvic floor functions as a holistic entity. The organs, bladder, bowel, smooth and striated muscles, nerves, ligaments and other connective tissues are directed cortically and reflexly from various levels of the nervous system. Such holistic integration is essential for the system's multiple functions, for example, pelvic girdle stability, continence, voiding/defecation, and sexuality. Pelvic floor dysfunction (PFD) is related to a variety of pelvic pain syndromes and organ problems of continence and evacuation. Prior to treatment, it is necessary to understand which part(s) of the system may be causing the dysfunction (s) of Chronic Pelvic Pain Syndrome (CPPS), pelvic girdle pain, sexual problems, Lower Urinary Tract Symptoms (LUTS), dysfunctional voiding, constipation, prolapse and incontinence. The interpretation of pelvic floor biomechanics is complex and involves multiple theories. Non-surgical treatment of PFD requires correct diagnosis and correctly supervised pelvic floor training.

The aims of this review are to analyze pelvic function and dysfunction. Because it is a holistic and entirely anatomically based system, we have accorded significant weight to the Integral Theory's explanations of function and dysfunction.

Keywords: bladder pain syndrome, chronic pelvic pain syndrome, Integral Theory, irritable bowel syndrome, LUTS, overactive bladder, pain, pelvic floor.

Financial Disclaimers/Conflict of Interest statement

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

Authors' contribution to the manuscript

Dr Jörgen Quaghebeur researched data for the article and wrote the manuscript. Prof Jean-Jacques Wyndaele MD, Prof Peter Petros MD, and Prof Stefan De Wachter MD made substantial contributions to content discussions.

Abbreviations

A fibers -alpha nerve fibers are myelinated and carry information related to proprioception

ATFP: arcus tendineus fascia pelvis

BPS/IC: bladder pain syndrome

CGRP: calcitonin-gene related peptide

CL: cardinal ligament

C-nerve fibers are unmyelinated. They carry information related to pain, temperature and itch.

CPPS: chronic pelvic pain syndrome

EAS: external anal sphincter

EUL: external urethral ligament

IBS: irritable bowel syndrome

IT: Integral theory (IT)

LUTS: lower urinary tract symptoms

n: nerve

N: bladder stretch receptors

OAB: overactive bladder

PB: perineal body

PCF: pubocervical fascia

PF: pelvic floor

PFD: pelvic floor dysfunction

PFM: pelvic floor muscle(s)

PFS: posterior fornix syndrome

PUL: pubourethral ligament

RVF: rectovaginal fascia

USL: uterosacral ligaments

WDR: wide dynamic range

1. Introduction

The pelvic floor (PF) is a complex anatomic structure with neurologically directed muscular and fascial components and a specific biomechanical function. The PF is essential for pelvic girdle stability, continence, voiding, defecation, sexual function and delivery.

Pelvic floor dysfunctions (PFD) need a correct diagnosis and an adapted pelvic floor training, preferably supervised for best results. Our aim is to anatomically analyze integral PF function, dysfunction especially in relation to chronic pain.

2. Pelvic Floor: Complex anatomic structure and biomechanical function

The PF is generally classified into a urogenital diaphragm that is important for urinary continence. Suspensory ligaments and facias are essential for suspension of the pelvic organs, levator ani muscles (e.g. puborectalis, pubococcygeus, levator plate, iliococcygeus) for function plus two external sphincters which assist closure of the urethra and anorectum. The bulbocavernosus and bulbospongiosus muscles surround the vaginal entrance and allows it to be closed. They act as a vaginal sphincter and play an essential role in sexual functioning.

The PF consists of different anatomical structures: (e.g. endopelvic fascia, ligaments, perineal membrane, levator ani muscles, muscles of the urogenital diaphragm, superficial perineal muscles). The PF supports the pelvic organs. Damage to the structural and functional interactions of the PF elements can cause multi-compartmental dysfunction. The myofibroblasts in the fascia have contractile properties that regulate the tension of myofascial tissue [1]. The fascia has metabolic properties and humoral activity [2].

The fascia contains nerves (e.g. A, C fibers and WDR neurons) [2], micro-channels of the primo vascular system (PVS) [2, 3] and is essential for the plasticity (CGRP and substance P) of the nervous system [1]. A study, using transabdominal ultrasound, showed that men with CPPS

have a decreased PFM mobility which alters tension in the supporting ligaments resulting in chronic pain.

2.1 Integral theory (IT)

The Integral Theory explains the suspensory function (e.g. muscular, fascial, and ligament system) bladder/bowel closure and evacuation mechanisms of the pelvic floor. Laxity of the vaginal wall, the perineal body or suspensory ligaments as a result of altered connective tissue or trauma, can be the reason for prolapse and LUTS such as stress urinary incontinence, urgency, dysfunctional bladder and bowel emptying, and some forms of pelvic pain (e.g. vulvar pain, BPS/IC, pudendus pain) [4].

The optimal sphincter function of the urethra, vagina, bowel, and the support of the organs in the pelvis are determined mainly by pelvic floor muscle force contraction against suspensory ligaments. Pelvic muscle contraction supports the role of the suspensory ligaments to give the perineal bridge form and strength.

The ligamentous system related to the sphincter function of the urethra and anus can be classified in an anterior, middle, posterior zone and in three levels [4]. The first level involves the uterosacral ligaments (USL), arcus tendineus fascia pelvis (ATFP) and pubocervical fascia (PCF). The pubourethral ligaments (PUL) and rectovaginal fascia (RVF) configure the second level. The perineal body (PB), perineal membrane, post-anal plate, and external ligament of the urethra (EUL) are situated in the third level. Figure 1 shows the ligaments suspending the organs in the pelvis.

The broad ligament expands from the cervix to the medial internal aspect of the pelvic sidewall. The apex of the bladder connects via the urachus, a fibrous remnant of the allantois, with the umbilicus. In women, the cardinal ligaments connect the cervix uteri to the pelvic side wall at the obturator membrane 2cm above and forward of the ischial spine. When the suspensory ligaments are too loose, the muscle contraction has less effect, causing dysfunction of the

closure or opening function of the PF. Also, the muscular tone and the ratio between fast and slow-twitch muscular fibers play a role in the optimal functioning of the PF. Without ligament suspension, the pelvic organ function (e.g. continence, evacuation) is disturbed because of the limitation of activity and inability to contract optimally and continuously. Together with the muscles underneath, the fascia, and the ligaments above, the vagina forms a suspension bridge for the bladder and uterus [5]. All the ligament structures are attached to the vagina, cervix or uterus forming an anchor point for suspension and stability. Damage to the vaginal support structure affects the bladder and rectal function. The perineal body (PB) separates the lower part of the vagina from the rectum. If the rectovaginal fascia is torn from its PB attachment, a rectocele into the vagina occurs. If the PB becomes overstretched, or if its attachment behind the junction of the upper 2/3 and lower 1/3 of the descending ramus by the deep transversus perineal ligament are overstretched, say by pressure of the head during delivery, a perineocele and descending perineal syndrome might be the result.

The bulbospongiosus, superficial transverse perineal and anterior aspect of the external anal sphincter attach to the PB and additionally the internal/deep attachment of the PB to the levator ani muscles are all part of the suspension mechanism.

Hysterectomy must be avoided wherever possible because the uterus is a central anchoring point for many essential ligaments, necessary to maintain the structure and function of the PF. The decreased production of estrogen after the menopause also weakens the ligament support as it results in the leaching out of collagen from the ligaments. This explains the increased incidence of incontinence and prolapse after the menopause. Difficult labor, chronic constipation and straining are also possible causes for destruction of the support mechanism. The same goes after removal of the uterus, which disrupts the balanced structure in the pelvis. The ceased blood supply to the cardinal and uterosacral ligaments after hysterectomy causes atrophy and predisposes to prolapse and symptom development of the posterior zone [6]. The

posterior fornix syndrome (PFS), as described in the Integral Theory, is caused by laxity of the apical support provided by the uterosacral ligaments (USLs). Lax USLs manifests as 4 main grouped symptoms known as the posterior fornix syndrome: CPP, urge, frequency, nocturia, abnormal emptying with often, raised post-void residual. The Bornstein test: local anesthetic injected into the USLs at 4 and 8 o'clock just behind the cervix is a definitive test for CPP caused by USL laxity. The speculum test inserts the lower blade of a bivalve speculum gently into the vagina. It mechanically supports loose USLs. In 70% of the time, it diminishes urge and pain due to uterosacral ligament laxity. As such it is a predictive test for success of surgery which seeks to reinforce the USLs, either by plication of by a posterior sling [7, 8]. Surgical uterosacral ligament repair has been suggested for CPP associated with loose suspensory ligaments and showed an essential improvement of the pain, LUTS, and also fecal incontinence [7, 9].

2.2 The pelvic floor muscle function

The pelvic muscles' dual function mainly consists of organ support, closure of the urethra and the anorectum based on muscle tone and contraction under subconscious control and voluntary opening of the sphincters, e.g. miction, making stool, and sexual function. The PF is also essential for voluntarily control of the sphincter postponement of miction during full bladder sensation and urgency. The anterior portion of the pubococcygeus muscle (PCM), the levator plate (LP), and the conjoint longitudinal muscle of the anus (LMA), compose three directional muscle forces that activate the urethral and anal canal closure and help to retain the position of the organs. Closure of the urethra is mainly determined by backward/downward muscle vector forces that stretch the proximal urethra around the pubourethral ligament [10]. Distal urethral closure of the urethra is provoked by anterior vector stretches that pull the suburethral hammock forward against the pubourethral ligament and pubis. The LP and LMA open out the urethra during micturition when PCM relaxes and the anal canal during defecation when PRM

(puborectalis muscle) relaxes. Opening out the urethra and anorectum by these posterior vectors exponentially reduces the internal resistance to evacuation by the bladder and rectum. If the uterosacral ligaments are loose, the contractile opening force is reduced and the bladder and bowel have to contact against an unopened urethra or anus. This is perceived by the patient as "obstructed" micturition or defecation("constipation") which, of course, it is! The puborectalis muscle can work independently of the three directional muscle forces. The external urethral and anal sphincters reinforce the urethra and anus closure. Figure 2 shows the muscles of the pelvic floor sphincter mechanisms.

The Integral Theory describes four directional striated muscles vectors [11]. The pubococcygeus (PCM), and puborectalis (PRM) muscles act in an anterior direction. The PCM is attached to the distal vagina and contracts forwards against the pubourethral ligament (PUL). The PRM contracts only against symphysis pubis. The levator plate (LP) and conjoint longitudinal muscle of the anus (LMA) or longitudinal muscle or the rectum are two posterior vectors. The LP is attached to the posterior wall of the rectum, and contracts backwards against the PUL anteriorly and USL posteriorly. The LMA inserts into the anterior portion of LP proximally and the external anal sphincter distally. The LMA contracts solely downwards against USLs.

The forwards, backwards, and downwards vectors are opposite directional forces that determine three main functions [11]. They provide the shape and influence the strength of the organs [10]. They act as continence and evacuation mechanisms controlling the micturition and defecation. They stretch vagina like the membrane of a drum to support the bladder stretch receptors 'N' from below, preventing the afferent impulses which activate the micturition reflex. They also provide tension to the USLs to support the nerve ganglia in the uterosacral ligaments.

During the storage phase, the bladder is in resting closed mode. Urethral closure is maintained by vaginal elasticity, urethral elasticity/smooth muscle, and slow-twitch striated muscle

contractions against the PUL. The ligaments anchor the urethra, distal vagina and rectum and the USL is angulated downwards. Fast-twitch forces acting against the PUL close the urethra during effort and stretch the distal vagina forwards. The proximal urethra, proximal vagina and rectum are stretched and rotated by backwards/downward vectors contracting against the PUL and USL. The bladder makes a rotational movement closing the bladder neck. During micturition, the forward force relaxes. With this, the posterior wall of the urethra is pulled backwards, and the bladder contracts to void.

In resting mode, the anorectal closure is maintained by slow-twitch muscle contraction of the PRM and organ elasticity/smooth muscle tension. During effort, straining or coughing closure is safeguarded by three fast-twitch muscle directional forces. The USLs are attached to the lateral walls of the rectum and are essential for anorectal closure. Before the LMA contraction, the LP stretches the rectum posteriorly against the PUL and keeps it tense. LMA contracts against USL and pulls the anterior part of LP downwards. This action rotates the rectum around the contracted puborectalis (PRM) forming the anorectal angle to close it [12]. The closure mechanism may be lost when the PUL or USL are loose. Defecation is an active process that is activated by three fast-twitch directional forces [12]. During defecation, the PRM relaxes, while the LP and LMA open the anorectal angle, and the rectum to evacuate the stool. LP/LMA stretch the anal wall posteriorly; PCM stretches the anal wall anteriorly; these actions open out the anorectum and the anorectal angle to facilitate emptying. The USLs are attached to the lateral walls of the rectum and the downward vector contracts directly against the USLs during defecation. When the USLs are loose, the contractile strength of a striated muscle potentially decreases, resulting in an obstructive defecation syndrome (ODS), and constipation [11].

The concomitant ligament and muscular functional unit is the mechanical component of the pelvic floor function. The pelvic floor is innervated by afferent and efferent nerves, visceral and somatic, that also supply the bladder, vagina, bowel, striated, and non-striated muscles. Organ

afferents transport sensory information to centers in the brain and brainstem that regulate the activity of the viscera, and the coordination with sphincters and pelvic floor muscle tone. In a normal situation, this process of coordination happens automatically without voluntary control. Disturbed proprioceptive stimuli because of ligament laxity or increased muscle tone, may cause LUTS (e.g. urgency, frequency, nocturia) caused by the continuous triggering of the micturition reflex by uncontrolled afferents impulses from the stretch receptors [13]. Overactivity of the stretch receptors in the bladder base and fascia provokes a premature stimulation of the micturition reflex, with detrusor overactivity, bowel symptoms, or sustained pelvic pain consequently.

Bergström' s urethral hanging theory* [14] accepts the IT's role for the PUL, but rejects the closure role for the 3 directional muscles. Instead he accepts Enhörning's theory of urethral closure by intraabdominal forces which has been disproved at many levels.

*Really a hypothesis. Bergström has never presented any experimental evidence to support his statements.

The contradictory interpretations of the sphincter function of the PF-unit, the related pain mechanism, and the implication for the treatment and surgical approach remain a challenge to understand the biomechanics related to PFD.

3. The pelvic floor and pelvic girdle stability

The PF plays a role in pelvic girdle stability. A disturbed PF function can play an essential role in pelvic girdle instability and pain [15]. The PF works as a synergist with other muscles related to the pelvic girdle and is part of the trunk stability mechanism [16].

4. Pelvic Floor: Essential for continence and voiding/defecation

PFM thickness (MRI evaluation) can be a prognostic test for stress or mixed UI [17]. Patients (77.2%) who presented with urinary, gastro or sexual complaints have measurable PF

dysfunction. However, to define the difference between a regular and elevated resting tone of the PF needs more study [18]. PFM training is essential for the restoration of urethral urinary incontinence [19].

5. Pelvic floor: Essential for sexual function and delivery

Definitions, terminology and PF, are available for sexual function in men [20], and women [21]. Pelvic floor dysfunctions are associated with delivery. Fear of perineal pain should not discourage women from starting PFM training shortly after childbirth [22]. PF exercise and perineal massage may prevent episiotomies and tears in primiparous women [23].

6. Pelvic floor terminology and assessment

The ICS standardization describes PF dysfunction based on symptoms, signs and circumstances [24]. The International Urogynecological Association (IUGA)/International Continence Society (ICS) reports describe the comprehensive terminology for PF management and for the assessment of the sexual health in women with PFD [25].

PFM assessment involves an evaluation of the PFM function, tone, pain, injury [20]. Table 1 summarizes the different aspects for evaluation of PF function [20].

Patients with PFD may present with pelvic organ prolapse, bladder/bowel problems or perineal pain. For the assessment of PFM hyperalgesia related to chronic pelvic pain (CPP), a digital pelvic examination can be done using the PFM hyperalgesia scoring system to rate severity of pain/discomfort as none (grade 0), mild (grade I), moderate (grade II) or severe (grade III). This scoring system is a reliable, valid and easy screening tool assessing women with CPP. Pelvic floor contraction is assessed with digital evaluation using the Oxford scale.

Relaxation problems of the PF can be related to voluntary or not voluntary control, and overactive PFM is often accompanied by bladder or functional bowel dysfunction.

The relation between muscle overactivity and pain is poorly understood. Nerves and blood vessels that go through overactive muscles can be compressed. Tonic muscle contractions also accumulate metabolites (e.g. lactic acid, potassium, etc.). Ischemia occurs, acidosis increases pain by giving increased afferent signals from the PF to the central nervous system, disturbing motor innervation, provoking further deterioration of the muscular function of the PF [26]. Repeated or chronic overload of muscles can activate trigger points. These pain points are hypersensitive areas that are painful with compression, touch, or in certain positions or movements. Trigger points can be found during the physical assessment, and the pain can be demonstrated with gentle palpation. A systematic review showed that the levator ani m. and the internal obturator m. are often involved [27]. Another study showed a prevalence of 85% myofascial trigger points in patients with urological, colorectal, and gynecological CPP [28]. High tone PFD and the associated myofascial trigger points may be a primary generator of CPPS [28]. Recently, high-density surface electromyography has been suggested for evaluation of PFM tone in patients with BPS/IC [29]. PFD can be related to many symptoms and signs, e.g. pain, incontinence, LUTS, bowel, prolapse or sexual dysfunction, and needs extensive assessment [30]. For PFD evaluation in women, the Pelvic Floor Distress Inventory-20 and Pelvic Floor Impact Questionnaire-7 can be used to assess emotional factors and consequences related to PFD.

7. Bladder pain syndrome and pelvic floor dysfunction

In patients with chronic pelvic pain, trigger points can often be found in synergic pelvic floor muscles such as the gluteal and piriformis muscles. Several studies showed the existence of myofascial pain and trigger points in patients with BPS/IC [31, 32]. In 30% of cases with BPS/IC, an association with PFDs was found associated [33]. Peters et al. showed levator ani pain with PFD in 87% of patients with BPS/IC [34]. In this study, (n=70 women) 50% reported IBS and 36% urgency urinary incontinence. In women with BPS/IC, 85% have PFD and PF

hypertonicity [29]. Pelvic floor dysfunction in children can result in dysfunctional voiding, constipation, pain, and prevalence of hypertonic PFD is mostly found [35].

8. Non-surgical treatment of pelvic floor dysfunction (PFD)

Non-surgical treatment of PFD mainly consists of manual approach, stimulation or relaxation techniques. Biofeedback with EMG or pressure electrodes can help the patient, to understand the execution of activity or relaxation during exercises [36]. Trigger points can be treated with local massage and stretching of the PFM [37]. Using post isometric contraction techniques might help to give better stretching abilities of muscles. An injection with a local anesthetic can decrease the pain, making it possible to do exercises [38]. Several studies showed the benefit of pelvic floor muscle therapy in decreasing the symptoms [39-41].

Manipulation of the sacroiliac joint helps to restore normal tension to the PFM. A pilot study in BPS/IC patients with hypertonic PFD (n=16) showed sacroiliac dysfunctions in all. A significant improvement (94%) in irritative voiding symptoms and dyspareunia has been found as a result of manual therapy, myofascial massage, and muscle energy techniques, along with a home exercise program that included stretch and strengthening exercises [42, 43]. Systematic reviews showed that osteopathic manipulative therapy could be beneficial in treating patients with PFD related syndromes (e.g. pelvic girdle pain related to pregnancy, IBS, CP/CPPS, LUTS, postvasectomy pain syndrome, or primary dysmenorrhea) [44-49].

Biofeedback offers patients with PFD the possibility to control their exercises by visual and or auditive signaling. Lack of proprioception can be improved using biofeedback techniques and can be a help when the contraction and relaxation execution is a problem. For patients with CPPS and hypertonic PFD, it is helpful to learn how to relax the PFM when the pain starts, and in so doing decrease the vicious circle of pain-hypertonia-pain. Biofeedback is commonly applied in patients with CPPS and urologic or proctologic dysfunction for PF relaxation, and to

increase proprioceptive functioning. Digital controlled exercises best support biofeedback applications, and a home training program to obtain a relaxation of the PF. A home training program to decrease the resting tone might be necessary, and can be done with a disposable biofeedback tool. Biofeedback treatment showed good results in treating chronic anal pain syndrome [50]. In dyssynergic defecation, the ability to expel a 50 mL water-filled balloon and to relax pelvic floor muscles after biofeedback treatment were predictive of a favorable therapeutic outcome, and the balloon technique is often used in proctologic dysfunctions to train evacuation of stool, avoiding concomitant contractions or tension in other muscles [50]. Electrostimulation techniques can be used to strengthen weak PFM and improve proprioception.

The Skilling squatting-based exercises are based on the IT. They strengthen the 3 reflex muscle forces and ligaments they contract against, PUL and USL. More than 50% symptom improvement in 70-90% of premenopausal women has been recorded for SUI, urge, frequency, nocturia, CPP, emptying problems and urinary retention [51].

Surgical treatments

There are literally hundreds of surgical operations for treatment of SUI and prolapse. Operations based on the Integral System work by shortening and reinforcing damaged ligaments: for SUI, pubourethral sling, 10,000,000 operations since 1996 [52]; for PFS symptoms, urge, frequency, nocturia, abnormal emptying, CPP, USL repair [53] initially, by native USL plication in women with minimal prolapse [53]. Later it was found native tissue plication only worked well in premenopausal women and that post-menopausal women needed a posterior sling for longer-term success. Inoue [54], using cardinal/USL TFS slings, reported minimal fall in cure rates at 5 years post-operatively: prolapse from 91% to 79%, SUI 94% to 82%, urge 97% to 92%, nocturia 95% to 58%.

References

1. Schleip R, Gabbiani G, Wilke J, et al. Fascia is able to actively contract and thereby influence musculoskeletal dynamics: a histochemical and mechanographic investigation. Front Physiol. 2019;10:336.
2. Avila Gonzalez CA, Driscoll M, Schleip R, et al. Frontiers in fascia research. J Bodyw MovTher. 2018;22(4):873-80.
3. Chikly B, Roberts P, Quaghebeur J. Primo Vascular System: a unique biological system shifting a medical paradigm. J Am Osteopath Assoc. 2016;116(1):12-21.
4. Petros P. The integral system. Cent European J Urol. 2011;64(3):110-9.
5. Petros PE, Ulmsten U. Role of the pelvic floor in bladder neck opening and closure II: vagina. Int Urogynecol J Pelvic Floor Dysfunct. 1997;8(2):69-73.
6. Petros P. Influence of hysterectomy on pelvic-floor dysfunction. Lancet. 2000;356(9237):1275.
7. Sekiguchi Y, Inoue H, Liedl B, et al. Is Chronic Pelvic Pain in the female surgically curable by uterosacral/cardinal ligament repair? Pelviperineol. 2017;36:74-8.
8. Zarfati D, Petros PP. The Bornstein Test- a local anaesthetic technique for testing uterosacral nerve plexus origins of chronic pelvic pain. Pelviperineol. 2017;36:89-91.
9. Petros P, Abendstein B. Pathways to causation and surgical cure of chronic pelvic pain of unknown origin, bladder and bowel dysfunction - an anatomical analysis. Cent European J Urol. 2018;71(4):448-52.
10. Petros PE, Ulmsten U. Role of the pelvic floor in bladder neck opening and closure I: muscle forces. Int Urogynecol J Pelvic Floor Dysfunct. 1997;8(2):74-80.
11. Sekiguchi Y, Inoue H, Nakamura R. A practical update on functional and dysfunctional anatomy of the female pelvic floor - Part 1 Function. Pelviperineol. 2019;38(1):16-20.
12. Petros PE, Bush MB. The same posterior muscle vectors act to open urethra and anus during micturition and defecation. Pelviperineol. 2017;36:35-6.
13. Petros PE. Detrusor instability and low compliance may represent different levels of disturbance in peripheral feedback control of the micturition reflex. Neurourol Urodyn. 1999;18(2):81-91.
14. Bergström BS. The urethral hanging theory and how it relates to Enhörning's theory and the integral theory. Int Urogynecol J. 2020;31(6):1175-80.
15. Stuge B, Morkved S, Dahl HH, Vollestad N. Abdominal and pelvic floor muscle function in women with and without long lasting pelvic girdle pain. Man Ther. 2006;11(4):287-96.
16. Asavasopon S, Rana M, Kirages DJ, et al. Cortical activation associated with muscle synergies of the human male pelvic floor. J Neurosci. 2014;34(41):13811-8.
17. Yasar L, Telci SO, Dogan K, Kaya E, Ekin M. Predictive role of measurement of pelvic floor muscle thickness with static MRI in stress and mixed urinary incontinence. Int Urogynecol J. 2019;30(2):271-7.
18. Voorham-van der Zalm PJ, Lycklama ANGA, Elzevier HW, Putter H, Pelger RCM. "Diagnostic investigation of the pelvic floor": a helpful tool in the approach in patients with complaints of micturition, defecation, and/or sexual dysfunction. J Sex Med. 2008;5(4):864-71.
19. Dumoulin C, Hay-Smith J, Habee-Seguin GM, Mercier J. Pelvic floor muscle training versus no treatment, or inactive control treatments, for urinary incontinence in women: a short version Cochrane systematic review with meta-analysis. Neurourol Urodyn. 2015;34(4):300-8.
20. D'Ancona C, Haylen B, Oelke M, et al. The International Continence Society (ICS) report on the terminology for adult male lower urinary tract and pelvic floor symptoms and dysfunction. Neurourol Urodyn. 2019;38(2):433-77.

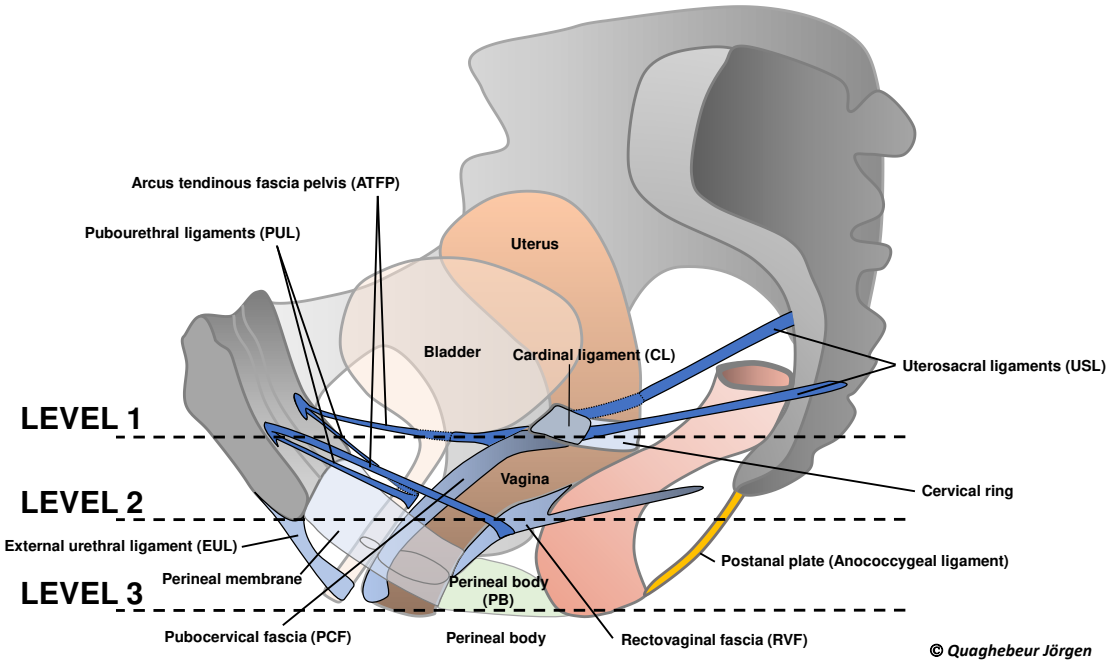
21. Billecocq S, Bo K, Dumoulin C, et al. [An International Urogynecological Association (IUGA)/International Continence Society (ICS) joint report on the terminology for the conservative and non-pharmacological management of female pelvic floor dysfunction]. Prog Urol. 2019;29(4):183-208.
22. Neels H, De Wachter S, Wyndaele JJ, Wyndaele M, Vermandel A. Does pelvic floor muscle contraction early after delivery cause perineal pain in postpartum women? Eur J Obstet Gynecol Reprod Biol. 2017;208:1-5.
23. Leon-Larios F, Corrales-Gutierrez I, Casado-Mejia R, Suarez-Serrano C. Influence of a pelvic floor training programme to prevent perineal trauma: A quasi-randomised controlled trial. Midwifery. 2017;50:72-7.
24. Messelink B, Benson T, Berghmans B, et al. Standardization of terminology of pelvic floor muscle function and dysfunction: report from the pelvic floor clinical assessment group of the International Continence Society. Neurourol Urodyn. 2005;24(4):374-80.
25. Bo K, Frawley HC, Haylen BT, et al. An International Urogynecological Association (IUGA)/International Continence Society (ICS) joint report on the terminology for the conservative and nonpharmacological management of female pelvic floor dysfunction. Int Urogynecol J. 2017;28(2):191-213.
26. Zermann DH, Ishigooka M, Doggweiler R, Schmidt RA. Neurourological insights into the etiology of genitourinary pain in men. J Urol. 1999;161(3):903-8.
27. Meister MR, Shivakumar N, Sutcliffe S, Spitznagle T, Lowder JL. Physical examination techniques for the assessment of pelvic floor myofascial pain: a systematic review. Am J Obstet Gynecol. 2018;219(5):497 e1- e13.
28. Moldwin RM, Fariello JY. Myofascial trigger points of the pelvic floor: associations with urological pain syndromes and treatment strategies including injection therapy. Curr Urol Rep. 2013;14(5):409-17.
29. Dias N, Zhang C, Spitznagle T, Lai HH, Zhang Y. High-Density Surface Electromyography Assessment of Pelvic Floor Dysfunction in Women with Interstitial Cystitis/Bladder Pain Syndrome. J Urol. 2020;204(6):1275-83.
30. Quaghebeur J, Wyndaele JJ. Chronic pelvic pain syndrome: Role of a thorough clinical assessment. Scand J Urol. 2015;49(2):81-9.
31. Gupta P, Gaines N, Sirls LT, Peters KM. A multidisciplinary approach to the evaluation and management of interstitial cystitis/bladder pain syndrome: an ideal model of care. Transl Androl Urol. 2015;4(6):611-9.
32. Bassaly R, Tidwell N, Bertolino S, Hoyte L, Downes K, Hart S. Myofascial pain and pelvic floor dysfunction in patients with interstitial cystitis. Int Urogynecol J. 2011;22(4):413-8.
33. Cervigni M, Natale F. Pelvic floor dysfunction in bladder pain syndrome. In: Nordling J, Wyndaele JJ, van de Merwe JP, Bouchelouche P, Cervigni M, Fall M, editors. Bladder pain syndrome A Guide for clinicians. New York: Springer; 2013. p. 128-9.
34. Peters KM, Carrico DJ, Kalinowski SE, Ibrahim IA, Diokno AC. Prevalence of pelvic floor dysfunction in patients with interstitial cystitis. Urol. 2007;70(1):16-8.
35. De Paepe H, Renson C, Van Laecke E, Raes A, Vande Walle J, Hoebeke P. Pelvic-floor therapy and toilet training in young children with dysfunctional voiding and obstipation. BJU Int. 2000;85(7):889-93.
36. Glazer HI, Rodke G, Swencionis C, Hertz R, Young AW. Treatment of vulvar vestibulitis syndrome with electromyographic biofeedback of pelvic floor musculature. J Reprod Med. 1995;40(4):283-90.
37. Anderson RU, Wise D, Sawyer T, Chan C. Integration of myofascial trigger point release and paradoxical relaxation training treatment of chronic pelvic pain in men. J Urol. 2005;174(1):155-60.

38. Bartley J, Han E, Gupta P, et al. Transvaginal Trigger Point Injections Improve Pain Scores in Women with Pelvic Floor Hypertonicity and Pelvic Pain Conditions. Female Pelvic Med Reconstr Surg. 2019;25(5).
39. Han E, Nguyen L, Sirls L, Peters K. Current best practice management of interstitial cystitis/bladder pain syndrome. Ther Adv Urol. 2018;10(7):197-211.
40. Bedaiwy MA, Patterson B, Mahajan S. Prevalence of myofascial chronic pelvic pain and the effectiveness of pelvic floor physical therapy. J Reprod Med. 2013;58(11-12):504-10.
41. FitzGerald MP, Payne CK, Lukacz ES, et al. Randomized multicenter clinical trial of myofascial physical therapy in women with interstitial cystitis/painful bladder syndrome and pelvic floor tenderness. J Urol. 2012;187(6):2113-8.
42. Lukban J, Whitmore K, Kellogg-Spadt S, Bologna R, Lesher A, Fletcher E. The effect of manual physical therapy in patients diagnosed with interstitial cystitis, high-tone pelvic floor dysfunction, and sacroiliac dysfunction. Urol. 2001;57(6 Suppl 1):121-2.
43. Lukban JC, Parkin JV, Holzberg AS, Caraballo R, Kellogg-Spadt S, Whitmore KE. Interstitial cystitis and pelvic floor dysfunction: a comprehensive review. Pain Med. 2001;2(1):60-71.
44. Muller A, Franke H, Resch KL, Fryer G. Effectiveness of osteopathic manipulative therapy for managing symptoms of irritable bowel syndrome: a systematic review. J Am Osteopath Assoc. 2014;114(6):470-9.
45. Franke H, Franke JD, Belz S, Fryer G. Osteopathic manipulative treatment for low back and pelvic girdle pain during and after pregnancy: A systematic review and meta-analysis. J Bodyw MovTher. 2017;21(4):752-62.
46. Franke H, Hoesele K. Osteopathic manipulative treatment (OMT) for lower urinary tract symptoms (LUTS) in women. J Bodyw MovTher. 2013;17(1):11-8.
47. Schwerla F, Wirthwein P, Rütz M, Resch KL. Osteopathic treatment in patients with primary dysmenorrhoea: A randomised controlled trial. Int J Osteopath Med. 2014;17(4):222-31.
48. Marx S, Cimniak U, Beckert R, Schwerla F, Resch KL. [Chronic prostatitis/chronic pelvic pain syndrome. Influence of osteopathic treatment - a randomized controlled study]. Urologe A. 2009;48(11):1339-45.
49. Gray RE, Kasper K. Osteopathic manipulative treatment as a novel way to manage postvasectomy pain syndrome. J Am Osteopath Assoc. 2019;119(4):263-7.
50. Qin Z, Wu J, Zhou J, Liu Z. Systematic Review of Acupuncture for Chronic Prostatitis/Chronic Pelvic Pain Syndrome. Med (Baltimore). 2016;95(11):e3095.
51. Skilling PM, Petros P. Synergistic non-surgical management of pelvic floor dysfunction: second report. Int Urogynecol J Pelvic Floor Dysfunct. 2004;15(2):106-10; discussion 10.
52. Ulmsten U, Petros P. Intravaginal slingplasty (IVS): an ambulatory surgical procedure for treatment of female urinary incontinence. Scand J Urol Nephrol. 1995;29(1):75-82.
53. Petros PE, Ulmsten U. The posterior fornix syndrome: A multiple symptom complex of pelvic pain and abnormal urinary symptoms deriving from laxity in the posterior fornix. Scand J Urol Nephrol. 1993;27(153):89-93.
54. Inoue H, Sekiguchi Y, Kohata Y, et al. Tissue fixation system (TFS) to repair uterovaginal prolapse with uterine preservation: a preliminary report on perioperative complications and safety. J Obstet Gynaecol Res. 2009;35(2):346-53.

Table 1: Evaluation of the pelvic floor function

Evaluation of the pelvic floor function
PFM muscle function
Perineal examination
Limited downward movement during coughing or bear down
Perineal elevation
Inward (ventro-cephalad) movement of the perineum
Perineal descent
Outward (dorso-caudal) movement of the perineum
PFM state at rest
Myalgia (Provoked by palpation)
Tender points (Tenderness to palpation of soft tissues)
Tone (Resting tension determined by resistance to passive movement)
Increased PFM tone (non-neurologic hypertonicity)
Decreased PFM tone (non-neurologic hypotonicity)
Symmetry
Different feel at the upper side of the PF?
PFM injury
Is there a sphincter gap?
PFM contractile function
Voluntary contractility
Strength
Endurance
Repeatability
Co-contraction
Relaxation ability
PFM response to increased intra-abdominal pressure
For example: Strain/Valsalva/cough aspects to assess
Direction of contraction
Elevation
Descent
Diagnoses related to PFM examinations
Overactive PFM
PFM which do not relax or contract when relaxation is needed during:
Voiding
Defaecation
Underactive PFM
PFM which cannot voluntarily contract when required

Ligaments suspending the organs in pelvis

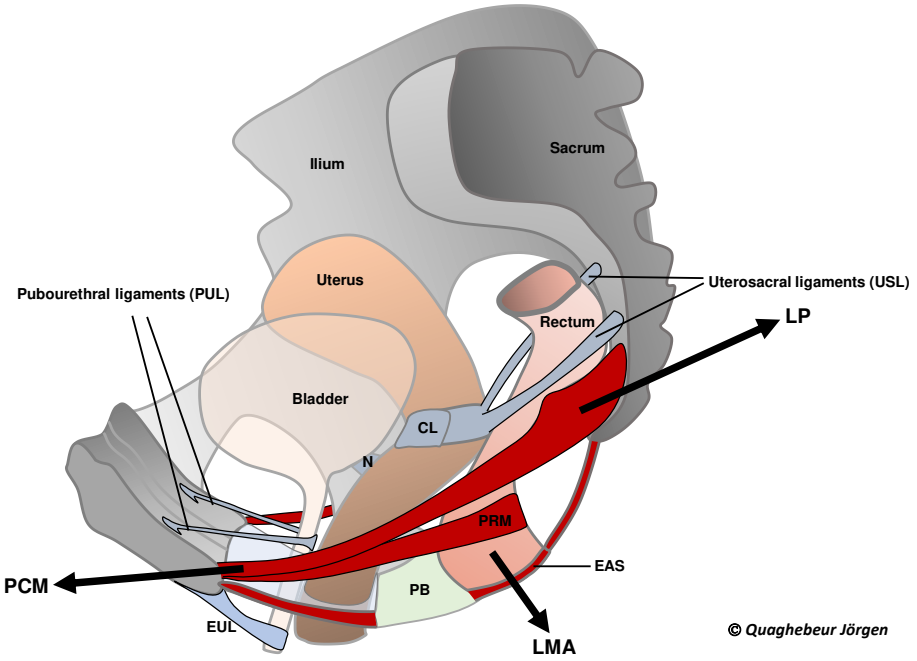


ATFP, arcus tendineus fascia pelvis; CL, cardinal ligament; EUL, external urethral ligament; PB, perineal body; PCF, pubocervical fascia; PUL, pubourethral ligament; RVF, rectovaginal fascia; USL, uterosacral ligament.

Adapted from: Petros P. The integral system. Cent European J Urol. 2011;64(3):110-9..

Figure 1: Ligaments which suspend the pelvic organs

Pelvic floor muscles and ligaments



CL, cardinal ligament; EAS, external anal sphincter; EUL, external urethral ligament; LMA, longitudinal muscle anus; N, bladder stretch receptors; PB, perineal body; PUL, pubourethral ligaments; USL, uterosacral ligaments.

Forward acting muscles: m. pubococcygeus (PCM), m. puborectalis (PRM). The PCM contracts against the pubourethral ligament (PUL). The PRM contracts only against symphysis pubis. Backwards acting muscles: levator plate (LP) contracts backwards against PUL anteriorly. The LMA contracts solely downwards against USLs.

Faecal continence is maintained by the LP/LMA vectors that stretch and rotate the rectum around a contracted PRM forming an anorectal angle. During defaecation, the PRM relaxes, and the LP/LMA contract to open out the anorectal angle and the rectum contracts to empty.

Adapted from: Sekiguchi Y, Inoue H, Nakamura R. A practical update on functional and dysfunctional anatomy of the female pelvic floor - Part 1 Function. Pelviperineol. 2019;38(1):16-20.

Figure 1: Pelvic floor muscles and ligaments related to continence and evacuation

The authors are:

- Dr. Jörgen Quaghebeur, PhD. Med. Sci.
- Prof. Dr. Peter Petros M.D.
- Prof. Dr. Jean-Jacques Wyndaele M.D.
- Prof. Dr. Stefan De Wachter M.D.

Competing interests statement.
The authors declare no competing interests.