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Reconsideration of pelvic floor muscle training to prevent and treat incontinence after radical prostatectomy

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Abstract

Urinary incontinence is common after radical prostatectomy. Pelvic floor muscle training provides a plausible solution. Although early trials provided promising results, systematic reviews have questioned the efficacy of this intervention. A major consideration is that most clinical trials in men have applied principles developed for pelvic floor muscle training for stress urinary incontinence in women, despite differences in anatomy between sexes and differences in the mechanisms for continence/incontinence. Literature regarding continence control in men has been conflicting and often based on erroneous anatomy. New understanding of continence mechanisms in men, including the complex contribution of multiple layers of striated pelvic floor muscles, and detailed consideration of the impact of radical prostatectomy on continence anatomy and physiology, have provided foundations for a new approach to pelvic floor muscle training to prevent and treat incontinence after prostatectomy. An approach to training can be designed to target the pathophysiology of incontinence. This approach relies on principles of motor learning and exercise physiology, in a manner that is tailored to the individual patient. The aims of this review are to consider new understanding of continence control in men, the mechanisms for incontinence after radical prostatectomy, and to review the characteristics of a pelvic floor muscle training program designed to specifically target recovery of continence after prostatectomy. © 2019 Elsevier Inc. All rights reserved.

Keywords: Pelvic floor muscle training; Radical prostatectomy; Incontinence; Conservative management; Striated urethral sphincter

1. Introduction

Prostate cancer is the most common noncutaneous cancer in men (1 in 7) and the second most common cause of cancer death [1]. Radical prostatectomy (RP) is a common curative treatment to prevent metastasis. Although mortality after RP is low (5-year survival—95% [1]), morbidity is high. Depending on how continence is defined, almost 80% of men experience incontinence after RP [2−4], and many are incontinent beyond 12 months [2]. This has a major impact on quality of life [5,6]. Robotic RP has not reduced incontinence rates [7]. On the basis of success of pelvic floor muscle training (PFMT) in female stress urinary incontinence

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[8], PFMT has been implemented in men undergoing RP. Although early outcomes were optimistic [9], and some clinical trials have provided positive outcomes [10,11], meta-analysis of the available studies in recent systematic reviews show evidence of no efficacy [12]. Many trials have applied principles developed for stress incontinence in women, to men [13,14]. Yet the mechanisms for incontinence are different; in women the common mechanism is levator ani muscles dysfunction secondary to pregnancy and vaginal birth [15], whereas in men after RP, it is primarily related to removal of prostatic urethra with its associated smooth muscle, and potential damage to the striated urethral sphincter [16]. Further, mechanisms for urinary continence differ in some respects between sexes [17]. It is plausible to speculate that translation of treatment from women to men may not be ideal. This review aims to consider a new understanding of continence in men, mechanisms for incontinence after RP, and consider characteristics of PFMT designed to specifically target recovery of continence after RP.

2. New understanding of continence control in men

The concept is simple—urinary continence requires the pressure in the urethra to exceed that in the bladder, but the solution is complex and incompletely understood. Urethral pressure in men is controlled by multiple mechanisms that include: circumferential smooth muscle of urethra/bladder neck (internal urethral sphincter/lissosphincter) that is thickest proximally near the bladder, controlled by the autonomic nervous system [18], and is responsible for tonic pressure to maintain continence; striated/skeletal pelvic floor muscles that are controlled by reflex and descending inputs to contribute to continence [19] and can be activated voluntarily; and coaptation of mucosal walls plus the urethral vasculature [20].

Anatomy and function of the striated muscles has been confusing. Although often depicted as a sheet-like muscular "urogenital diaphragm" [21], there are in fact multiple muscles that interact to constrict the urethra, and none fitting that description. The striated urethral sphincter (rhabdosphincter/external urethral sphincter) lies at the inferior end of the prostate and generates the greatest urethral pressure of the striated muscles. It is omega shaped on the anterior and lateral sides of the urethra, attaching posteriorly to the posterior median raphe [18] and perineal body [17], and on contraction draws the urethra posteriorly [18,22] against the plate formed by the perineal body and Denonvilliers' fascia (rectogenital septum) that forms an incomplete partition between the rectum and urogenital organs [23] (Fig. 1). The muscle is thickest distally where it surrounds the membranous urethra and continues proximally with increasingly sparse muscle fibres on the external surface of the prostate [17,18,24]. It is innervated by branches of the pudendal [24,25] and cavernous nerves [26]. Although, commonly excluded from descriptions of continence control in men, the levator ani and bulbocavernosus (bulbospongiosus) also constrict the urethra. The levator ani has 3 main parts:

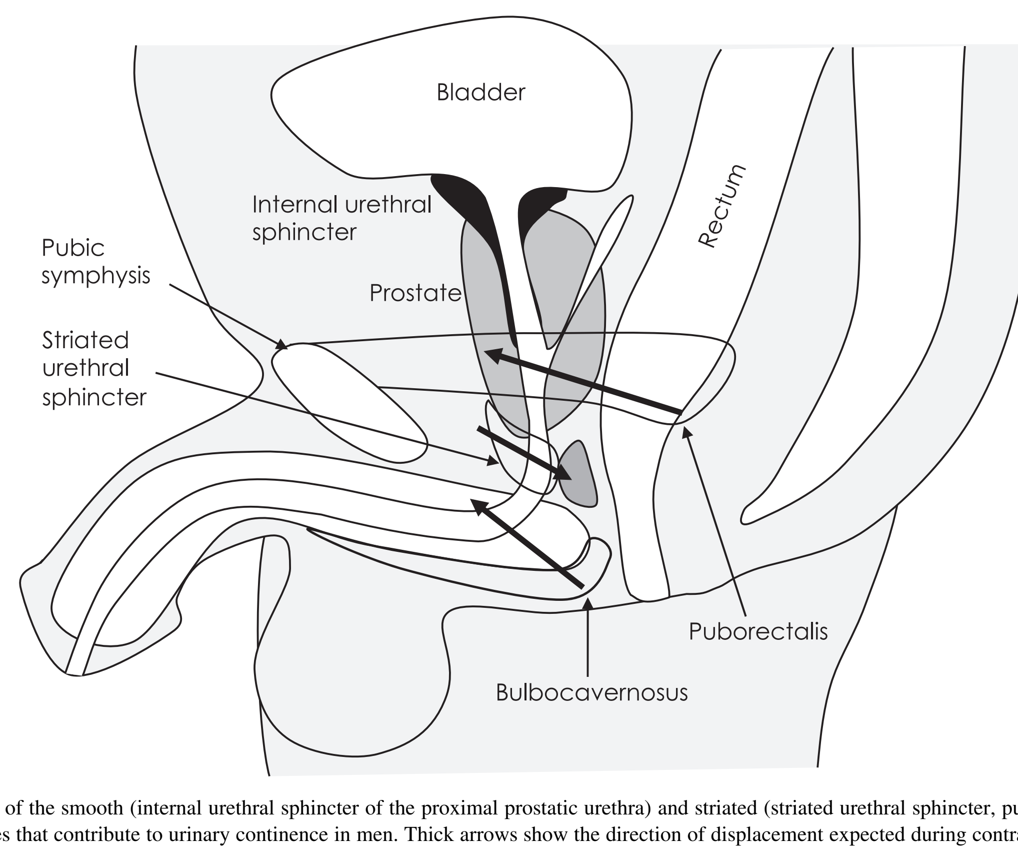

Fig. 1. Anatomy of the smooth (internal urethral sphincter of the proximal prostatic urethra) and striated (striated urethral sphincter, puborectalis, bulbocavernosus) muscles that contribute to urinary continence in men. Thick arrows show the direction of displacement expected during contraction of each of the striated muscles.

puborectalis—from the pubic rami and looping behind the rectum, with attachment of its inferior fibres to the posterolateral aspect of the perineal body [17] where it sandwiches the striated urethral sphincter [26]; pubovisceralis—includes external and internal layers extending posteriorly and superiorly from the pubic bone, tendinous arch, and ischial spine down towards the rectococcygeal muscle posteriorly and puborectalis inferiorly [17], and iliococcygeus—from the obturator fascia (between the obturator canal and ischial spine) to the anococcygeal ligament and coccyx [27]. Bulbocavernosus extends to the perineal body superiorly and cups the penile bulb inferiorly [17]. The ischiocavernosus muscle courses from the ischial ramus to the crus penis and contributes to maintenance of erection by compressing the veins of the crus [28].

Puborectalis moves the anorectal junction (ARJ) and urethrovesical junction forwards and upwards to compress the urethra against the pubic symphysis [22]. It may also support and elevate the urethra via its attachments to striated urethral sphincter [29], although the nature of the attachment between the muscles might not support this assumption [26]. Bulbocavernosus compresses the bulb of penis to constrict the urethra distal to the striated urethral sphincter, and in the opposite direction to striated urethral sphincter (i.e., dorsal-to-ventral) [22], to assist continence. Bulbocavernosus is also involved in ejaculation [30] and "milking" the urethra to remove residual urine after micturition [31]. The external anal sphincter constricts the anus to support the smooth muscle internal sphincter [32] with no role in urethral constriction. The urinary continence equation is also impacted by bladder pressure which is increased by detrusor (smooth muscle) contraction and/or increased intra-abdominal pressure (IAP) induced by contraction of the abdominal and diaphragm muscles [33,34].

Although function of the striated muscles has generally been predicted from their anatomy, recordings of activation of each striated muscle layer are beginning to emerge [35,36]. This is providing novel insight into the interplay between muscles and their overlay on autonomic mechanisms. During the storage phase, detrusor muscle is inhibited, and sympathetic drive maintains tonic activity of the internal urethral sphincter of the proximal urethra [37,38]. Although early reports suggested the striated urethral sphincter is composed solely of slow twitch muscle fibres, inferring contribution to tonic compression [39], other data highlight slow and fast twitch fibres [40]. This concurs with observations of tonic and phasic activity of striated urethral sphincter from electromyography (EMG) recordings made with urethral catheter electrodes stabilized with suction onto the urethral mucosa adjacent to the striated urethral sphincter [36]. Similar observations have been made with transperineal ultrasound imaging (Fig. 2), where posterior displacement of the mid-urethra, distal to the prostate, has been validated against EMG recordings as a measure of striated urethral sphincter muscle activation [35]. These methods reveal tonic activation at rest [22], plus superimposed phasic bursts of activity in advance of, and during, periods of increased demand when IAP rises. This has been shown during coughing [41] and postural tasks where IAP increases to control the trunk [22]. Those tasks also involve contraction of bulbocavernosus and puborectalis, generally in a distal-to-proximal sequence (i.e., striated urethral sphincter and bulbocavernosus, before puborectalis). During micturition, the detrusor contracts and the smooth and striated muscles of the urethra relax [37,38]. Together these observations indicate that the striated muscles all contribute to urethral pressure control, and rather than en block activation, they are activated differentially, but in a coordinated manner.

3. Impact of radical prostatectomy on urinary continence

RP removes or causes trauma to key elements of the continence mechanism. First, RP removes the proximal/prostatic urethra including the surrounding smooth muscle, thus reducing the contribution of autonomicaly controlled internal urethral sphincter to continence [16], and reducing the urethral length (Fig. 3). Second, there is variable bladder neck removal/disruption [42], which can lead to funneling [42−44] (Fig. 3). Third, there is potential removal, damage and scarring of striated urethral sphincter [45,46] and/or its neurovascular supply [42] (striated urethral sphincter innervation lies 0.3−1.3 cm from apex of prostate [47]) with consequent reduction in pressure increase in the mid-urethra during voluntary pelvic floor muscle contraction [43]. Fourth, there is variable disruption of the supporting connective tissue/ligaments [48]. Preservation [49] or restoration of passive support (e.g., puboprostatic ligaments; posterior musculofascial support [50]) during RP might maintain better urethral support and capacity to maintain urethral compression. Fifth, there is modified detrusor contractility (e.g., detrusor overactivity (involuntary detrusor muscle contraction during filling) [51] or hypoactivity [52]) that may be secondary to trauma/revascularization/irritation/denervation of the bladder during surgery [16], and reduced bladder capacity/compliance [52,53] for multiple reasons, including failure to hold urine in the bladder postoperatively [45]. A relationship between detrusor overactivity and poor striated urethral sphincter function, suggests reflex contraction of the bladder is a responses to leakage of urine into the proximal urethral [54]. Sixth, although postoperative stricture/scaring at the anastomosis will reduce flow, it will also reduce elasticity [55] and urethral closure [56]. There will be variation between individuals regarding the manner in which surgery impacts continence and the potential for recovery. Some preoperative anatomical features can predict outcome (e.g., larger prostate size risks greater damage and poorer outcomes [57]; shorter membranous urethral length permits less length for striatal muscles to compress and worse outcomes [58]; and lower preoperative maximal urethral closure pressure predicts worse continence [59]).

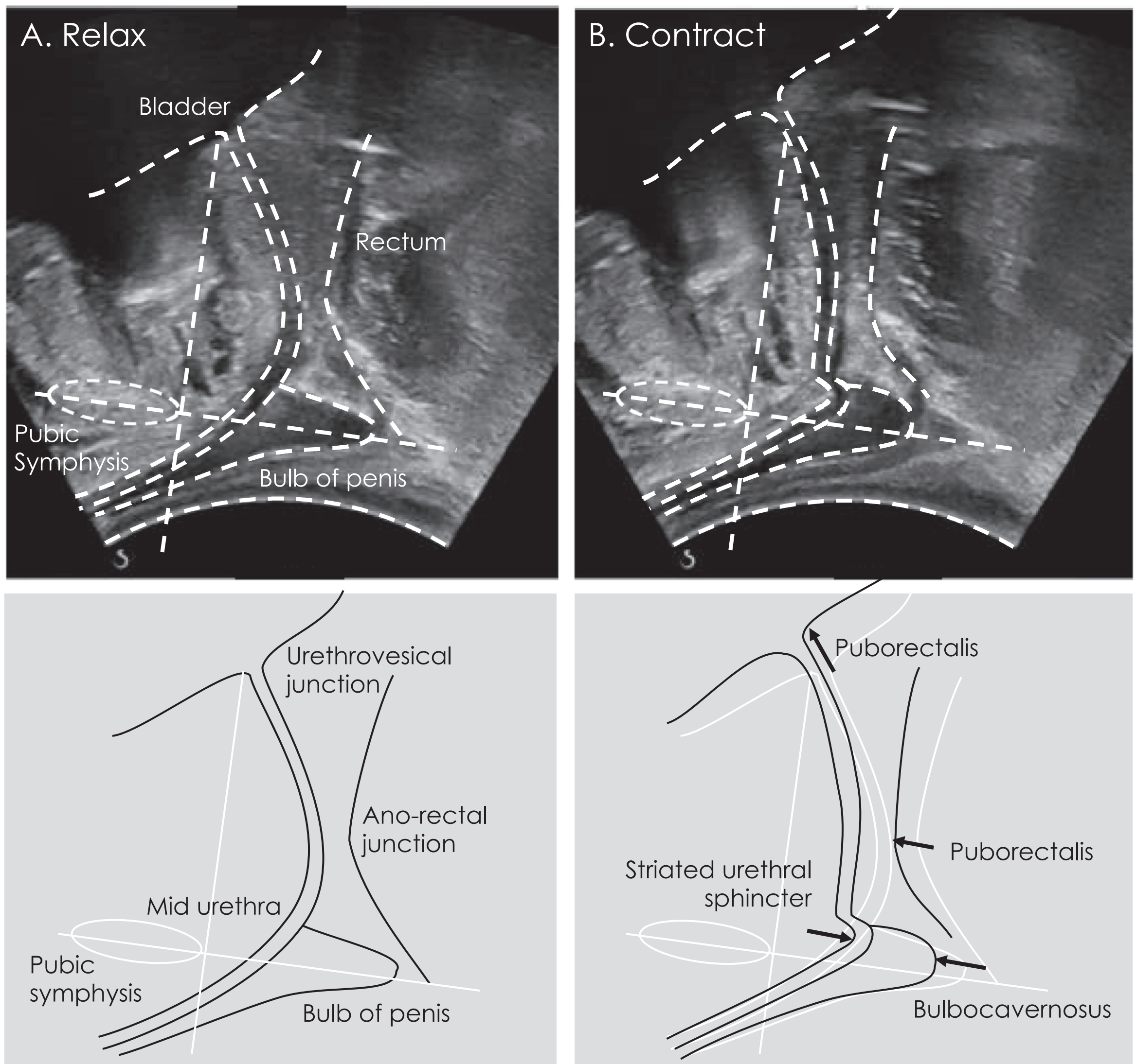

Fig. 2. Transperineal ultrasound investigation of the striated pelvic floor muscles at (A) rest and (B) during contraction in a healthy man with no history of prostate cancer. Arrows in the bottom right panel show the direction of displacement of pelvic landmarks induced by contraction of each muscle.

Finally, there are several variations of surgical technique that have been developed to improve continence outcomes. These include: urethral sparing to preserve the smooth muscular internal sphincter and proximal urethra [60]; nerve sparing which preserves innervation of vascular structures, but might impact continence by reduced disruption of intrapelvic branches of the pudendal nerve [61]; preservation of the natural bladder neck to maintain proximal urethral smooth muscle [62]; preservation of the anterior/puboprostatic ligaments to maintain passive support of the urethra [63]; and reconstruction of the posterior prostatic support to restore posterior support for the striated urethral sphincter and provide a rigid structure for the striated urethral sphincter (located anterior/lateral to the urethra) to compress the urethra [64] or combined anterior/posterior supports to achieve combined benefits of both techniques [65]. There is some evidence, ranging from small trials to systematic reviews, to support the benefit of many of these approaches [50,60,64,66−68], which needs to be considered when planning management.

Each surgical impact on the continence mechanism may contribute to urinary incontinence after surgery. Rather than considering "why" men are incontinent after surgery, it is perhaps more relevant to question "how" is it possible for men to be continent after RP as there would need to be compensation by the striated muscles to restore continence. Of the potential mechanisms for incontinence, the literature identifies "sphincter insufficiency" as the leading cause (40% −88% [51,69]). This would be mediated by both loss of the smooth muscle of the prostatic urethra [51], and insufficient function of striated urethral sphincter (and other striated muscles). Although sphincter insufficiency is commonly considered to be mediated by striated urethral sphincter injury [45,47,70−72], the observation that continence generally improves over time, has been interpreted as evidence that the insufficiency is explained by interference with innervation or

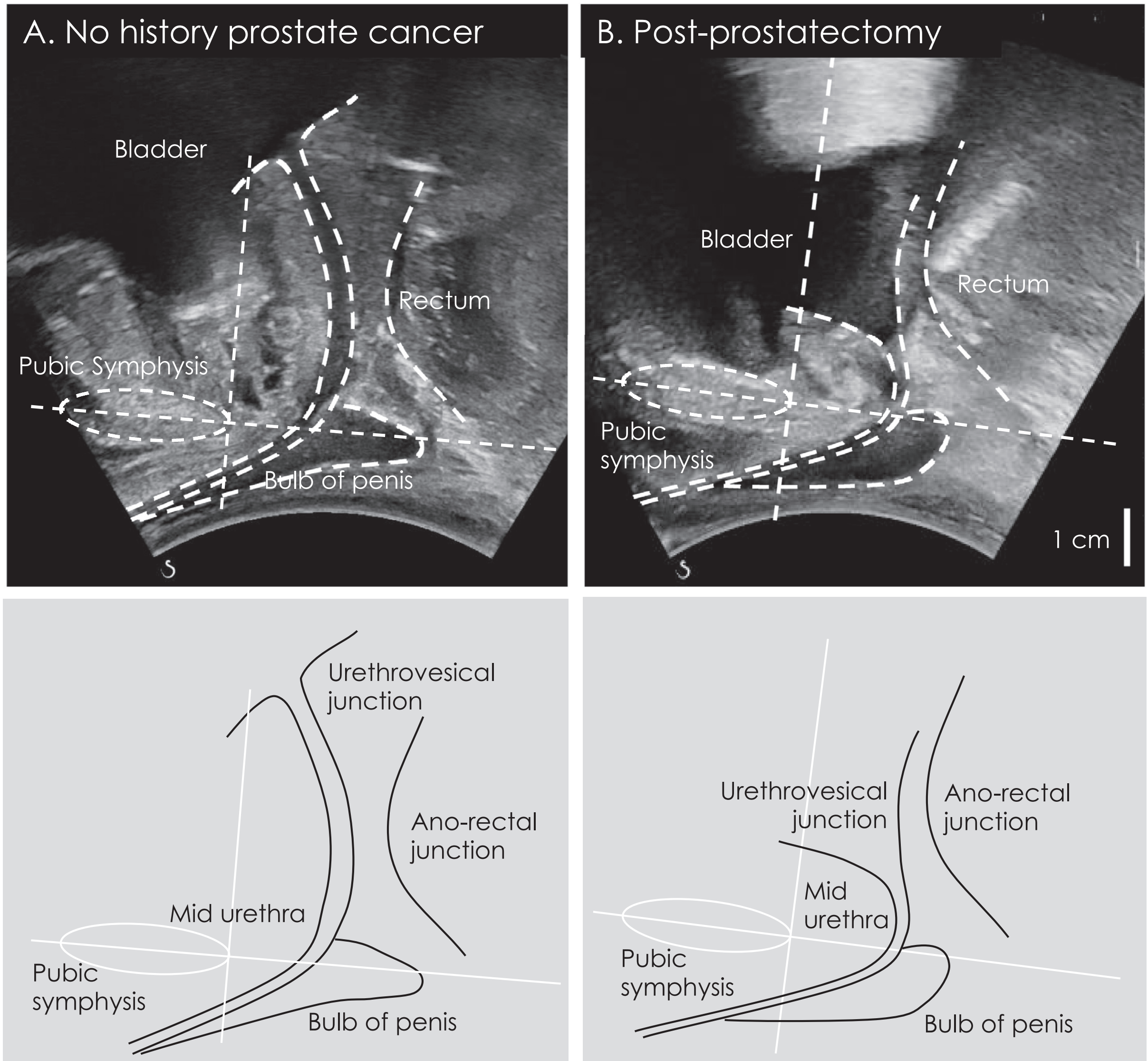

Fig. 3. Transperineal ultrasound investigation of the striated pelvic floor muscles of (A) a healthy man with no history of prostate cancer and (B) a man after radical prostatectomy, both at rest. Note the lower position of the bladder, funneling of the bladder neck, and shorter urethral length of the man after prostatectomy.

supporting tissues [73]. Alternatively, it may not be compromised activation of the sphincter but rather an inability of the striated muscles to meet the additional demand to compensate for loss of smooth muscle [74]. The latter may be further compromised by trauma to/denervation of the striated urethral sphincter muscle. The other most common explanations for incontinence are detrusor overactivity (13%−67% [45,51,75]), but rarely as a sole cause of incontinence, and bladder neck funneling [43].

Recent work using transperineal ultrasound imaging has shown that men who have regained continence after RP have greater shortening/activation of the striated urethral sphincter, bulbocavernosus, and puborectalis during voluntary contractions and coughing than men who are incontinent [74] (Stafford et al., 2019 unpublished data). Further, shortening/activation of bulbocavernosus and puborectalis in men who are continent after RP are even greater than that identified in men with no history of prostate cancer during coughing (Stafford et al., 2019 unpublished data). This suggests that continence recovery depends on better than normal function of striated muscles, to compensate for smooth muscle loss with RP. However, when activation of striated urethral sphincter is poor, exceptional contraction of bulbocavernosus and puborectalis is required to compensate [74]. Other work shows that preoperative measures of puborectalis shortening (bladder neck elevation) do not predict postoperative continence [76] and PFMT focused on strengthening of the pelvic floor muscles as assessed via digital rectal examination (i.e., puborectalis contraction) does not improve postoperative maximal urethral closure pressure [59]. Taken together, these data highlight treatment may be most effective if the striated urethral sphincter is the focus of treatment, when possible. An additional challenge, which has also been observed in women with stress urinary incontinence [77], is counterintuitive descent of the bladder neck (lengthening of puborectalis) during voluntary pelvic floor muscle contractions and during coughing [74]. This is interpreted to indicate excessive IAP from recruitment of abdominal muscles [74,78] or might be caused by excessive compliance of the pelvic floor.

4. Recovery of continence after prostatectomy

Considering the mechanisms presented above and differences in muscle contraction between men with and without incontinence after RP, it is reasonable to hypothesize that recovery of urinary continence would require; (i) enhanced function of striated urethral sphincter (and other striated muscles puborectalis and bulbocavernosus) to compensate for the lost or reduced contribution of smooth muscle. This would likely require enhanced capacity, involving both neural and muscle fibre adaptations, for low intensity sustained contraction or greater resting stiffness to compensate for the reduced tonic contribution of the smooth muscles, and enhanced phasic recruitment for transient increases in IAP; (ii) compensation by the greater than normal activation of puborectalis and bulbocavernosus if the striated urethral sphincter is affected by surgery; (iii) reduced detrusor overactivity; and (iv) training of the bladder to maintain volume and, therefore, compliance.

These components that we propose as targets for intervention, that are based on the pathophysiology of incontinence after RP, differ markedly from the conventional intervention commonly implemented in trials of PFMT for post-RP incontinence [79], which is based on the effective treatment for stress urinary incontinence in women [8]. For women, PFMT involves repeated maximal contraction of the levator ani [80], often with digital, EMG or pressure examination via the vagina [81], and can include feedback [82] and electrical muscle stimulation via the vagina [83]. Direct extrapolation to men has involved inclusion of assessment [14], feedback [84,85], and electrical stimulation [85,86] via the anus, and a focus on brief maximal contractions [13,87,88] around the anus [14].

Considering the pathophysiology of incontinence after RP, this intervention appears to focus on the incorrect muscles. Digital rectal examination and biofeedback using electrodes in the anus provides information of external anal sphincter [89] and potentially levator ani (including puborectalis) activity, but cannot provide information of the striated urethral sphincter and bulbocavernosus. Instructions to tighten around the anus, might generate some co-contraction of all pelvic floor muscle (PFM), but the bias is to muscles that do not constrict the urethra [90]. A recent systematic review has shown that when separate meta-analyses are conducted with the trials grouped based features of the training program, the treatment is more effective than control if the treatment includes instruction to contract around the urethra, but not if the instruction encourages contraction around the anus alone (Hall et al. 2019 unpublished data).

The emphasis on maximal voluntary contraction of the PFM might increase the strength of the PFM and could increase muscle stiffness, but is at odds with the requirement to sustain low levels of tension and brief phasic burst tightly coupled with tasks that elevate IAP [36]. A training program directed to more functional control of the urethral closure mechanisms may be required.

A final issue to consider is when to commence PFMT. An important consideration is whether training should start before or after surgery. From 1 perspective, as incontinence is caused by the surgery, the pathophysiology cannot be assessed until after surgery and PFMT cannot be tailored until that is known. From another perspective, despite the specific impact of surgery, it can be beneficial to train the postoperative regime preoperatively, and begin to condition the system to compensate for the loss of smooth muscle mechanisms that will occur with surgery. Similar "pre"-habilitation is applied in other conditions (e.g., total joint replacement [91]). Observation of 2 strategies for contraction of the striated urethral sphincter and puborectalis (1 that is biased to striated urethral sphincter; and 1 biased to puborectalis [19]) has led to the hypothesis that men with a bias to puborectalis rather than striated urethral sphincter contraction, may require greater conditioning/training of striated urethral sphincter to recover continence and this may be best to commence preoperatively [92]. Although individual trials show outcomes both for [84,93] and against [94] commencement of training prior to surgery, a recent systematic review showed that when meta-analysis is undertaken separately on trials that commence before or after surgery, only trials that commence preoperatively are significantly more effective than control interventions(Hall et al. 2019 unpublished data).

Taken together, it seems reasonable to speculate that the variable success of PFMT for prevention and rehabilitation of incontinence after RP may be explained by failure to design rehabilitation programs to address the pathophysiology of incontinence. Targeted and tailored intervention may achieve improved results. Although not yet tested in a randomized controlled clinical trial (current trial is underway [92]), we propose such an intervention below.

5. Pelvic floor muscle training tailored to pathophysiology of postprostatectomy incontinence to maintain or restore continence

Considering the mechanisms for continence and incontinence presented above, a program can be devised to specifically address the pathophysiology of incontinence (Table 1). Tailoring of the intervention to the individual man would require detailed assessment of striated muscle anatomy and capacity. PFMT is considered with respect to 6 steps based on contemporary motor learning theory and exercise physiology principles. Based on the requirement to

Table 1
Principles of application of pelvic floor muscle training program

1.	Training commences preoperatively to being conditioning the striated pelvic floor muscles for their adapted role after radical prostatectomy
2.	Training recommences postoperatively after catheter removal
3.	Training targets the pathophysiology of incontinence after radical prostatectomy (i.e., enhanced striated urethral sphincter activation to compensate for the loss/reduction of smooth muscle; discourage abdominal muscle contraction; compensation by bulbocavernosus and puborectalis if required; maintain bladder compliance/reduce detrusor overactivity)
4.	Training is guided by findings of assessment: targeted to features of striated muscle function that are compromised/deficient on assessment, but generally biased to the striated urethral sphincter
5.	Training is NOT focused on contraction of the anal muscles
6.	Transperineal ultrasound imaging is used for assessment and feedback
7.	Training uses principles of *motor learning* and *exercise physiology*
8.	Training encourages improved/enhanced coordination of the striated pelvic floor muscles in function rather than unidimensional focus on muscle strengthening
9.	Patients have a clearly defined home program
10.	Regularly assess adherence to home program and consider methods to achieve behavior change to incorporate training into lifestyle
11.	Training progresses to functional re-education as soon as possible

compensate for the reduced smooth muscle contribution to continence, it would be expected that training should aim to: (i) use motor learning principles to encourage a specific pattern of activation of striated muscles that is biased to striated urethral sphincter; (ii) encourage enhanced low intensity tonic activation to maintain continence at rest, with support of bulbocavernosus and puborectalis; (iii) enhance capacity to increase activity both in anticipation of predictable increases in IAP, and quickly in response to increases that cannot be predicted; (iv) encourage automatic integration of activation of these muscles in to functional activities; (v) train strength and endurance for high intensity demands; and (vi) incorporate bladder training as required to maintain bladder volume and compliance.

5.1. Assessment of striated muscle contribution to continence

In addition to standard measures of continence status (e.g., symptoms of urinary incontinence using questionnaires and/or pad usage/24-hour pad test and/or bladder diary, ability to stop urine flow mid-stream, analysis of episodes of stress incontinence [when, what tasks/activities], frequency of voiding, continence at night, and symptoms of detrusor overactivity) treatment is guided by assessment of striated muscle contribution to continence. This requires methods to individually investigate the multiple muscles. Digital rectal examination or anal/rectal EMG can provide information regarding resting tone and contraction of the external anal sphincter [89] and puborectalis [13,95], but this is insufficient to provide information regarding urethral mechanisms. Bulbocavernosus can be investigated with perineal palpation and superficial perineal EMG electrodes [96]. Scrotal lift and retraction of the penis towards the abdomen occurs with instruction to stop the flow of urine, suggesting indirect evidence of contraction of striated urethral sphincter [13]. Transabdominal ultrasound imaging provides information of bladder elevation (puborectalis) [95], but cannot provide evidence of activation of striated urethral sphincter or bulbocavernosus. Valid measures are also difficult to obtain from transabdominal ultrasound because there is no bony landmark for reference, and bracing of the abdominal muscles can move the transducer and distort the measure [97]. The most comprehensive assessment of striated muscles is provided by transperineal ultrasound imaging, which provides a noninvasive and validated [35] method to evaluate and provide feedback of puborectalis, striated urethral sphincter and bulbocavernosus contraction, simultaneously.

Application of transperineal ultrasound imaging to the pelvic floor in men is presented in Fig. 4. Anatomical features that can be assessed are; bladder neck position and shape (e.g., funnel shaped bladder neck may compromise continence); bladder position relative to the ARJ position (e.g., low bladder position and disruption of the bladder neck may place puborectalis behind the bladder such that contraction might compresses the bladder rather than urethra); angle of ARJ and distance from pubic symphysis (e.g., acute angle and short distance, and limited capacity to move these structures with contraction, may indicate increased tone of puborectalis [98], which may interfere with continence or induce pain); and urethral length (e.g., short distance from bladder neck to penile bulb may indicate limited potential for striated muscles to compress the urethra).

Activation of striated pelvic floor muscles is quantified by displacements of specific anatomical landmarks on the urethra (Table 2) that have been validated against EMG recordings [35]. Assessment of each muscle can identify capacity to contract the striated urethral sphincter, puborectalis, and bulbocavernosus voluntarily and automatically (e.g., cough), the ability to relax, and the endurance. Although assessment of muscle thickness might provide additional detail, function of the muscles cannot be inferred from this parameter, and its measurement parameter is difficult, if not impossible with ultrasound imaging as, unlike motion induced by muscle contraction, muscle boundaries can be difficult to delineate. Comprehensive assessment would involve measurement during a series of tasks

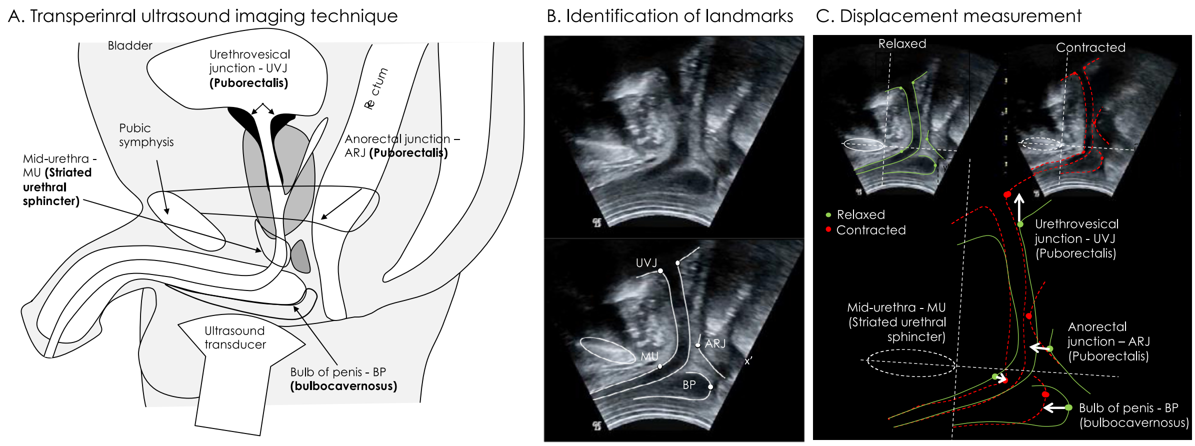

Fig. 4. Technique for imaging and analysis of pelvic floor muscles with transperineal ultrasound imaging in men. (A) Imaging technique with the transducer placed in the mid sagittal line on the perineum between the anus and scrotum. (B) Placement of the axis system relative to the pubic symphysis and identification of the pelvic landmarks used to measure activation of each of the striated muscles of the pelvic floor. (C) Measurement of displacement of pelvic landmarks between rest and voluntary contraction of the pelvic floor muscles. ARJ = anorectal junction; BP = bulb of penis; MU = mid-urethra; UVJ = urethrovesical junction.

(Table 3). Based on the assessment, priority features can be identified for tailoring of the PFMT program.

5.2. Goal 1: Optimize pattern of pelvic floor muscle contraction

A first goal to recover continence would be to optimize the pattern of activation of the striated muscles with bias to striated urethral sphincter, as able, to encourage adequate compensation for reduced contribution from smooth muscle (see Table 4 for detailed description). This requires "motor learning", which is the relatively permanent change in performance of a task as a result of practice [99]. Motor learning can be broken into *cognitive*, *associative,* and *automatic* phases [100] and can be measured as *acquisition*, *retention,* and *transfer* [101]. This first step of PFMT for incontinence after RP involves the cognitive phase to acquire the motor skill of activation of the striated pelvic floor muscles. As with learning any new skill, the initial cognitive phase involves conscious practice of the component of the task that requires improvement [102]. Instruction is critical for the patient to get the correct "idea" of the task. Recent work has highlighted that recruitment of pelvic floor muscles can be biased to striated urethral sphincter by use of specific instructions such as "retract the penis" or "contract as if stopping the flow of urine" [90]. It may be necessary to reduce excessive activation of puborectalis or external anal sphincter if contraction of these muscles is dominant rather than striated urethral sphincter, or abdominal muscles if there is depression of the urethrovesical junction, indicative of excessive IAP [74]. Reduced activation of the puborectalis might be particularly important if the action of this muscle compromises continence, such as might occur when the bladder position is too low or bladder neck shape is disrupted such that puborectalis increases pressure in the bladder rather than the urethra. Feedback is important to obtain *knowledge of performance* [99]. This can be provided visually by transperineal ultrasound imaging as described above, or simple indirect forms of feedback such as palpation of the perineum for bulbocavernosus or visible

Table 2
Landmarks and displacement used to quantify contraction of the individual striated pelvic floor muscles

Muscle	Measurement point	Measure of displacement with contraction
Striated urethral sphincter	Mid-urethra—most prominent apex of dorsal movement during contraction	Distance of displacement (between rest and contraction) along a line drawn from the dorsal pole of the symphysis pubis to most prominent apex in the contracted image
Bulbocavernosus	Bulb of penis—most dorsal aspect of bulb of penis	Distance of anteroposterior displacement (between rest and contraction) along a line drawn parallel to the anteroposterior axis of symphysis pubis
Puborectalis	Urethrovesical junction—dorsal edge of the urethra at the urethrovesical junction Anorectal junction —apex of curve aligned to the ventral aspect of the rectum at the anorectal junction	Distance of displacement (between rest and contraction) along a line drawn parallel to anteroposterior axis of symphysis pubis

Table 3
Tasks included in detailed assessment of striated pelvic floor muscle control with transperineal ultrasound imaging (TPUS)

Task	Instructions	Performance characteristics	Ideal response	Suboptimal features
Voluntary activation	First, assessment with minimal instruction to test "raw" strategy. Basic instruction should be limited, such as "gently contract the muscles of the pelvic floor as if you are trying to 'hold on' to delay urination" Second, identify best strategy to activate urethral striated muscles, particularly striated urethral sphincter. Example instructions are; "Stop flow of urine" or "Retract the penis"	Effort: gentle contraction at 5%−20% with emphasis on precision rather than intensity Duration: up to ~10 s or duration of ~3 breaths Patient position: either long sitting with the trunk supported and thighs slightly abducted or supine lying with supported bent knees. May consider assessment in sitting, standing, lying	*Striated urethral sphincter:* TPUS—Dorsal motion of mid-urethra (MU). Other assessment—Visual observation of retraction of penis *Bulbocavernosus:* TPUS—Compression of bulb of penis (BP). Other assessment—Palpation of tension in perineum behind scrotum *Puborectalis:* TPUS—Bladder neck/urethrovesical juntion elevation + ventral motion of anorectal junction Ensure that superficial/upper abdominal (obliquus externus abdominis and rectus abdominis) and leg muscles are relaxed. Activation of deep/lower abdominal muscles (e.g., transversus abdominis) is acceptable, but should be gentle. Observation/palpation abdominal muscles can be used	UVJ/ARJ depression/abdominal pressurisation No motion of the MU No BP compression (no "pinch" of urethra) Bias to anal/puborectalis contraction Minimal displacement of bladder neck Inability to relax (particularly puborectalis) Inability to breathe while holding contraction Inability to hold for more than a brief contraction
Repeated contraction ×10	Task 1: "Contract the pelvic floor muscles rapidly and hold for 3−5 s for up to 10 repetitions" Task 2: "Contract the pelvic floor muscles as quickly as possible for up to 10 repetitions"	Task 1: Rapid contraction and hold for 3−5 s; Task 2; Rapid contraction and rapid relaxation Effort: moderate Duration: up to 10 repetitions	Rapid dorsal motion of MU (striated urethral sphincter), compression of bulb of penis (bulbocavernosus), and UVJ/ARJ (puborectalis) elevation, with intervening rapid complete relaxation	Depression of UVJ/ARJ Slow/incomplete contraction Slow/incomplete relaxation.
Cough	"Do a single cough with moderate effort"	Effort: moderate	Rapid/early dorsal displacement of MU before expulsion Sustained dorsal displacement of MU during expulsive phase of cough Mild depression of UVJ/ARJ is expected during the expulsion phase, but not before	Excessive depression of UVJ/ARJ during pressurisation phase and/or expulsion phase Absence/ delayed dorsal displacement of MU
Cough with preactivation	"Contract the pelvic floor muscles, hold this and do a single cough with moderate effort"	Effort: gentle precontraction and moderate effort cough	Preactivation of striated urethral sphincter (dorsal displacement of MU) As for cough, but less depression of UVJ/ARJ	Excessive depression of UVJ/ARJ Absence/ delayed dorsal displacement of MU
Sustained hold to evaluate endurance	"Gently contract the pelvic floor muscles, build this up to contract as hard as you can, then sustain that for as long as you can"	Effort: maximum Strong encouragement is required throughout the task Duration: until unable to continue. Record duration of hold	Dorsal motion of MU Compression of BP Elevation of UVJ Ventral motion of ARJ Sustained hold	Inability to hold contraction Flickering contraction—particularly striated urethral sphincter Release and regain ("drop" and "catch") Depression of UVJ/ARJ

Table 4
Pelvic floor muscle training program to address pathophysiology of incontinence after radical prostatectomy

Training goal	Aim	Decision rule	Assessment	Treatment session	Home program
Goal 1: Optimize pattern of pelvic floor muscle contraction	Optimize pattern with bias to striated urethral sphincter	Commence preoperatively. Postoperatively commence after catheter removal	Assess using transperineal ultrasound imaging and other techniques (e.g., observation; palpation) Ideal response Smooth controlled contraction biased to striated urethral sphincter (minor contraction of bulbocavernosus, gentle contraction only of puborectalis) Hold for at least 2−3 s initially Continue breathing Discourage Bias to posterior contraction (anal) Excessive activation of abdominal muscles Breath holding.	Educate anatomy and actions of pelvic floor muscles Contraction of striated urethral sphincter with careful use of instructions; “retract penis”; “shorten penis”; “pull the turtle’s head into its shell”; “stop the flow of urine”; “imaging peeing up the wall” Gentle contraction of transversus abdominis to enhance awareness, but striated urethral sphincter contraction must be confirmed Contraction of bulbocavernosus; “contract as if squeezing out the last few drops” Gentle contraction of puborectalis; “stop flow of urine”; “contract to prevent passing wind” Trial of slowing/stopping of urination midstream to test contraction of striated pelvic floor muscles Relaxation after contraction Breathing while holding the pelvic floor muscle contraction	Continue to use cue/instruction identified for the individual patient Gentle contraction intensity to begin to train optimal pattern of muscle activation—progress from 5% to 20%. Hold—Start at 2−3 s, Progress to 10 s Relax smoothly. Sets of ~5−10 repetitions Emphasis on quality, not intensity or number of repetitions Consider using feedback at home; e.g., In front of a mirror to observe features such as penile retraction, palpate tension in bulbocavernosus superficial to bulb of penis Positions—Sitting, standing, supine Consider that some pelvic floor muscles (e.g., puborectalis) could demonstrate increased tone
Goal 2: Integrate pelvic floor muscle control into function	Train preactivation before exertion Maintain hold for longer periods, but with low intensity	Commence early Match intensity of contraction and difficulty of task to patient’s capacity Progress to higher level functions as able	Assess using transperineal ultrasound imaging and other techniques (e.g., observation; palpation) Evaluate pattern with voluntary activation Evaluate rapid repeated contraction Evaluate cough Evaluate cough with preactivation Can add feedback with paper towel inside underwear/pad for quick assessment of urine loss	Create priority list of tasks to work through Example tasks; Sit-to-stand Walk Moving object on bench/table Turning/Bending/Squat Run Cough—vary cough intensity to challenge capacity Teach “leak and repeat” protocol (If you leak, STOP! CONTRACT. REPEAT) When leaking is experienced during a task (e.g., lifting)—Stop, consciously precontract, repeat without leak Practice several (at least 3) repetitions	Practice preactivation before tasks Practice “leak and repeat” Practice preactivation at different intensities Match to demands of the task (e.g., high intensity for cough/sit-to-stand; low intensity for step) Maintain hold of activation for longer. Progress from low to high intensity functions Match training intensity to the demands the patient is exposed in their function/lifestyle
Goal 3: Bladder training	Commence advice early Priority for patients who experience symptoms of urge. Man aid men with continual drip induced by detrusor contraction	Commence early	Bladder diary	Gradually hold urine for longer periods rather than maintain empty bladder. Example instructions; “Don’t try to keep the bladder empty by responding to every urge or urinating every time you change a pad,” “Contract the pelvic floor muscles and say no to the urge. Put it off as long as possible without getting wet—even if only for a few seconds initially”. Aim to empty bladder 6 times per day and 1 time per night	Other advice; Decrease caffeine, Maintain hydration, Avoid constipation—diet/medication, Advice for voiding strategy (“Squeeze out last few drops” at end of urination to prevent postmicturition dribble).

(*continued on next page*)

Table 4 (***Continued***)

Training goal	Aim	Decision rule	Assessment	Treatment session	Home program
				Keep bladder chart/diary Frequent, pelvic floor muscles contractions (e.g., duration of 10−15s to reduce detrusor activity) Implement urge suppression techniques if experience the feeling of urge to urinate; e.g., “Stay calm and breath (panic makes things worse)” “Sit down or stand still for 1 minute until urge disappears” “Think of something to distract thoughts (e.g., count backwards from 100; count backwards in 7 s)” “Contract pelvic floor muscles to supress urge (can also try gluteal muscle squeeze or curling the toes)” etc.	
Goal 4: Low intensity tonic hold training for sustained tasks	Condition muscles striated urethral sphincter to hold for longer periods to compensate for loss of smooth muscle Commence low intensity.	Commence once pattern of striated muscle activation is optimal.	Assess using transperineal ultrasound imaging and other techniques (e.g., observation; palpation) Evaluate pattern with voluntary activation Evaluate holding time to guide home program Evaluate with low and high intensity activation.	Maintain optimal pattern Contraction intensity—~10% effort Hold time—Progress from 10 s to 30−60 s Repetitions—up to 10. Frequency—start at 2−3 times per day; progress to frequent holds during the day (e.g., 60−100 per day) While driving, standing in a queue, etc.	Aim for functional use of holding at times when greater likelihood of leak Relax fully between repetitions Commence in standing (sitting or lying might be necessary initially) Progress to contraction during movement (e.g., walking) Train breathing control while maintain tonic activation.
Goal 5: High level strength and endurance training for high intensity	Enhance strength of pelvic floor muscles for high intensity function Enhance endurance of pelvic floor muscles for high intensity function Enhance speed of PFM contraction for ballistic contractions	Commence once pattern of striated muscle activation is optimal and hold can be maintained for at least 30 s	Assess using transperineal ultrasound imaging and other techniques (e.g., observation; palpation) Evaluate pattern with voluntary activation Evaluate holding time to guide home program	Training for strength—Brief high intensity contractions Contraction intensity—near maximal (MVC) effort Hold time—3−10 s Repetitions—8−12 Sets—1−3 Rest—2−3 min between sets Some contractions with rapid increase for ballistic tasks. Training for endurance—Sustained moderate intensity Contraction intensity—70% effort Hold time—start with 5 s and progress to 20 s Repetitions—early phase—more reps, shorter .holds (10−20 reps of 5 s hold), later phase—less reps, longer holds (20 s holds) Sets−2−4. Rest—30 s−1 min between sets	Increase load by: Increase contraction intensity, Increase intra-abdominal pressure, incorporating tasks that involve lifting, pushing, pulling, Shorten rest, Increase speed, reps, frequency/duration Alternate between strength & endurance Consider timing of training (later in day may be more challenging and a progression)
Goal 6: High performance training for demand & unexpected challenges	Train control for intermittent very high demand Maintain continence despite high intra-abdominal pressure	Commence once strength and endurance is improving and continence can be maintained with moderate exertion	Assess using transperineal ultrasound imaging and other techniques (e.g., observation; palpation) Evaluate pattern with voluntary activation	Whole body training program with high intra-abdominal pressure demand and complex tasks (physically demanding and cognitively distracting) Examples; “Core” exercise with elevated intra-abdominal pressure, Pilates program may be appropriate, Gym program with weight machines	

retraction of the penis. Quality of practice, rather than quantity, is critical in the initial phase. Skill training leads to greater changes in brain motor networks than strength training [103] or unskilled practice [104] and no additional benefit in the early stage of learning is achieved by excessive practice [105]. However, it is also clear that substantial repetition over time is required to consolidate learning [106].

5.3. Goal 2: Integrate pelvic floor muscle control into function

Once striated muscle contraction can be performed with an optimal pattern, motor learning principles mandate that this should be integrated into function (Table 4). Pelvic floor muscles form the floor of the abdominal cavity and their activity is required to both control continence when IAP is increased, and also to contribute to modulation of IAP [34]. As such, pelvic floor muscle activity is expected to increase with any task that involves increased IAP, including postural challenges (IAP is involved in postural control of the spine/trunk [107]), coughing, and breathing [108], to name a few. Pelvic floor muscle activity can be initiated in advance of tasks that are predictable (e.g., coughing [41], stepping [36]) and rapidly in response to unpredictable challenges [109], or continuously when the challenge is ongoing [34]. During the breathing cycle, activation of the pelvic floor muscles modulates with the changes in IAP [34]. After RP, men often complain of urine leakage with tasks such as coughing and sit-to-stand. Integration of pelvic floor muscle activation into these tasks is essential.

This is the *associative* phase of learning where the objective is *retention* and *transfer* of the skill into function. To achieve transfer to function it is essential to practice the new motor skill in a variety of contexts [110] (e.g., different body positions, at different times of the day) and to practice the task as close to functional use as possible in order to achieve transfer to function [111] and, ultimately, reach the *automatic* phase of motor learning. A particular objective of this phase of training is to control urine leak on exertion. For this, men should be encouraged to activate the PFM with the optimized pattern in advance of performance of a task that would challenge continence, similar to the “knack” used in stress urinary incontinence in women [112]. A useful strategy is “leak and repeat”—when a man experiences a loss of urine during a task (e.g., sit-to-stand; cough; step), he should stop and repeat the task, but with optimized pre-activation of the PFM, and then repeat several times to encourage fixation of the motor pattern. It may be necessary to modify functional activities initially and progress as tolerated as the capacity to control continence improves in terms of longer periods and tasks with higher demand.

5.4. Goal 3: Bladder training

Bladder training should commence early to maintain bladder volume and compliance (Table 4). Men often adopt 2 strategies to prevent/limit incontinence episodes; restriction of fluid intake and/or emptying the bladder at every opportunity. These strategies limit urine storage with potential to reduce bladder volume and compliance, in addition to other causes [113]. Men require training to gradually increase time between urination, and may need to adopt strategies to reduce urge sensations [114] (see Table 4 for details). Advice to consider reduction of consumption of alcohol, caffeine, and other diuretics has been suggested, but not yet strongly supported by randomized controlled trial (RCT) evidence [115].

5.5. Goal 4: Low intensity tonic hold training for sustained tasks

As the striated muscles are required to compensate for the loss of smooth muscle, the pathophysiology suggests that conditioning the striated muscles to maintain gentle tonic contractions for longer periods is an important treatment goal (Table 4). This would be challenging if there has been denervation of the striated urethral sphincter. In healthy men, striated urethral sphincter and puborectalis sustain some low-level tonic activity at rest, this can be superimposed with higher amplitude activation as required by function [36] (Hodges et al. 2019 unpublished data). In contrast, bulbocavernosus tends to be recruited only in a phasic manner for additional support (Hodges et al. 2019 unpublished data).

Low load training of slow and tonic contractions can increase tonic muscle activation that transfers to functional tasks for other muscles [102,116] in addition to increasing muscle strength and size [116]. For sustained activation, the intensity of contraction is important to consider because intramuscular pressure increases linearly with activation [117], and this in turn impedes muscle blood flow [118] and, consequently, induces muscle fatigue [119]. As only low-level contraction (<10% maximum voluntary contraction) enables sufficient blood flow to maintain homeostasis [119], exercise for tonic activation should be targeted at this low percentage.

Improved capacity of striated muscles to maintain urethral pressure might require both neural (shift to enhanced tonic activation) and muscle fibre adaptation (enhanced capacity of slow twitch, fatigue-resistant muscle fibres), however, this has not yet been studied in detail. Progression would involve incremental increases in holding time, and sustained holding during function. Tonic maintenance may be more difficult later in the day, and may require training for endurance in upright postures.

5.6. Goal 5: High level strength and endurance training for high intensity function

Although not the primary goal of training in men (in contrast to the training objective in women with stress urinary incontinence [80]), the pelvic floor muscles must have sufficient strength and endurance to meet demands of higher-level function. The aim of strength and endurance training is to enhance the capacity of the pelvic floor muscles to generate force and to change muscle morphology (i.e., increase cross sectional area, enhance neural drive, increase muscle stiffness, modify connective tissue, etc.) [80], which might further enhance the passive compression of the urethra. As for any skeletal muscle, training involves progressive overload [120]. This is challenging for the pelvic floor muscles because there is no simple method to add resistance as would be applied to the limbs. In this case training requires strong voluntary contraction or resistance applied by elevated IAP. Training in this manner has been shown to change the pelvic floor muscle thickness and a more elevated position in women [121], but when focused on anal contraction in men this does not improve maximal urethral closure pressure [59]. This latter point reinforces that the focus on striated urethral sphincter should continue during strength training.

Training should follow the principles of exercise physiology with training parameters separately optimized for strength and for endurance (Table 4) [120]. In general, strength training involves few repetitions with greater load and near maximum efforts, whereas endurance training involves a greater number of repetitions of less intense contractions [120]. An additional consideration for endurance training is that muscle fatigue includes both changes in the muscle (peripheral fatigue) and reduced capacity to voluntarily activate the muscle by the central nervous system (central fatigue) [122]. There is evidence that central fatigue develops quickly in pelvic floor muscles (shown for the external anal sphincter [123]), and this could limit the potential to impose a training load on the pelvic floor muscles, as the ability to strongly activate the muscle declines.

5.7. *Goal 6: High performance training for demand and unexpected challenges*

Pelvic floor muscles will generally require capacity for occasional events with high demand, such as instances of high IAP. Whole body exercise challenges coordination of the timing and amplitude of activity of muscles around the abdominal cavity, including the pelvic floor, abdominal, and diaphragm muscles [34]. There is some evidence of changes in timing and amplitude of activity of pelvic floor and abdominal muscles in women with stress urinary incontinence [124−126]. This has not yet been tested in men with incontinence after RP. Training of whole-body exercises with high IAP and unexpected challenges may be required (Table 4). This is also likely to aid integration of pelvic floor muscle activation into function.

This phase in particular involves individualization of goal setting. Men's aspirations to return to work or recreational activities will vary greatly and goals should reflect individual needs. This will in turn influence the requirements of a training program e.g., from sedentary to physically demanding work and recreational tasks (e.g., manual labour, elite sport).

5.8. *Additional considerations for recovery of continence*

Optimal recovery of continence is likely to also require consideration of several additional aspects. These include attention to adherence to exercise and adjunct issues that will influence general health and wellbeing.

5.1.1. *Adherence to exercise*

A major barrier to success of any training program is adherence [127]. PFMT is no different. Some work has been undertaken to enhance adherence to PFMT for women [128−130] and these principles can be applied to men (Table 5). Future work should consider whether different strategies are required for men.

5.1.2. *Adjunct considerations*

Management of bowel dysfunction: Bowel dysfunction is common after RP [131,132] and may require management with diet, medication, or behavioral management.

Table 5
Patient-focused exercise adherence strategies[a]

1. Use strategies to influence "intention to adhere"—educate and motivate commencing preoperatively
2. Offer sufficient accurate information to grow patient "knowledge"
3. Teach the "physical skills" of a correct PFM contraction, then enhance performance and develop patient confidence/self-efficacy
4. Promote positive and decrease negative "feelings about PFMT" and perceived benefits of the PFMT
5. Counter negative with positive PFMT role models
6. Identify barriers to adherence (e.g., no time, forget) and seek solutions
7. Enable constructive "cognitive analysis, planning, and attention" to problem solve common barriers to and enhance PFMT facilitators in daily life
8. Boost the "prioritisation" of PFMT in patients' lives
9. Introduce "action planning" process;
   - Goal setting—behavior
   - Goal setting—outcome
   - Track improvement
10. Discuss strategies to integrate PFMT into daily activities, e. g., precontract when perform task
11. Discuss strategies to make training enjoyable—particularly with higher level training—e.g., Consider joining exercise group for higher level training
12. Consider ways to remind patient—e.g., contract every time they go to perform an activity that might challenge their continence, etc.
13. Engage partner/family members in encouraging training

[a] Also see Frawley et al. [130].

Maintenance of mental health: Mental health issues are prevalent in men undergoing RP [133]. This has an impact on quality of life and may impact adherence to management. It is necessary to prepare for possible outcomes before prostatectomy, provide reassurance, maintain positive attitude, provide emotional support, and address mental health as a barrier to adherence [134].

Reinforce general exercise: General exercise has well-known benefits in prostate cancer including an up to 49% reduction in mortality and 61% reduction in prostate cancer death [135]. Any PFMT program should be accompanied by reinforcement of the positive benefits of physical fitness for cancer recovery and for health/wellbeing. The advice for physical activity may need to be considered with respect to exercise tolerance of pelvic floor muscles to maintain continence. This may require pacing of exercise and regular rest periods while pelvic floor muscle control improves. Rather than avoiding physical activity men should be educated that they will be likely to experience urinary incontinence with higher intensity exercise, which should diminish as pelvic floor muscle function improves.

Reinforce weight loss: Worse continence outcomes have been observed in obese men [136]. Whether this can be improved by weight-loss requires investigation. Reinforcement of weight control is likely to have other health benefits.

Erectile dysfunction and penile rehabilitation: RCT evidence shows that PFMT can improve erectile function [137], which may be related to improved vascular regulation in the penile crus by the ischiocavernosis and bulbocavernosus muscles. Consideration should be given to training and advice regarding options and reasons for penile rehabilitation to maintain the health/elasticity of vascular/penile tissue and this may include physical intervention (vacuum pumps) or pharmacological approaches [138].

6. Evidence for efficacy of the proposed targeted approach

What is the evidence for efficacy of the proposed approach to PFMT for RP? No RCT has been completed to test the efficacy of the presented approach to PFMT, although a current trial is underway [92]. The foundation of this approach is based on alignment of the program with the pathophysiology of continence after RP, yet this physiological rationale cannot predict the size of any potential clinical effect. A recent systematic review has provided support for some key aspects of the program: treatment is more effective than control if the instructions for PFM contraction include reference to the urethra (rather than anus), if biofeedback is provided, and if training starts preoperatively (rather than postoperatively) (Hall et al. 2019 unpublished data).

Although promising, PFMT according to these principles is unlikely to be successful for all men. In some men it may not be possible to recover continence with conservative management, despite enhanced function of the striated muscles. Possible mechanisms for continued incontinence, despite training, include; (i) surgical trauma to striated urethral sphincter or its innervation that does not recover or cannot be compensated by bulbocavernosus and puborectalis; (ii) scaring of the urethra that causes stiffening and prevents urethral closure; (iii) shape of bladder neck (funneling); (iv) short length of urethra with insufficient length over which muscles can generate urethral pressure; (v) caudal location of the bladder such that the puborectalis compresses the bladder rather than the urethra; and (vi) lack of recovery of automatic maintenance of striated muscle contraction. These possibilities require investigation.

7. Conclusion

Although evidence for existing PFMT programs to prevent and rehabilitate incontinence after RP is inconsistent, new understanding of continence control in men and pathophysiology of incontinence after RP provides a plausible explanation and proposes opportunities to create more effective management. This paper reviewed the contemporary understanding of continence and incontinence and proposes a targeted program that can be tailored to match the needs of an individual patient.

Conflict of Interest

None.

References

[1] Australian Insititute of Health and Welfare. Cancer in Australia 2017. Cancer series no101. Canberra: Australian Insititute of Health and Welfare.; 2017.

[2] Litwin MS, Melmed GY, Nakazon T. Life after radical prostatectomy: a longitudinal study. J Urol 2001;166:587–92.

[3] Goluboff ET, Saidi JA, Mazer S, Bagiella E, Heitjan DF, Benson MC, et al. Urinary continence after radical prostatectomy: the Columbia experience. J Urol 1998;159:1276–80.

[4] Wilson LC, Gilling PJ. Post-prostatectomy urinary incontinence: a review of surgical treatment options. BJU Int 2011;107(Suppl 3):7–10.

[5] Fowler FJ Jr., Barry MJ, Lu-Yao G, Wasson J, Roman A, Wennberg J. Effect of radical prostatectomy for prostate cancer on patient quality of life: results from a Medicare survey. Urology 1995;45:1007–13.

[6] Katz G, Rodriguez R. Changes in continence and health-related quality of life after curative treatment and watchful waiting of prostate cancer. Urol 2007;69:1157–60.

[7] Yaxley JW, Coughlin GD, Chambers SK, Occhipinti S, Samaratunga H, Zajdlewicz L, et al. Robot-assisted laparoscopic prostatectomy versus open radical retropubic prostatectomy: early outcomes from a randomised controlled phase 3 study. Lancet 2016;388:1057–66.

[8] Dumoulin C, Hay-Smith J. Pelvic floor muscle training versus no treatment, or inactive control treatments, for urinary incontinence in women. Cochrane Database Syst Rev 2010:Issue 1. Art. No.: CD005654.

[9] Van Kampen M, De Weerdt W, Van Poppel H, De Ridder D, Feys H, Baert L. Effect of pelvic-floor re-education on duration and degree of incontinence after radical prostatectomy: a randomised controlled trial. Lancet 2000;355:98–102.

[10] Parekh AR, Feng MI, Kirages D, Bremner H, Kaswick J, Aboseif S. The role of pelvic floor exercises on post-prostatectomy incontinence. J Urol 2003;170:130–3.

[11] Ribeiro LH, Prota C, Gomes CM, de Bessa J Jr., Boldarine MP, Dall'Oglio MF, et al. Long-term effect of early postoperative pelvic floor biofeedback on continence in men undergoing radical prostatectomy: a prospective, randomized, controlled trial. J Urol 2010;184:1034–9.

[12] Campbell SE, Glazener CM, Hunter KF, Cody JD, Moore KN. Conservative management for postprostatectomy urinary incontinence. Cochrane Database Syst Rev 2012;1:CD001843.

[13] Dorey G, Glazener C, Buckley B, Cochran C, Moore K. Developing a pelvic floor muscle training regimen for use in a trial intervention. Physiotherpy 2009;95:199–209.

[14] Glazener C, Boachie C, Buckley B, Cochran C, Dorey G, Grant A, et al. Urinary incontinence in men after formal one-to-one pelvic-floor muscle training following radical prostatectomy or transurethral resection of the prostate (MAPS): two parallel randomised controlled trials. Lancet 2011;378:328–37.

[15] Delancey JO, Kane Low L, Miller JM, Patel DA, Tumbarello JA. Graphic integration of causal factors of pelvic floor disorders: an integrated life span model. Am J Obstet Gynecol 2008;199:610.:e1-5.

[16] Song C, Doo CK, Hong JH, Choo MS, Kim CS, Ahn H. Relationship between the integrity of the pelvic floor muscles and early recovery of continence after radical prostatectomy. J Urol 2007;178:208–11.

[17] Wu Y, Dabhoiwala NF, Hagoort J, Hikspoors J, Tan LW, Mommen G, et al. Architecture of structures in the urogenital triangle of young adult males; comparison with females. J Anat 2018;233:447–59.

[18] Koraitim MM. The male urethral sphincter complex revisited: an anatomical concept and its physiological correlate. J Urol 2008;179: 1683–9.

[19] Stafford RE, Ashton-Miller JA, Constantinou CE, Hodges PW. A new method to quantify male pelvic floor displacement from 2D transperineal ultrasound images. Urol 2013;81:685–9.

[20] Elbadawi A. Functional anatomy of the organs of micturition. Urol Clin North Am 1996;23:177–210.

[21] Mirilas P, Skandalakis JE. Urogenital diaphragm: an erroneous concept casting its shadow over the sphincter urethrae and deep perineal space. J Am Coll Surg 2004;198:279–90.

[22] Stafford RE, Ashton-Miller JA, Constantinou CE, Hodges PW. Novel insight into the dynamics of male pelvic floor contractions through transperineal ultrasound imaging. J Urol 2012;188:1224–30.

[23] Aigner F, Zbar AP, Ludwikowski B, Kreczy A, Kovacs P, Fritsch H. The rectogenital septum: morphology, function, and clinical relevance. Dis Colon Rectum 2004;47:131–40.

[24] Golomb J, Chertin B, Mor Y. Anatomy of urinary continence and neurogenic incontinence. Therapy 2009;6:151–5.

[25] Loughlin KR, Prasad MM. Post-prostatectomy urinary incontinence: a confluence of 3 factors. J Urol 2010;183:871–7.

[26] Hinata N, Sejima T, Takenaka A. Progress in pelvic anatomy from the viewpoint of radical prostatectomy. Int J Urol 2013;20:260–70.

[27] Raizada V, Mittal RK. Pelvic floor anatomy and applied physiology. Gastroenterol Clin North Am 2008;37:493–509.

[28] Claes H, Bijnens B, Baert L. The hemodynamic influence of the ischiocavernosus muscles on erectile function. J Urol 1996;156:986–90.

[29] Schroder HD, Reske-Nielsen E. Fiber types in the striated urethral and anal sphincters. Acta Neuropath 1983;60:278–82.

[30] Shafik A, El-Sibai O. Mechanism of ejection during ejaculation: identification of a urethrocavernosus reflex. Arch Androl 2000;44: 77–83.

[31] Vereecken RL, Verduyn H. The electrical activity of the paraurethral and perineal muscles in normal and pathological conditions. Br J Urol 1970;42:457–63.

[32] Matsufuji H, Yokoyama J. Neural control of the internal anal sphincter motility. J Smooth Muscle Res 2003;39:11–20.

[33] Aguilera LG, Gallart L, Alvarez JC, Valles J, Gea J. Rectal, central venous, gastric and bladder pressures versus esophageal pressure for the measurement of cough strength: a prospective clinical comparison. Respir Res 2018;19:191.

[34] Hodges PW, Sapsford R, Pengel HM. Postural and respiratory functions of the pelvic floor muscles. Neurourol Urodyn 2007;26:362–71.

[35] Stafford RE, Coughlin G, Lutton NJ, Hodges PW. Validity of estimation of pelvic floor muscle activity from transperineal ultrasound imaging in men. PLoS One 2015;10:e0144342.

[36] Stafford RE, Ashton-Miller JA, Sapsford R, Hodges PW. Activation of the striated urethral sphincter to maintain continence during dynamic tasks in healthy men. Neurourol Urodyn 2012;31:36–43.

[37] Mahony DT, Laferte RO, Blais DJ. Integral storage and voiding reflexes. Neurophysiologic concept of continence and micturition. Urology. 1977;9:95–106.

[38] de Groat WC. Integrative control of the lower urinary tract: preclinical perspective. Br J Pharmacol 2006;147(Suppl 2):S25–40.

[39] Gosling JA, Dixon JS, Critchley HO, Thompson SA. A comparative study of the human external sphincter and periurethral levator ani muscles. Br J Urol 1981;53:35–41.

[40] Elbadawi A, Mathews R, Light JK, Wheeler TM. Immunohistochemical and ultrastructural study of rhabdosphincter component of the prostatic capsule. J Urol 1997;158:1819–28.

[41] Stafford RE, Mazzone S, Ashton-Miller JA, Constantinou C, Hodges PW. Dynamics of male pelvic floor muscle contraction observed with transperineal ultrasound imaging differ between voluntary and evoked coughs. J Appl Physiol 2014;116:953–60.

[42] Presti JC Jr., Schmidt RA, Narayan PA, Carroll PR, Tanagho EA. Pathophysiology of urinary incontinence after radical prostatectomy. J Urol 1990;143:975–8.

[43] Cameron AP, Suskind AM, Neer C, Hussain H, Montgomery J, Latini JM, et al. Functional and anatomical differences between continent and incontinent men post radical prostatectomy on urodynamics and 3T MRI: a pilot study. Neurourol Urodyn 2015;34:527–32.

[44] Kirschner-Hermanns R, Najjari L, Brehmer B, Blum R, Zeuch V, Maass N, et al. Two- and three-/four dimensional perineal ultrasonography in men with urinary incontinence after radical prostatectomy. BJU Int 2012;109:46–51.

[45] Desautel MG, Kapoor R, Badlani GH. Sphincteric incontinence: the primary cause of post-prostatectomy incontinence in patients with prostate cancer. Neurourol Urodyn 1997;16:153–60.

[46] Strasser H, Frauscher F, Helweg G, Colleselli K, Reissigl A, Bartsch G. Transurethral ultrasound: evaluation of anatomy and function of the rhabdosphincter of the male urethra. J Urol 1998;159:100–4.

[47] Egawa S, Minei S, Iwamura M, Uchida T, Koshiba K. Urinary continence following radical prostatectomy. Jpn J Clin Oncol 1997;27: 71–5.

[48] Heesakkers J, Farag F, Bauer RM, Sandhu J, De Ridder D, Stenzl A. Pathophysiology and contributing factors in postprostatectomy incontinence: a review. Eur Urol 2017;71:936–44.

[49] Soljanik I, Bauer RM, Becker AJ, Stief CG, Gozzi C, Solyanik O, et al. Is a wider angle of the membranous urethra associated with incontinence after radical prostatectomy? World J Urol. 2014;32:1375–83.

[50] Ficarra V, Novara G, Rosen RC, Artibani W, Carroll PR, Costello A, et al. Systematic review and meta-analysis of studies reporting urinary continence recovery after robot-assisted radical prostatectomy. Eur Urol 2012;62:405–17.

[51] Groutz A, Blaivas JG, Chaikin DC, Weiss JP, Verhaaren M. The pathophysiology of post-radical prostatectomy incontinence: a clinical and video urodynamic study. J Urol 2000;163:1767–70.

[52] Giannantoni A, Mearini E, Di Stasi SM, Mearini L, Bini V, Pizzirusso G, et al. Assessment of bladder and urethral sphincter function before and after radical retropubic prostatectomy. J Urol 2004;171: 1563–6.

[53] Porena M, Mearini E, Mearini L, Vianello A, Giannantoni A. Voiding dysfunction after radical retropubic prostatectomy: more than external urethral sphincter deficiency. Eur Urol 2007;52:38–45.

[54] Matsukawa Y, Yoshino Y, Ishida S, Fujita T, Majima T, Funahashi Y, et al. De novo overactive bladder after robot-assisted laparoscopic radical prostatectomy. Neurourol Urodyn 2018;37:2008–14.

[55] Paparel P, Akin O, Sandhu JS, Otero JR, Serio AM, Scardino PT, et al. Recovery of urinary continence after radical prostatectomy: association with urethral length and urethral fibrosis measured by preoperative and postoperative endorectal magnetic resonance imaging. Eur Urol 2009;55:629–37.
[56] Chao R, Mayo ME. Incontinence after radical prostatectomy: detrusor or sphincter causes. J Urol 1995;154:16–8.
[57] Konety BR, Sadetsky N, Carroll PR, Ca PI. Recovery of urinary continence following radical prostatectomy: the impact of prostate volume—analysis of data from the CaPSURE Database. J Urol 2007;177:1423–5.
[58] Mungovan SF, Sandhu JS, Akin O, Smart NA, Graham PL, Patel MI. Preoperative membranous urethral length measurement and continence recovery following radical prostatectomy: a systematic review and meta-analysis. Eur Urol 2017;71:368–78.
[59] Dubbelman YD, Groen J, Wildhagen MF, Rikken B, Bosch JLHR. Urodynamic quantification of decrease in sphincter function after radical prostatectomy: relation to postoperative continence status and the effect of intensive pelvic floor muscle exercises. Neurourol Urodyn 2012;31:646–51.
[60] Brunocilla E, Pultrone C, Pernetti R, Schiavina R, Martorana G. Preservation of the smooth muscular internal (vesical) sphincter and of the proximal urethra during retropubic radical prostatectomy: description of the technique. Int J Urol 2012;19:783–5.
[61] Burkhard FC, Kessler TM, Fleischmann A, Thalmann GN, Schumacher M, Studer UE. Nerve sparing open radical retropubic prostatectomy—does it have an impact on urinary continence? J Urol. 2006;176:189–95.
[62] Deliveliotis C, Protogerou V, Alargof E, Varkarakis J. Radical prostatectomy: bladder neck preservation and puboprostatic ligament sparing —effects on continence and positive margins. Urol 2002;60:855–8.
[63] Lowe BA. Preservation of the anterior urethral ligamentous attachments in maintaining post-prostatectomy urinary continence: a comparative study. J Urol 1997;158:2137–41.
[64] Rocco F, Carmignani L, Acquati P, Gadda F, Dell'Orto P, Rocco B, et al. Restoration of posterior aspect of rhabdosphincter shortens continence time after radical retropubic prostatectomy. J Urol 2006;175:2201–6.
[65] Hurtes X, Roupret M, Vaessen C, Pereira H, Faivre d'Arcier B, Cormier L, et al. Anterior suspension combined with posterior reconstruction during robot-assisted laparoscopic prostatectomy improves early return of urinary continence: a prospective randomized multicentre trial. BJU Int 2012;110:875–83.
[66] Ko YH, Coelho RF, Chauhan S, Sivaraman A, Schatloff O, Cheon J, et al. Factors affecting return of continence 3 months after robot-assisted radical prostatectomy: analysis from a large, prospective data by a single surgeon. J Urol 2012;187:190–4.
[67] Lee Z, Sehgal SS, Graves RV, Su YK, Llukani E, Monahan K, et al. Functional and oncologic outcomes of graded bladder neck preservation during robot-assisted radical prostatectomy. J Endourol 2014;28:48–55.
[68] Poore RE, McCullough DL, Jarow JP. Puboprostatic ligament sparing improves urinary continence after radical retropubic prostatectomy. Urol 1998;51:67–72.
[69] Leach GE, Trockman B, Wong A, Hamilton J, Haab F, Zimmern PE. Post-prostatectomy incontinence: urodynamic findings and treatment outcomes. J Urol 1996;155:1256–9.
[70] Atiemo HO, Moy L, Vasavada S, Rackley R. Evaluating and managing urinary incontinence after prostatectomy: beyond pads and diapers. Cleve Clin J Med 2007;74:57–63.
[71] Ficazzola MA, Nitti VW. The etiology of post-radical prostatectomy incontinence and correlation of symptoms with urodynamic findings. J Urol 1998;160:1317–20.
[72] Winters JC, Appell RA, Rackley RR. Urodynamic findings in postprostatectomy incontinence. Neurourol Urodyn 1998;17: 493–8.
[73] van der Poel HG, de Blok W, Joshi N, van Muilekom E. Preservation of lateral prostatic fascia is associated with urine continence after robotic-assisted prostatectomy. Eur Urol 2009;55:892–900.
[74] Stafford RE, van den Hoorn W, Coughlin G, Hodges PW. Postprostatectomy incontinence is related to pelvic floor displacements observed with trans-perineal ultrasound imaging. Neurourol Urodyn 2018;37:658–65.
[75] Gomha MA, Boone TB. Voiding patterns in patients with post-prostatectomy incontinence: urodynamic and demographic analysis. J Urol 2003;169:1766–9.
[76] Neumann PB, O'Callaghan M. The role of preoperative puborectal muscle function assessed by transperineal ultrasound in urinary continence outcomes at 3, 6, and 12 months after robotic-assisted radical prostatectomy. Int Neurourol J 2018;22:114–22.
[77] Thompson JA, O'Sullivan PB. Levator plate movement during voluntary pelvic floor muscle contraction in subjects with incontinence and prolapse: a cross-sectional study and review. Int Urogynecol J Pelvic Floor Dysfunct 2003;14:84–8.
[78] Thompson JA, O'Sullivan PB, Briffa NK, Neumann P. Altered muscle activation patterns in symptomatic women during pelvic floor muscle contraction and Valsalva manouevre. Neurourol Urodyn 2006;25:268–76.
[79] Hall LM, Aljuraifani R, Hodges PW. Design of programs to train pelvic floor muscles in men with urinary dysfunction: systematic review. Neurourol Urodyn 2018;37:2053–87.
[80] Bo K. Pelvic floor muscle training is effective in treatment of female stress urinary incontinence, but how does it work? Int Urogynecol J Pelvic Floor Dysfunct. 2004;15:76–84.
[81] Bo K, Sherburn M. Evaluation of female pelvic-floor muscle function and strength. Phys Ther 2005;85:269–82.
[82] Morkved S, Bo K, Fjortoft T. Effect of adding biofeedback to pelvic floor muscle training to treat urodynamic stress incontinence. Obstet Gynecol 2002;100:730–9.
[83] Bo K, Talseth T, Holme I. Single blind, randomised controlled trial of pelvic floor exercises, electrical stimulation, vaginal cones, and no treatment in management of genuine stress incontinence in women. BMJ 1999;318:487–93.
[84] Burgio KL, Goode PS, Urban DA, Umlauf MG, Locher JL, Bueschen A, et al. Preoperative biofeedback assisted behavioral training to decrease post-prostatectomy incontinence: a randomized, controlled trial. J Urol 2006;175:196–201:J Sex Med; discussion.
[85] Marchiori D, Bertaccini A, Manferrari F, Ferri C, Martorana G. Pelvic floor rehabilitation for continence recovery after radical prostatectomy: role of a personal training re-educational program. Anticancer Res 2010;30:553–6.
[86] Berghmans B, Hendriks E, Bernards A, de Bie R, Omar MI. Electrical stimulation with non-implanted electrodes for urinary incontinence in men. Cochrane Database Syst Rev 2013:Issue 6. Art. No.:CD001202.
[87] Overgård M, Angelsen A, Lydersen S, Mørkved S. Does physiotherapist-guided pelvic floor muscle training reduce urinary incontinence after radical prostatectomy? A randomised controlled trial. Eur Urol 2008;54:438–48.
[88] Moore KN, Valiquette L, Chetner MP, Byrniak S, Herbison GP. Return to continence after radical retropubic prostatectomy: a randomized trial of verbal and written instructions versus therapist-directed pelvic floor muscle therapy. Urol 2008;72:1280–6.
[89] Soh JS, Lee HJ, Jung KW, Yoon IJ, Koo HS, Seo SY, et al. The diagnostic value of a digital rectal examination compared with high-resolution anorectal manometry in patients with chronic constipation and fecal incontinence. Am J Gastroenterol 2015;110:1197–204.
[90] Stafford RE, Ashton-Miller JA, Constantinou C, Coughlin G, Lutton NJ, Hodges PW. Pattern of activation of pelvic floor muscles in men differs with verbal instructions. Neurourol Urodyn 2016;35:457–63.
[91] Wang L, Lee M, Zhang Z, Moodie J, Cheng D, Martin J. Does preoperative rehabilitation for patients planning to undergo joint replacement surgery improve outcomes? A systematic review and meta-analysis of randomised controlled trials. BMJ open 2016;6:e009857.

[92] Hodges P, Stafford R, Coughlin GD, Kasza J, Ashton-Miller J, Cameron AP, et al. Efficacy of a personalised pelvic floor muscle training programme on urinary incontinence after radical prostatectomy (MaTchUP): protocol for a randomised controlled trial. BMJ open 2019;9:e028288.
[93] Centemero A, Rigatti L, Giraudo D, Lazzeri M, Lughezzani G, Zugna D, et al. Preoperative pelvic floor muscle exercise for early continence after radical prostatectomy: a randomised controlled study. Eur Urol 2010;57:1039–43.
[94] Geraerts I, Van Poppel H, Devoogdt N, Joniau S, Van Cleynenbreugel B, De Groef A, et al. Influence of preoperative and postoperative pelvic floor muscle training (PFMT) compared with postoperative PFMT on urinary incontinence after radical prostatectomy: a randomized controlled trial. Eur Urol 2013;64:766–72.
[95] Nahon I, Waddington G, Adams R, Dorey G. Assessing muscle function of the male pelvic floor using real time ultrasound. Neurourol Urodyn 2011;30:1329–32.
[96] Perretti A, Catalano A, Mirone V, Imbimbo C, Balbi P, Palmieri A, et al. Neurophysiologic evaluation of central-peripheral sensory and motor pudendal pathways in primary premature ejaculation. Urol 2003;61:623–8.
[97] Whittaker JL, Thompson JA, Teyhen DS, Hodges P. Rehabilitative ultrasound imaging of pelvic floor muscle function. J Orthop Sports Phys Ther 2007;37:487–98.
[98] Davis SN, Morin M, Binik YM, Khalife S, Carrier S. Use of pelvic floor ultrasound to assess pelvic floor muscle function in urological chronic pelvic pain syndrome in men. J Sex Med 2011;8:3173–80.
[99] Schmidt RA, Lee TD. Motor control and learning: a behavioural emphasis. 3rd ed. Champaign, Illinois: Human Kinetics Publishers; 1999.
[100] Fitts PM, Posner MI. Human performance. Belmont, CA: Brooks/Cole; 1967.
[101] Magill RA. Motor learning: concepts and applications. 6th ed. New York: McGraw-Hill; 2001.
[102] Tsao H, Hodges PW. Immediate changes in feedforward postural adjustments following voluntary motor training. Exp Brain Res 2007;181:537–46.
[103] Remple MS, Bruneau RM, VandenBerg PM, Goertzen C, Kleim JA. Sensitivity of cortical movement representations to motor experience: evidence that skill learning but not strength training induces cortical reorganization. Behav Brain Res 2001;123:133–41.
[104] Perez MA, Lungholt BK, Nyborg K, Nielsen JB. Motor skill training induces changes in the excitability of the leg cortical area in healthy humans. Exp Brain Res 2004;159:197–205.
[105] Boudreau SA, Hennings K, Svensson P, Sessle BJ, Arendt-Nielsen L. The effects of training time, sensory loss and pain on human motor learning. J Oral Rehabil 2010;37:704–18.
[106] Nudo RJ, Milliken GW, Jenkins WM, Merzenich MM. Use-dependent alterations of movement representations in primary motor cortex of adult squirrel monkeys. J Neurosci 1996;16:785–807.
[107] Hodges PW, Cresswell AG, Daggfeldt K, Thorstensson A. In vivo measurement of the effect of intra-abdominal pressure on the human spine. J Biomech 2001;34:347–53.
[108] Campbell EJM, Green JH. The variation in intra-abdominal pressure and the activity of the abdominal muscles during breathing: a study in man. J Physiol 1953;122:282–90.
[109] Smith M, Coppieters M, Hodges PW. Postural response of the pelvic floor and abdominal muscles in women with and without incontinence. Neurourol Urodyn 2007;26:377–85.
[110] Kerr R, Booth B. Specific and varied practice of motor skill. Percept Mot Skills 1978;46:395–401.
[111] Pacheco MM, Newell KM. Transfer of a learned coordination function: specific, individual and generalizable. Hum Mov Sci 2018;59:66–80.
[112] Miller JM, Ashton-Miller JA, DeLancey JO. A pelvic muscle precontraction can reduce cough-related urine loss in selected women with mild SUI. J Am Geriatr Soc 1998;46:870–4.
[113] Hennessey DB, Hoag N, Gani J. Impact of bladder dysfunction in the management of post radical prostatectomy stress urinary incontinence-a review. Trans Androl Urol 2017;6:S103–S11.
[114] Burgio KL. Update on behavioral and physical therapies for incontinence and overactive bladder: the role of pelvic floor muscle training. Curr Urol Rep 2013;14:457–64.
[115] Imamura M, Williams K, Wells M, McGrother C. Lifestyle interventions for the treatment of urinary incontinence in adults. Cochrane Database Syst Rev 2015:Issue 12. Art. No.:CD003505.
[116] Tanimoto M, Arakawa H, Sanada K, Miyachi M, Ishii N. Changes in muscle activation and force generation patterns during cycling movements because of low-intensity squat training with slow movement and tonic force generation. J Strength Cond Res 2009;23:2367–76.
[117] Sadamoto T, Bonde-Petersen F, Suzuki Y. Skeletal muscle tension, flow, pressure, and EMG during sustained isometric contractions in humans. Eur J Appl Physiol Occup Physiol 1983;51:395–408.
[118] McNeil CJ, Allen MD, Olympico E, Shoemaker JK, Rice CL. Blood flow and muscle oxygenation during low, moderate, and maximal sustained isometric contractions. Am J physiol Regulat, Integr Comp Physiol 2015;309:R475–81.
[119] Sjogaard G, Savard G, Juel C. Muscle blood flow during isometric activity and its relation to muscle fatigue. Eur J Appl Physiol Occup Physiol 1988;57:327–35.
[120] Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc 2011;43:1334–59.
[121] Braekken IH, Majida M, Engh ME, Bo K. Morphological changes after pelvic floor muscle training measured by 3-dimensional ultrasonography: a randomized controlled trial. Obstet Gynecol 2010; 115:317–24.
[122] Gandevia S. Spinal and supraspinal factors in human muscle fatigue. Physiol Rev 2001;81:1725–89.
[123] Schabrun SM, Stafford RE, Hodges PW. Anal sphincter fatigue: is the mechanism peripheral or central? Neurourol Urodyn 2011;30: 1550–6.
[124] Smith MD, Coppieters MW, Hodges PW. Postural response of the pelvic floor and abdominal muscles in women with and without incontinence. Neurourol Urodyn 2007;26:377–85.
[125] Smith MD, Coppieters MW, Hodges PW. Postural activity of the pelvic floor muscles is delayed during rapid arm movements in women with stress urinary incontinence. Int Urogynecol J Pelvic Floor Dysfunct 2007;18:901–11.
[126] Moser H, Leitner M, Baeyens JP, Radlinger L. Pelvic floor muscle activity during impact activities in continent and incontinent women: a systematic review. Int Urogyn J 2018;29:179–96.
[127] Sluijs EM, Kok GJ, van der Zee J. Correlates of exercise compliance in physical therapy. Phys Ther 1993;73:771–82.
[128] Hay-Smith EJ, McClurg D, Frawley H, Dean SG. Exercise adherence: integrating theory, evidence and behaviour change techniques. Physiotherapy 2016;102:7–9.
[129] Dumoulin C, Hay-Smith J, Frawley H, McClurg D, Alewijnse D, Bo K, et al. 2014 consensus statement on improving pelvic floor muscle training adherence: International Continence Society 2011 State-of-the-Science Seminar. Neurourol Urodyn. 2015;34:600–5.
[130] Frawley HC, Dean SG, Slade SC, Hay-Smith EJC. Is pelvic-floor muscle training a physical therapy or a behavioral therapy? A call to name and report the physical, cognitive, and behavioral elements. Phys Ther 2017;97:425–37.
[131] Dahm P, Silverstein AD, Weizer AZ, Young MD, Vieweg J, Albala DM, et al. A longitudinal assessment of bowel related symptoms and fecal incontinence following radical perineal prostatectomy. J Urol 2003;169:2220–4.

[132] Litwin MS, Sadetsky N, Pasta DJ, Lubeck DP. Bowel function and bother after treatment for early stage prostate cancer: a longitudinal quality of life analysis from CaPSURE. J Urol 2004;172:515–9.

[133] Ravi P, Karakiewicz PI, Roghmann F, Gandaglia G, Choueiri TK, Menon M, et al. Mental health outcomes in elderly men with prostate cancer. Urol Oncol 2014;32:1333–40.

[134] Chambers S, Galvão D, Green A, Lazenby M, Newton R, Oliffe J, et al. A psychosocial care model for men with prostate cancer. Sydney: Prostate Cancer Foundation of Australia and University of Technology Sydney; 2019.

[135] Kenfield SA, Stampfer MJ, Giovannucci E, Chan JM. Physical activity and survival after prostate cancer diagnosis in the health professionals follow-up study. J Clin Oncol 2011;29: 726–32.

[136] Campeggi A, Xylinas E, Ploussard G, Ouzaid I, Fabre A, Allory Y, et al. Impact of body mass index on perioperative morbidity, oncological, and functional outcomes after extraperitoneal laparoscopic radical prostatectomy. Urol 2012;80:576–84.

[137] Dorey G, Speakman M, Feneley R, Swinkels A, Dunn C, Ewings P. Randomised controlled trial of pelvic floor muscle exercises and manometric biofeedback for erectile dysfunction. Br J Gen Pract 2004;54:819–25.

[138] Liu C, Lopez DS, Chen M, Wang R. Penile rehabilitation therapy following radical prostatectomy: a meta-analysis. J Sex Med 2017;14: 1496–503.