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Preoperative exercise interventions to optimize continence outcomes following radical prostatectomy

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Abstract | Urinary incontinence is a common and predictable consequence among men with localized prostate cancer who have undergone radical prostatectomy. Despite advances in the surgical technique, urinary continence recovery time remains variable. A range of surgical and patient-related risk factors contributing to urinary incontinence after radical prostatectomy have been described, including age, BMI, membranous urethral length and urethral sphincter insufficiency. Physical activity interventions incorporating aerobic exercise, resistance training and pelvic floor muscle training programmes can positively influence the return to continence in men after radical prostatectomy. Traditional approaches to improving urinary continence after radical prostatectomy have typically focused on interventions delivered during the postoperative period (rehabilitation). However, the limited efficacy of these postoperative approaches has led to a shift from the traditional reactive model of care to more comprehensive interventions incorporating exercise-based programmes that begin in the preoperative period (prehabilitation) and continue after surgery. Comprehensive prehabilitation interventions include appropriately prescribed aerobic exercise, resistance training and specific pelvic floor muscle instruction and exercise training programmes. Transperineal ultrasonography is a non-invasive and validated method for the visualization of the action of the pelvic floor musculature, providing real-time visual biofeedback to the patient during specific pelvic floor muscle instruction and training. Importantly, the waiting time before surgery can be used for the delivery of comprehensive prehabilitation exercise-based interventions to increase patient preparedness in the lead-up to surgery and optimize continence and health-related quality-of-life outcomes following radical prostatectomy.

Prostate cancer is a common malignancy and, as the fifth most common cause of cancer deaths in men, is a global public health problem[1,2]. GLOBOCAN 2020 estimates reported 1,414,259 new cases of prostate cancer globally in 2020, with a higher prevalence in developed countries[1]. Despite geographical and ethnic variations in the incidence rate, prostate cancer is one of the most frequently diagnosed non-cutaneous cancers. The highest estimated incidence rates per 100,000 males have been reported in Australia and New Zealand, North America, Western and Northern Europe and the Caribbean[2]. The incidence rate of prostate cancer has been reported to be on an upward trajectory in Eastern Europe[2], the Middle East[3], North Africa[4] and in Central and South America[5].

Not all prostate cancer diagnoses are terminal. The indolent nature of the disease is widely recognized and can be successfully managed and treated[6]. Accurate tumour grading remains the cornerstone for diagnosis, risk stratification and clinical management decisions. Classification methods that guide the clinical management of prostate cancer incorporate tumour grade, the tumour, node, metastasis stage and PSA level. Patients with prostate cancer can be stratified into low-risk, intermediate-risk and high-risk disease groups[7]. In developed countries, most men who receive a diagnosis of prostate cancer present with organ-confined and potentially curable disease[7,8].

The high incidence rate and need for effective treatment options has led to extensive efforts to improve the assessment and clinical management of patients with prostate cancer. Treatment options continue to evolve to support patient-centred models of care, which

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Key points

- The oncological curative effectiveness of radical prostatectomy can be diminished by treatment-related adverse effects that include urinary incontinence, reduced physiological functional capacity and psychosocial well-being.
- The increasing survival of men following radical prostatectomy has resulted in the development of preoperative interventions that can improve the patients' preoperative and postoperative experience and optimize health-related quality-of-life outcomes.
- Preoperative exercise interventions comprising a combination of aerobic exercise, resistance training and specific pelvic floor muscle training programmes are designed to enhance the patients' physiological functional capacity and mitigate the treatment-related adverse effects of radical prostatectomy including urinary incontinence.
- Transperineal ultrasonography can provide a non-invasive and validated method to improve the quality and specificity of the delivery of pelvic floor muscle training interventions in men before and after they undergo radical prostatectomy.
- A structured and coordinated prehabilitation model of care can be initiated by the surgeon and delivered through their multidisciplinary team to extend the surgical care provided to patients and optimize preoperative and postoperative functional outcomes.

are based on informed and shared decision-making between the patient and their clinicians[9]. Prostate cancer encompasses a wide spectrum of disease, ranging from indolent to highly aggressive tumours. The range of treatment options available to successfully manage clinically localized prostate cancer has evolved because of the significant variation in the potential clinical course of the disease and a better understanding of the genetic and molecular profile of the disease[10–12]. These treatment options include active surveillance and definitive curative interventions including surgical resection, radiotherapy including external-beam and interstitial radiation, energy ablative technologies and/or androgen deprivation therapy (ADT)[13]. Although each treatment option has a unique efficacy profile, including treatment-related risks, benefits and adverse effects, the lack of robust comparative effectiveness trials mean that, as yet, no single treatment option has emerged as the most appropriate for patients with prostate cancer. In a patient-centred model of care, achieving the optimal balance of potential benefits, risks and adverse effects for each treatment option adds to the complexity of informed and shared clinical decision-making for patients with localized prostate cancer.

Low-risk localized prostate cancer, which includes most men with Gleason Grade Group 1 disease, can be carefully monitored and managed using active surveillance protocols, delaying the need for curative interventions until evidence of disease progression is seen. Active surveillance was developed to personalize the need for early intervention, potentially circumventing the risk of functional impairments and other negative consequences of definitive curative treatment options[14]. For men with prostate cancer who require definitive curative treatment, the management options for localized prostate cancer include radical prostatectomy, radiotherapy, focal therapy and/or ADT, low-dose-rate brachytherapy and focal therapy alone[15,16]. Men who present with locally advanced prostate cancer typically receive ADT as the primary intervention in conjunction with radiotherapy or, in some instances, surgery[17]. Although metastatic prostate cancer disease is primarily treated with ADT, clinical trials have reported the benefit of including docetaxel chemotherapy[18,19] or abiraterone acetate to improve survival[20,21]. Evidence suggests that radiotherapy and radical prostatectomy reduces disease burden and the need for palliative treatment, even in patients with metastatic disease[22].

Radical prostatectomy

The surgical technique of prostatectomy has changed considerably over time from simple prostatectomy, which removed only parts of the prostate, to removal of the entire prostate using radical prostatectomy[23] (FIG. 1). The radical approach to prostatectomy was first reported in 1905 by Hugh Hampton Young[24] and remains the mainstay of surgical curative treatment for men with localized prostate cancer. Randomized controlled trials (RCTs) have confirmed that radical prostatectomy improves prostate cancer survival and reduces the incidence of metastasis compared with observation[25,26]. The growing number of men who survive prostate cancer has widened the focus of clinical management to improve the patients' preoperative and postoperative experience, reduce the impact and hasten the recovery of treatment-related adverse effects and improve health-related quality of life.

Radical prostatectomy is a substantial life event for the patient[27]. The majority of men who undergo radical prostatectomy experience predictable functional impairments including urinary incontinence and erectile dysfunction, regardless of the surgical approach — open retropubic, perineal and minimally invasive laparoscopic or robotic-assisted surgery[28,29]. The combined effect of urinary incontinence and erectile dysfunction have far-reaching personal and societal consequences; a decrease in quality of life and psychosocial well-being, an increase in the use of health-care resources and lost work productivity[30,31]. For men undergoing radical prostatectomy, the optimal postoperative outcomes include oncological control, return of urinary continence, erectile function, physiological functional capacity, as well as improved quality of life[27,31–34]. Understanding

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the importance of the neuromuscular, vascular and soft-tissue anatomical components of the lower urinary tract, in particular the urethral sphincter complex, has been integral to the development and modifications of the surgical technique[35–37] and for the development of exercise-based therapies to improve continence outcomes following radical prostatectomy[38].

In this Review, we describe the state of the art and evidence base for the inclusion of preoperative exercise interventions to optimize functional outcomes, particularly urinary continence, after radical prostatectomy. We highlight the opportunities provided by the implementation of a prehabilitation model of care to increase patient preparedness in the lead-up to surgery to optimize continence and health-related quality-of-life outcomes following radical prostatectomy.

Urinary continence and incontinence

The functional male lower urinary tract system consists of the bladder, which acts as a reservoir, and the bladder neck, urethra and the urethral sphincter complex, which form the outlet (FIG. 2). Voluntary urination (micturition) is a fundamental human function that is dependent on the coordination of the collection, storage and the controlled periodic release of urine from the bladder. The change from a storage to a voiding function occurs under voluntary control, following either a strong sensation that bladder emptying is necessary or in anticipation that future emptying might be difficult or not possible[39]. Voluntary urination is a highly integrated function, and relies on a complex hierarchy of peripheral and central nervous system regulation that coordinates the activity of the smooth and striated musculature of the bladder and urethra[40,41]. The micturition cycle is defined according to two phases: the bladder functioning as a reservoir (storage phase) and the urine being expelled (voiding phase)[39].

The voiding phase of the micturition cycle occurs via a coordinated detrusor contraction in conjunction with the opening or release of the outlet. The relaxation of the bladder neck and urinary sphincter complex decreases urethral pressure and resistance to outflow[39,42]. At the completion of bladder emptying, voiding ceases and the lower urinary tract system returns to the default collection and storage function[43]. Urinary continence is maintained when the outlet or urethral pressure is greater than storage or bladder pressure. Conversely, when involuntary uncontrolled urinary flow occurs (urinary incontinence), bladder pressure has exceeded urethral pressure and voluntary control is diminished temporarily or lost entirely[39,44–46].

Urinary incontinence after radical prostatectomy

Following radical prostatectomy, men can experience urinary incontinence symptoms or 'leakage' in supine positions, while upright and during activities that involve effort and exertion such as coughing, standing up, lifting weighted objects and walking[47–49]. Despite the prevalence of incontinence after radical prostatectomy, no consistent or universally accepted definition of postprostatectomy incontinence is available. No consensus has been reached either for the standardization of data collection procedures to effectively quantify the degree or severity of postprostatectomy incontinence outcomes[50,51].

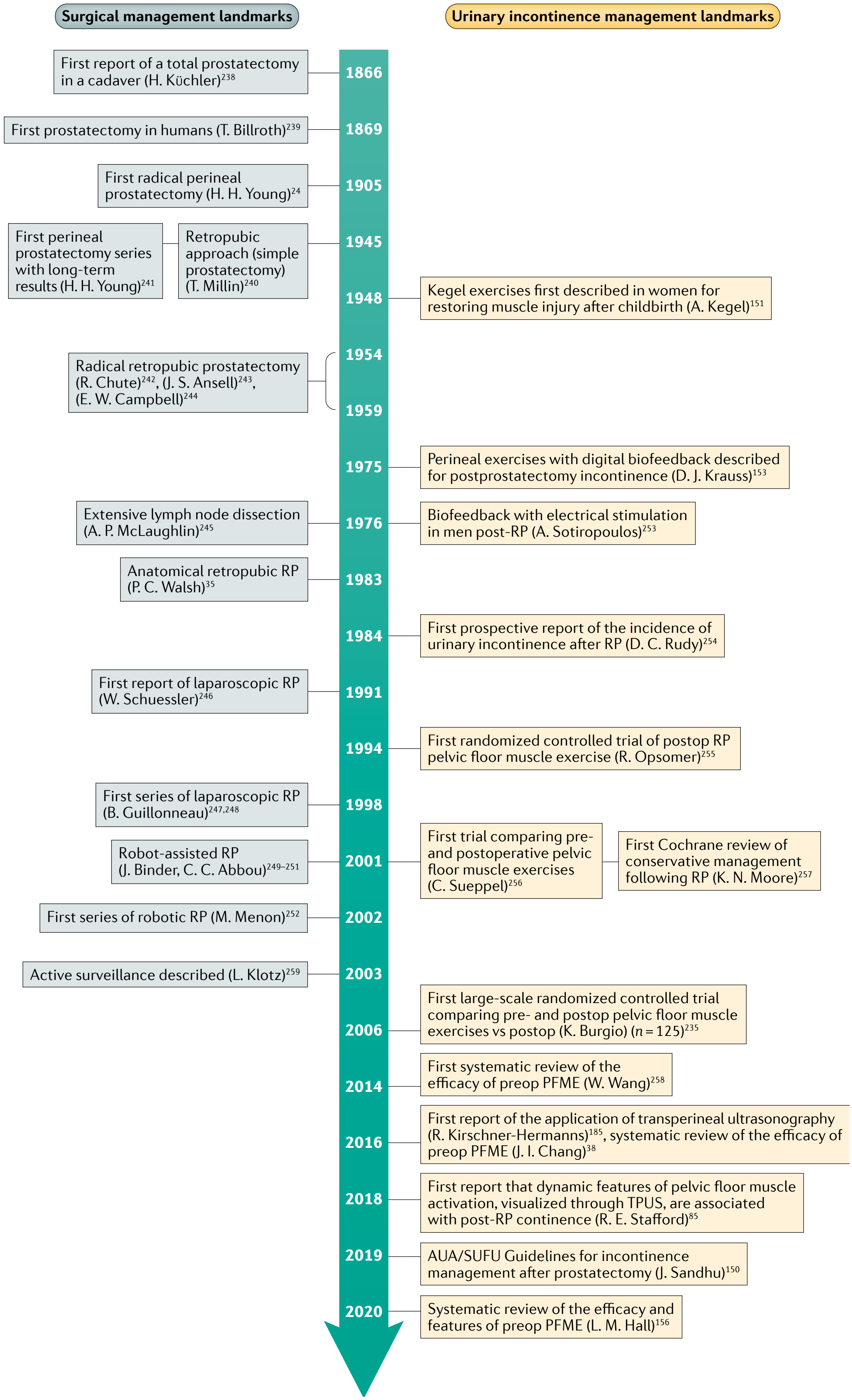
Postprostatectomy incontinence can be attributed to three types of incontinence: intrinsic urethral sphincter deficiency (stress urinary incontinence; SUI), detrusor overactivity and/or reduced bladder compliance (urge urinary incontinence), or a combination of stress and urge urinary incontinence (mixed urinary incontinence)[52–54]. SUI (also known as exertional urinary incontinence) occurs during functional activities when an increase in intra-abdominal pressure is transferred into the pelvis, resulting in uncontrolled leakage of urine[55,56]. The Prostate Testing for Cancer and Treatment (ProtecT) trial, a clinical RCT that compared active surveillance, prostatectomy and radiotherapy with ADT, reported that radical prostatectomy had the greatest negative effect on urinary continence outcomes; 46% of men who underwent radical prostatectomy reported using pads for urinary incontinence at 6 months after prostatectomy and approximately 17% were still using pads for urinary incontinence 6 years after surgery[57]. This continued use of bulky absorbent pads or diapers is often associated with embarrassment, can lead to low self-esteem and depression and compromise intimate relationships[58]. The fear of leaking urine, the continued use of absorbent pads and potential urine odours can cause men to avoid their previous physical, intimate and social activities[59]. Persistent postprostatectomy incontinence can also have economic consequences; the cost of incontinence-related health-care services, pads, diapers, undergarments[60] and delays in the return to work[32,61]. Consequently, the return to continence should be an important point of discussion between the patient and their clinicians before and after radical prostatectomy.

Pathophysiology and risk factors

The pathophysiology of incontinence in men following radical prostatectomy is not completely understood. Notably, the pathophysiology of urinary incontinence in men is less well understood than incontinence in women as it has not been investigated to the same extent.

Aetiology and pathophysiology

Typically, the recovery of continence following radical prostatectomy is one of progressive improvement, gradually resolving in the first year with further improvements in urinary continence occurring up to 2 years after surgery[54]. Although the functional anatomy of the lower urinary tract system is well described[37,62], the aetiology and pathophysiology of urinary incontinence following radical prostatectomy are less well understood. However, the variability of recovery time to continence is well documented[63,64]. The resulting variation in the recovery time to continence and the possibility of not regaining continence can be a potential barrier to patient consent for curative surgery for prostate cancer. Persistent postprostatectomy incontinence following radical prostatectomy can also contribute to decisional regret for having consented to undergo radical prostatectomy[65].


Surgical management landmarks
Urinary incontinence management landmarks
1866
First report of a total prostatectomy in a cadaver (H. Küchler)[238]
1869
First prostatectomy in humans (T. Billroth)[239]
1905
First radical perineal prostatectomy (H. H. Young)[24]
1945
First perineal prostatectomy series with long-term results (H. H. Young)[241]
Retropubic approach (simple prostatectomy) (T. Millin)[240]
1948
Kegel exercises first described in women for restoring muscle injury after childbirth (A. Kegel)[151]
1954
1959
Radical retropubic prostatectomy (R. Chute)[242], (J. S. Ansell)[243], (E. W. Campbell)[244]
1975
Perineal exercises with digital biofeedback described for postprostatectomy incontinence (D. J. Krauss)[153]
1976
Extensive lymph node dissection (A. P. McLaughlin)[245]
Biofeedback with electrical stimulation in men post-RP (A. Sotiropoulos)[253]
1983
Anatomical retropubic RP (P. C. Walsh)[35]
1984
First prospective report of the incidence of urinary incontinence after RP (D. C. Rudy)[254]
1991
First report of laparoscopic RP (W. Schuessler)[246]
1994
First randomized controlled trial of postop RP pelvic floor muscle exercise (R. Opsomer)[255]
1998
First series of laparoscopic RP (B. Guillonneau)[247,248]
2001
Robot-assisted RP (J. Binder, C. C. Abbou)[249–251]
First trial comparing pre- and postoperative pelvic floor muscle exercises (C. Sueppel)[256]
First Cochrane review of conservative management following RP (K. N. Moore)[257]
2002
First series of robotic RP (M. Menon)[252]
2003
Active surveillance described (L. Klotz)[259]
2006
First large-scale randomized controlled trial comparing pre- and postop pelvic floor muscle exercises vs postop (K. Burgio) (n = 125)[235]
2014
First systematic review of the efficacy of preop PFME (W. Wang)[258]
2016
First report of the application of transperineal ultrasonography (R. Kirschner-Hermanns)[185], systematic review of the efficacy of preop PFME (J. I. Chang)[38]
2018
First report that dynamic features of pelvic floor muscle activation, visualized through TPUS, are associated with post-RP continence (R. E. Stafford)[85]
2019
AUA/SUFU Guidelines for incontinence management after prostatectomy (J. Sandhu)[150]
2020
Systematic review of the efficacy and features of preop PFME (L. M. Hall)[156]

◀ Fig. 1 | **A timeline of surgery for prostate cancer.** The surgical technique for performing radical prostatectomy has evolved over time, from total prostatectomy in the late nineteenth century to the robot-assisted procedure in the 2000s. The development of exercise-based interventions and pelvic floor muscle exercise programmes to manage postprostatectomy incontinence has been more recent, with the development of preoperative models of care and the application of transperineal ultrasonography for pelvic floor muscle training programmes[238–258]. AUA, American Urological Association; PFME, pelvic floor muscle exercise; RP, radical prostatectomy; SUFU, Society of Urodynamics, Female Pelvic Medicine and Urogenital Reconstruction; TPUS, transperineal ultrasonography.

The membranous urethral length (MUL) — the distance from the prostatic apex to the point of entry of the membranous urethra at the penile bulb (FIG. 3) — and the preoperative and postoperative urethral sphincter function are important factors contributing to postprostatectomy incontinence[63,66–76]. The MUL ranges from 5 mm to 34 mm (REF.[71]), contains smoosth muscle fibres and is surrounded along its entire length by the striated urethral sphincter musculature (also known as the rhabdosphincter)[62,77,78]. The combined and coordinated functionality of the smooth and striated muscle fibres has an important role in maintaining and increasing urethral closure function by increasing urethral pressure[78,79]. A longer preoperative MUL is significantly associated with the return to continence after radical prostatectomy. Each extra millimetre of MUL confers a stepwise increase in the return of continence (HR 1.05, 95% CI 1.02–1.08, $P<0.001$)[71].

Urethral sphincter insufficiency (inadequate urethral sphincter function) can lead to a reduction in urethral pressure and functional urethral sphincter closure. Factors that affect urethral sphincter insufficiency include a short MUL[72], direct surgical trauma to the sphincteric muscular structures surrounding the MUL during prostate resection, a disruption to the sphincteric innervation and supporting connective tissue structures, and hypoperfusion[63,80–82]. Urodynamic investigations in men before and after radical prostatectomy have highlighted the importance of urethral sphincter closure function on continence recovery time after radical prostatectomy[68,72,74]. Impaired urethral sphincter closure and the associated reduction in the maximal urethral closure pressure before and after radical prostatectomy are associated with postprostatectomy incontinence[72–76]. A progressive and partial recovery of urethral sphincteric closure function has been reported after radical prostatectomy. Continent patients demonstrate a greater capacity to increase urethral pressure with voluntary pelvic floor muscle contractions compared with incontinent patients[72,83,84]. Continent patients are able to increase their urethral pressure 2.6 times higher than incontinent men during a voluntary pelvic floor muscle contraction (147.5 cmH_2O versus 56.3 cmH_2O, $P=0.04$)[72]. The activation and coordinated function of the pelvic floor musculature to generate urethral closure pressures contributes to functional urethral sphincter closure and has been identified as an important determinant of continence status following radical prostatectomy[85]. Prostatectomy removes the smooth muscle within the prostatic urethra, contributing to a reduction in urethral pressure[37]. A postoperative anastomotic stricture can result in a reduction in urethral pressure during pelvic floor muscle contractions owing to an increase in urethral stiffness and a decrease in urethral elasticity[63].

Surgical risk factors

Risk factors contributing to the pathophysiology of postprostatectomy incontinence can be categorized as surgery-related and patient-related. An understanding of these factors is important for risk stratification for postprostatectomy incontinence and surgical planning as well as preoperative and postoperative patient counselling. For example, understanding the surgical and patient-related risk factors can assist clinicians in explaining to patients the variability in continence recovery time that occurs between patients and if incontinence symptoms persist for an extended period of time. Preoperative and postoperative strategies to reduce postprostatectomy incontinence can be prioritized to meet the risk profile of each patient.

Regardless of the surgical approach to removing the prostate, changes will occur in the position and function of the remaining lower urinary tract anatomical structures including the bladder, membranous urethra, and the urinary sphincter complex. The urethrovesical junction is typically displaced inferiorly and the proximal membranous urethral stump is displaced within the pelvis to enable the formation of the urethrovesicular anastomosis[86–88]. The preservation of the MUL, maintaining the functional integrity of the pelvic floor musculature and the supporting urethral structures, is important in determining postoperative functional outcomes[89]. In 1905, Ballenger noted the critical relationship between the integrity of the membranous urethra and the risk of urinary incontinence, commenting "avoid laceration of membranous urethra, as incontinence of urine will follow"[90]. Knowledge of the preoperative MUL alone or when incorporated into a nomogram can lead to effective preoperative patient counselling, to providing realistic expectations for the return to continence, and to help identify patients at increased risk of urinary incontinence[91].

Surgical damage to the neuromuscular components of the membranous urethra, including the urethral sphincter complex can occur during prostatectomy, resulting in sphincter insufficiency[63]. Damage to, or removal of, the neurovascular bundles can affect continence recovery[63,92], and the substantial variability in the return to continence. To minimize surgery-related neuromuscular effects of radical prostatectomy, modifications to the surgical technique have included Retzius-sparing surgery, endopelvic fascia preservation, and the use of different sutures and stitches. However, these modifications to the surgical technique have not been universally accepted owing to the inability to identify, preoperatively, patients at high risk of urinary incontinence, concerns about overtreatment and a lack of empirical data demonstrating effectiveness of the modifications[93–95].

Whether posterior musculofascial reconstruction (the Rocco stitch) can improve continence is controversial and requires further investigation in prospective, robust, large-scale RCTs. A systematic review and meta-analysis reported that posterior musculofascial reconstruction significantly improved return to continence at 3–7 days, 30 days and 90 days after catheter removal: relative risk (RR) 1.90, 95% CI 1.25–2.90, $P = 0.003$ (9 studies, of which 1 was an RCT), RR 1.77, 95% CI 1.43–2.20, $P < 0.001$ (16 studies, of which 2 were RCTs) and RR 1.32, 95% CI 1.10–1.59, $P = 0.003$ (16 studies, of which 2 were RCTs), respectively). A smaller, but still statistically significant, advantage was observed at 6 months (RR 1.13, 95% CI 1.02–1.26, $P = 0.025$ (13 studies, of which 1 was an RCT))[96]. The surgical techniques have evolved, whereby some surgeons have proposed other operative technical steps around the urinary sphincter complex to improve continence, including a suburethral stitch, dissection methods to maximize urethral length and Retzius-sparing surgery[23]. Other surgeons advocate for a 'minimalist' approach to avoid additional damage to the striated urethral sphincter and/or its innervation[81]. Surgeon skill and experience are important determinants of the oncological (biochemical recurrence; BCR) and functional (urinary and erectile function) outcomes after radical prostatectomy. Surgeons who have performed an increased number of radical prostatectomies report improved oncological and functional patient outcomes[97–103].

Patient risk factors

Prognostic patient risk factors affect the severity, duration and the recovery of postprostatectomy incontinence[63,91]. Many of these risk factors are non-modifiable, for example, patient age[63,91,104], the preoperative MUL[71] and prostate size[63]. The duration of the continence recovery and the risk of persistent urinary incontinence symptoms increases with advancing age[63,91], a shorter MUL[71] and greater prostate size[63,66]. Advancing age and MUL have consistently been reported as predictors of poor continence outcomes and are associated with a decrease in the volume and density of striated muscle cells in the striated urethral sphincter[63,104]. Patients who present with non-modifiable risk factors should consider additional targeted preoperative interventions including a focus on training the striated urethral sphincter to mitigate the additional risk[105]. An understanding of non-modifiable risk factors can be important during preoperative discussions with patients when setting expectations about the time course of the recovery of continence and the possibility of prolonged postprostatectomy incontinence. Understanding these non-modifiable risk factors can also be motivational for patients to undertake comprehensive preoperative exercise interventions to improve the continence recovery time.

Modifiable patient risk factors for the return to continence include BMI, metabolic comorbidities such as diabetes, pre-existing lower urinary tract symptoms and a lower preoperative maximal closure pressure[54,63,68,70,83,105]. BMI is a known risk factor for prostate cancer progression and postprostatectomy incontinence[91,106]. A study of 2,849 patients from a high-volume single centre reported that the risk of incontinence at 6 and 12 months following prostatectomy increased with a shorter MUL, increasing age and BMI[91]. Exercise-based interventions include aerobic exercise, resistance training and targeted pelvic floor muscle training (PFMT) programmes and are introduced during the preoperative period to modify the risk factors to improve continence outcomes.

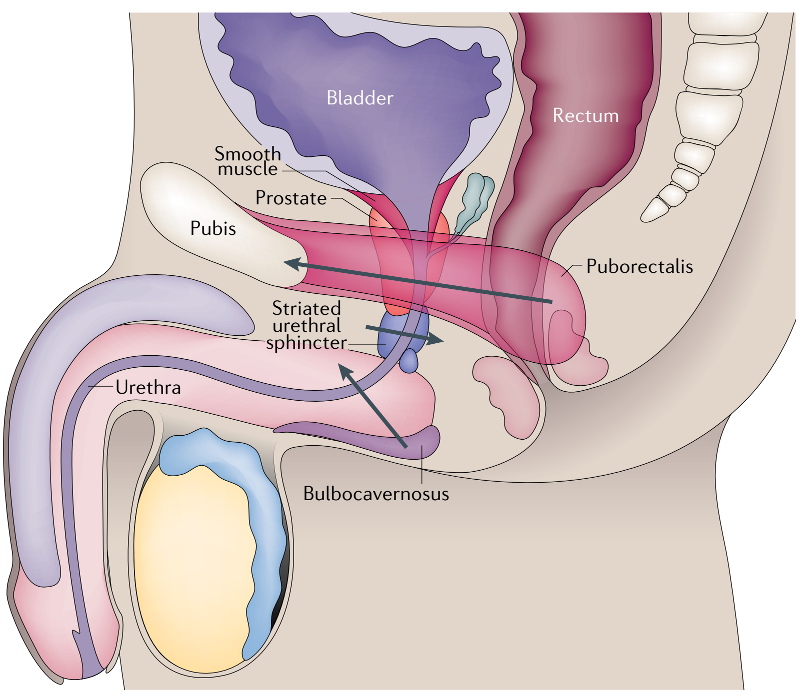


Fig. 2 | **A sagittal view of the anatomy of the male lower urinary tract system.** The action of the puborectalis, striated urethral sphincter and bulbocavernosus muscles during voluntary pelvic floor muscle contraction is indicated by the arrows. Reprinted with permission from REF.[157], Elsevier.

Rehabilitation and prehabilitation

The excellent long-term oncological outcomes associated with radical prostatectomy have shifted the focus from oncological control to refinement of the surgical technique and delivering interventions to optimize postoperative functional outcomes. A return to continence is a major priority for the patient, the surgeon and their multidisciplinary health-care team. Traditional approaches to improving postprostatectomy continence outcomes have focused on technical advances in the surgical technique and postoperative PFMT interventions or rehabilitation[64,107]. For persistent postprostatectomy incontinence, where conservative treatments have not been effective, surgical placement of a circumferential artificial urinary sphincter or a non-circumferential retrourethral transobturator sling device is used for the management of patients with persistent postprostatectomy incontinence symptoms[108]. The traditional model of care for the management of postprostatectomy incontinence has focused on treatment interventions commencing in the postoperative period. Such an approach to clinical management disregards the opportunities offered by those same treatment interventions delivered in the preoperative period and known as 'prehabilitation'.

Prehabilitation

In prostate cancer care, prehabilitation is a model of care that commences preoperatively. The aim of preoperative interventions is to improve the postoperative functional capacity, the trajectory of the recovery from urinary continence, and patient well-being and quality of life[38,109–111]. The duration of a patient-centred prehabilitation programme is determined partly by the length of each patient's surgical wait time, which is defined as the time from prostate cancer diagnosis to the date of surgery. Surgical wait time can typically range from less than 2 weeks to several months, depending upon the patient, surgeon, hospital, health-care system, health insurance status and societal factors including access to health care and transportation[112–117]. Countries operating under publicly funded health-care systems, such as Sweden, the UK, Canada and Australia, have surgical wait times for radical prostatectomy[112–114]. For example, the mean surgical wait time for radical prostatectomy in Sweden in 2017 was 38 days, with the mean total time from the initial referral to the urologist by the primary care practitioner to the date of surgery 137 days[114]. The 2017–2018 mean wait time from prostate cancer diagnosis to surgery in public hospitals in Australia was 47 days[115].

In countries where private health-care systems operate, the surgical wait time at private hospitals can be determined by the surgeon and/or institutional availability and insurance clearance requirements. Additional tests, examinations and prostate cancer staging investigations, such as CT imaging, bone scans and PSMA-PET scans can increase the surgical wait time[118]. The current clinical management of the COVID-19 pandemic has affected health-care resource allocation, resulting in an increase in wait time for curative oncological procedures, for example, radical prostatectomy[119,120]. The involvement of multidisciplinary health-care teams, in which the patient plan of management includes a comprehensive informed and shared decision-making protocol, might result in patients taking additional time to seek a second opinion from other specialists, including urologists, radiation oncologists or medical oncologists. The surgical wait time, once viewed as an impediment, now presents a unique opportunity for implementation of prehabilitation programmes to prepare patients physically and psychologically to mitigate the predictable consequences of radical prostatectomy. Shorter surgical wait times can limit the prehabilitation opportunity[121].

During the surgical wait time, patients can experience anxiety, uncertainty, depression and fear of disease progression[122,123]. The effects of surgical wait times on oncological outcomes and survival rates following radical prostatectomy have been investigated with conflicting results. Some studies have supported[124–126] and others have refuted[117,127–133] the increased risk of poorer oncological outcomes from extended surgical wait times. At present, no consensus or evidence-based guidelines have been established to define a safe maximum surgical wait time for the management of clinically localized prostate cancer. Clinically, the recommended maximum surgical wait time for men with high-grade disease is shorter than that for men with low-risk disease[134,135]. Abern and colleagues reported a significantly increased risk of positive surgical margins and BCR after radical prostatectomy among men with intermediate-risk prostate cancer when surgery was delayed by >9 months (odds ratio (OR) 4.08, 95% CI 1.52–10.91, $P = 0.005$ for positive margins and HR 2.19, 95% CI 1.24–3.87, $P = 0.007$ for BCR)[127]. However, Vickers and colleagues report data from 3,149 consecutive patients undergoing radical prostatectomy and found no significant evidence that delaying the time between diagnosis and surgery increased the risk of BCR at 3, 5, 8 and 10 years (ORs per month delay were all close to 1, all P values > 0.2). For patients undergoing surgery <6 months after diagnosis, the OR for each additional month of delay was 1.07 (95% CI 0.94–1.21, $P = 0.3$) for 5-year BCR and 1.02 (95% CI 0.85–1.22, $P = 0.9$) for 10-year BCR. Taken together, these results suggest that the effect of surgical wait time on oncological outcomes is moderate at 6–12 months; however, the 95% confidence intervals (CIs) were wide and included the possibility that minor

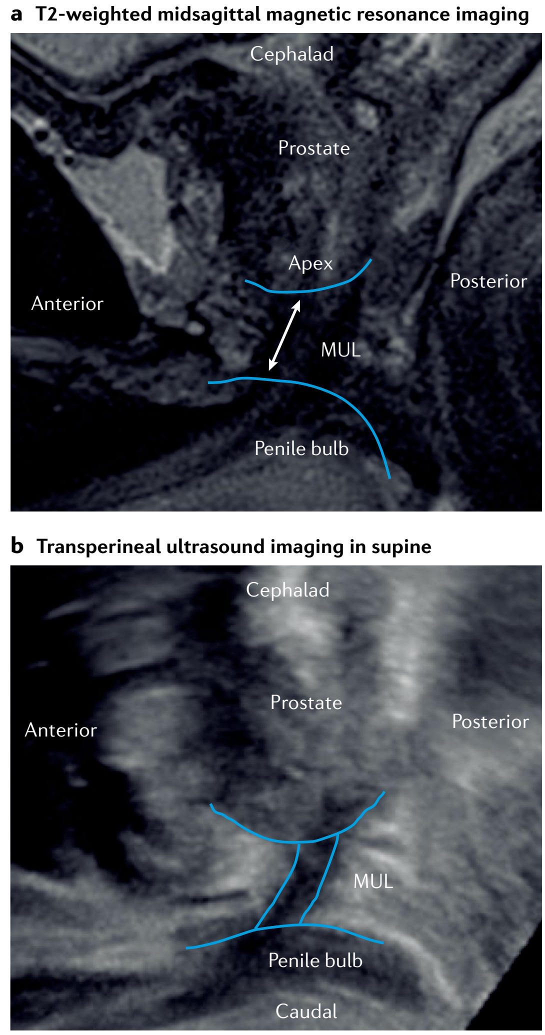


Fig. 3 | **Imaging measurement of membranous urethral length.** These images show a T2-weighted mid-sagittal magnetic resonance image (part **a**) and a 2D transperineal ultrasound image of the male lower urinary tract system (part **b**). The apex of the prostate, the penile bulb and the membranous urethra are identified. The length of the membranous urethra is measured from the apex of the prostate to the point of entry at the penile bulb. MUL, membranous urethral length. Adapted with permission from REF.[192], Taylor & Francis.

delays in surgery might have a large impact on the risk of BCR[130]. These data are supported by further studies. Redaniel and colleagues found no significant difference in 5-year and 10-year survival in men who underwent radical prostatectomy at 0–3 months after their diagnosis compared with men who underwent radical prostatectomy 4–6 months after diagnosis (5-year relative survival (a measure of survival, having accounted for underlying mortality rates) 1.04, 95% CI 1.03–1.04 in those men who underwent surgery at 0–3 months after diagnosis, versus 1.05, 95% CI 1.04–1.05 among those who had surgery at 4–6 months after diagnosis; 10-year relative survival 1.07, 95% CI 1.05–1.09 versus 1.08, 95% CI 1.06–1.10, *P* not reported)[132]. Boorjian and colleagues used multivariate modelling to adjust for year of biopsy, PSA before biopsy, clinical stage and biopsy Gleason score, and reported that surgical wait time before prostatectomy within 1 year of diagnosis (either as continuous variable or categorized at 3 months) was not associated with a significantly increased risk of BCR (HR 0.98, 95% CI 0.95–1.02, $P = 0.252$ for the continuous variable and HR 1.01, 95% CI 0.81–1.26, $P = 0.939$ for the categorical variable)[131]. Finally, Lee and colleagues reported no significant correlation between the biopsy-to-surgery time that ranged from 14 to 378 days and postoperative oncological outcomes (multivariate logistic regression adjusting for Gleason score, PSA at biopsy and age, OR 0.999, 95% CI 0.991–1.006, $P = 0.715$ for positive surgical margins and OR 0.994, 95% CI 0.971–1.017, $P = 0.62$ for BCR)[117].

A structured, targeted and coordinated prehabilitation model of care led by the surgeon and delivered through their multidisciplinary health-care team can extend the surgical care provided to the patient. Surgical wait time should now be considered an important component of the patients' surgical care pathway, during which time each patient actively participates in a structured and defined programme of prehabilitation. This prehabilitation period is aimed at reducing the patient's risk of postoperative functional impairments before their surgery and increasing their physical functional capacity, including aerobic exercise capacity, muscle strength and psychosocial well-being. Such prehabilitation programmes that incorporate exercise-based interventions represent a shift from the traditional 'reactive' postoperative rehabilitation model for managing the predictable consequences of radical prostatectomy to a 'proactive' model that provides 'patients with the opportunity to be an active participant in the clinical management of his prostate cancer. Prehabilitation programmes can be individually designed and implemented to address and manage each patient's risk factors and to improve the postoperative physical and psychosocial outcomes.

Multidimensional prehabilitation programmes can incorporate structured exercise, psychological, nutritional and behavioural interventions. Exercise-based prehabilitation programmes are based on the principles that a structured and sustained exercise-training stimulus during the surgical wait time can lead to positive physiological adaptations and psychological benefits, with significant positive consequences for the patient preoperatively and postoperatively[38,109–111].

Preoperative exercise-based interventions

Prescribing an appropriate exercise stimulus for men before their radical prostatectomy surgery can result in beneficial adaptations at the individual muscle level and across the cardiovascular, respiratory, musculoskeletal, neurological, metabolic and endocrine body systems. In addition to these physiological adaptations are positive psychosocial benefits, including a decrease in anxiety, improving mood and quality of life and reduced sick leave[109,136–138]. Physical exercise interventions to improve functional outcomes before and after radical prostatectomy are categorized as aerobic exercise, resistance training and specific PFMT programmes. Prescribed exercise interventions require regular and sustained patterns of exercise behaviours in the preoperative period that are maintained and transferred into the postoperative period. Despite the increasing prescription of exercise in the preoperative period, little consensus exists as to the optimal exercise dose–response relationship. For example, exercise recommendations vary regarding the numbers of weeks prior to prostatectomy to commence the pelvic floor muscle exercise (PFME) programme, the number of sessions per day, the number of repetitions per session to optimize postsurgical outcomes after radical prostatectomy[139].

Aerobic exercise and resistance training

Radical prostatectomy results in a decreased physiological functional capacity[28]. Contributing to the decrease in physiological functional capacity are the effects of the surgery, anaesthesia, wound healing, generalized fatigue and subsequently reduced physical activity during the postoperative period[28,140]. Surgeons typically recommend that patients stay 'physically active', but often do not offer any specific exercise prescription to do so. Aerobic exercise typically incorporates activities using large muscle groups, for example, walking, running and cycling. Aerobic exercise can be continuous or intermittent and undertaken over varying periods of time and with different levels of intensity. The dose of aerobic exercise includes the frequency (times per week), duration (the length of each session (mins)) and the length of the entire exercise programme (weeks). The intensity of the exercise prescribed is usually a percentage of a maximum physiological response; for example, the age-predicted maximum heart rate (calculated HR_{max}) or measured or predicted oxygen uptake, or as a rating of perceived exertion (effort) using the Borg Scale[141]. The American Cancer Society's Nutrition and Physical Activity Guidelines for Cancer Survivors recommend undertaking a minimum amount of 'moderately' intense aerobic exercise for a total of 150 min per week, in bouts of 10 min or more[142] or when time is a barrier, patients undertake a minimum of 75 min of 'vigorously' high-intensity aerobic exercise per week with similar effect[142]. The American Cancer Society[142], American College of Sports Medicine[143] and Physical Activity Guidelines Advisory Committee's physical activity guidelines have recommended aerobic exercise intensities for cancer survivors[144] (TABLE 1). Such recommendations are only general guidelines that can guide patient-centred programmes. Each exercise prescription

Table 1 | **Recommended exercise intensity based on guidelines for cancer survivors**

Exercise category	HR_{max} (%)	Rate of perceived exertion (Borg Scale)	Recommended duration
Mild	<60	≤10	NA
Moderate	60–84	11–14	150 min per week
Vigorous/high-intensity	≥85	≥15	75 min per week

Recommendations based on the American Cancer Society[142], American College of Sports Medicine[143] and Physical Activity Guidelines Advisory Committee[144]. NA, not applicable; HR_{max} age-predicted maximum heart rate, calculated as 220 – age (years).

should be tailored to each patient's medical history, physical capabilities and health status.

By contrast, resistance training involves repeated sets of movements against an external load or resistance[142]. In a systematic review and meta-analysis of 25 RCTs involving 819 participants, Borde and colleagues reported that resistance training programmes in healthy men 60–90 years of age resulted in a significant increase in upper and lower limb muscle strength compared with a control group of men who were not physically active (standardized mean difference between groups across studies SMD_{bs} 1.57, 95% CI 1.20–1.94, $P<0.01$) indicative of a large effect size (Cohen's d ≥ 0.80)[145]. The benefits of resistance training programmes can extend beyond improvements in muscle strength and morphology, with improvements in functional mobility (walking endurance, gait speed, stair climbing), balance and falls prevention. Resistance training programmes of longer duration can result in greater increases in muscle strength. The resistance training programmes of 50–53 weeks typically have the greatest effect[145] (TABLE 2). Although the duration of preoperative resistance training programmes will be largely determined by the surgical wait time; a study of men aged 70–80 years reported a significant increase in maximum lower limb muscle strength after 4 weeks of resistance training (from a mean of 41.9 kg (standard error of the mean (s.e.m.) 6.3) to 57.3 kg (s.e.m. 7.4) in the intervention group, $P<0.001$) compared with control and aerobic exercise groups[146]. The resistance training exercise dose for this investigation included low-intensity resistance training for weeks 1 and 2: 50% of 1 repetition maximum (1RM), where 1RM is equal to the maximum weight that can be lifted for one repetition only, 3 sets of 8–10 repetitions and 3 sessions/week; followed by high-intensity resistance training for weeks 3 and 4: 70–80% of 1RM, 3 sets and 6–10 repetitions and 3 sessions/week[146]. The recommended dose is consistent with that described by Borde and colleagues[145].

The benefits of a structured prehabilitation programme for the patient have been reported. An RCT that included 86 men undergoing radical prostatectomy reported that prehabilitation — comprising 60 min of home-based moderately intense exercise, 3 to 4 days per week, for approximately 6 weeks before surgery — significantly decreased participants' BMI and waist circumference (mean between-group difference 0.48 kg/m^2, 95% CI 0.16–0.79, $P=0.003$, 1.38 cm, 95% CI 0.20–2.55, $P=0.022$), improved the 6-min walk test distance (m) at 4 weeks (mean between-group difference 39 m, 95% CI 11–66, $P=0.006$), and reduced anxiety (mean between-group difference in Hospital Anxiety and Depression Scale score −1.59, 95% CI −2.99 to −0.20, $P=0.025$) compared with controls. The controls received usual care that included information about PFMT, mobilization and time frames for the return to normal activities from a urology nurse over the phone and in a study manual. No adverse events were reported[109,147]. Further support for prehabilitation programmes is from an observational study of men undergoing radical prostatectomy who were prescribed a supervised resistance and aerobic exercise programme twice a week, for 6 weeks before surgery. A significant increase in muscular strength (increased by 7.5% to 24.3%, $P<0.05$) and a decrease in 400-m walk test time by 7.4% between baseline and presurgery (mean difference −17.2 s faster, 95% CI −30.3, −4.1, $P=0.012$) were reported. These significant improvements in strength and 400-m walk test time were maintained postoperatively. Importantly, no adverse effects of the combined exercise programme were reported[148].

Pelvic floor muscle training

Exercising the pelvic floor musculature is the primary, non-invasive conservative intervention for the management of postprostatectomy incontinence[108]. PFMT can be defined as 'any programme of repeated voluntary pelvic floor muscle contractions taught by a health-care professional'[149]. The American Urological Association (AUA) and Society of Urodynamics, Female Pelvic Medicine and Urogenital Reconstruction (SUFU) both distinguish between PFMEs, which are self-guided programmes, and PFMT, which involves a health-practitioner-guided training programme specific to the pelvic floor musculature[150]. PFMT for urinary incontinence in women is well-described. In 1948, Arnold Kegel first described pelvic floor exercises for women with SUI[151]. PFMT for female incontinence has evolved considerably since that time[152]. In 1975, Krauss and colleagues described perineal exercises with digital biofeedback to 're-educate' the sphincter in men who had undergone radical prostectomy[153]. However, the development and delivery of PFMT programmes for men undergoing radical prostatectomy is variable[139,154]. The standard of care for men has traditionally included non-standardized verbal and written instructions to teach and encourage 'Kegel exercises' before surgery and then instructions for the patient to commence limited PFMT after their surgery[139]. The Kegel exercise programme typically focuses on concentric contractions of the pelvic floor musculature whilst in stationary postures, such as sitting, and not necessarily during coordinated dynamic functional tasks, such as standing up, walking or lifting weighted objects, which typically provoke postprostatectomy incontinence symptoms. This ad hoc approach to the teaching and prescription of PFMEs can result in men not performing these exercises correctly and not achieving the expected pelvic floor muscle adaptations[139,155,156]. Furthermore, the composition of the reported PFMT interventions is particularly heterogeneous. The duration of treatment sessions to teach pelvic floor muscle contractions can range from 15 to 90 min, the number of sessions provided can range

Table 2 | **Recommendations for resistance training programmes in healthy older men**[145]

Resistance training factors	Recommendation
Types of resistance training equipment that can be used	Resistance bands, free weights, weight machines and body weight exercise that incorporate large muscle groups
Type of muscle contraction	Concentric, eccentric and isometric
Training frequency (number of sessions per week)	A minimum of two non-consecutive sessions per week
Training intensity, percentage of 1RM[a]	High: ≥70% 1RM; moderate: <50–70% 1RM; low : ≤50% 1RM 70–79% 1RM for optimal strength training effects
Number of repeated bouts (sets) per muscle group	Two to three sets per muscle group exercise, 60-s rest between each set
Number of repetitions ('reps') within each set of exercise	7–9 reps per set, 4-s rest between each repetition

[a]1RM is equal to the maximum weight that can be lifted for one repetition only.

between 1 and 74 sessions and the quality of the training instructions can vary[139]. As a result, the modest reported efficacy of postoperative PFMT programmes might be due to the ad hoc instructions and prescription of the exercise training intervention rather than the intervention itself[156,157]. Despite the limited efficacy, postoperative training of the pelvic floor musculature continues to be the primary treatment approach to postprostatectomy incontinence[53,150].

The suggested mechanisms of action for PFMT to improve continence outcomes after prostatectomy are mediated through an improvement in activation, coordination, strength and endurance of the pelvic floor musculature[157]. The reported hypertrophy of the striated muscles and an increase in strength, endurance and coordination of the pelvic floor musculature can amplify urethral pressure to reduce postprostatectomy incontinence symptoms[157–159]. The efficacy of PFMEs and/or PFMT might depend on the pelvic floor muscle targeted and the exercise training stimulus applied to the targeted pelvic floor muscle[157]. Continence recovery after radical prostatectomy is associated with an increase in striated pelvic floor muscle function[85,160]. Men who regain continence after radical prostatectomy demonstrate a greater displacement of the mid-urethra (striated urethral sphincter), anorectal angle (puborectalis) and the penile bulb (bulbocavernosus) during voluntary pelvic floor muscle contractions and when coughing than men with postprostatectomy incontinence and men who have not undergone radical prostatectomy[160]. When striated urethral sphincter function is reduced following prostatectomy, compensatory activation of the bulbocavernosus and puborectalis has been identified[85].

Evidence for rehabilitative PFMT. Prescribing PFMEs in the management of postprostatectomy incontinence remains part of the current standard of care after radical prostatectomy, as recommended in clinical practice guidelines[161]. The 2019 AUA/SUFU guideline for incontinence after prostatectomy recommends that clinicians offer PFMEs and/or PFMT in the 'immediate postoperative period'[150]. RCTs have supported the notion that PFMEs and/or PFMT started postoperatively to improve the time-to-continence compared with controls (in most studies, controls receive usual care; verbal and/or written instructions to start limited PFMEs postoperatively)[150,156,162–165] (TABLE 3). However, a 2020 systematic review and meta-analysis that included 10 RCTs of PFMEs starting postoperatively found no significant difference in the risk of incontinence 3 months after surgery between men who had performed postoperative PFMEs and the control group (in most studies, usual care) (RR 0.90, 95% CI 0.79–1.02, $P = 0.10$)[156]. Similarly, other studies of PFMEs commencing after surgery have also reported no significant differences in long-term urinary continence outcome between men who received the postoperative PFMT intervention versus controls (in most studies, usual care)[154,155,166,167]. A 2015 Cochrane review that included eight RCTs comprising a total of 2,736 patients found no significant difference in 12-month continence rates between men who undertook postoperative PFMEs and/or PMFT compared with control patients who did not (57% urinary incontinence at 12 months in the intervention groups versus 62% in the control group; RR 0.85, 95% CI 0.60–1.22)[166].

The prescribed intensity of the PFME or PFMT programme might partially explain its efficacy. A meta-analysis showed that postoperative PFME training comprising at least 3 sets of 10 repetitions per set daily improved urinary incontinence in both the short term (RR 2.16, 95% CI 1.79–2.60 at 3 months, $P < 0.001$, 4 studies) and the long term (RR 1.23, 95% CI 1.04–1.47 at 12 months, $P = 0.019$) when compared with controls[162]. The long-term data included 3 studies, one of which used an intensive programme that started at the time of catheter removal and continued while incontinence persisted[168].

Evidence for prehabilitative PFMT. PFMT can be effective at restoring continence after radical prostatectomy if men are taught to correctly activate and effectively train the pelvic floor musculature starting before surgery (prehabilitation), rather than after surgery (rehabilitation). The biological rationale for starting PFMT before surgery includes an increase in the neuromuscular reserve, that includes increased muscle mass, strength and endurance of the striated muscles of the pelvic floor to compensate for the loss of smooth and striated muscles during radical prostatectomy[157]. In addition, the preoperative PFMT prepares patients with the motor skills to begin exercise immediately after removal of the urinary catheter[157,169].

Although the 2019 AUA/SUFU guideline states that the "effectiveness of PFME/PFMT has not been definitively shown in the preoperative period", those same guidelines recommend that patients can be offered prehabilitative PFME and/or PFMT because the "potential benefits outweigh any potential risks"[150]. The guidelines suggest starting exercises 3–4 weeks preoperatively to enable neuromuscular adaptation to increase the neuromuscular reserve.

The evidence supporting the commencement of PFMEs preoperatively is growing. A number of studies have compared preoperative PFMT with control groups,

Table 3 | **Trials of prehabilitative PFME programmes versus standard of care**

Refs	Study design	Intervention	Control	Time of postoperative evaluation	Outcomes	Limitations	Authors' conclusions
Yoshida et al. (2019)[188]	Prospective cohort	PFMT with TPUS biofeedback for <4 weeks preoperatively (*n* = 36)	Verbal instructions after RP (*n* = 80)	1, 3, 6 months	Time to continence recovery: intervention: 76 ± 100 days; control: 122 ± 132 days ($P = 0.037$); continence defined as number of days requiring a small pad (20 g) per day by self-report	Small study Not an RCT; risk for selection bias Imbalanced study groups	Preoperative TPUS-PFMT was associated with early recovery of urinary continence after RP
Milios et al. (2019)[228]	RCT	PFMT (6 sets/day) with transabdominal ultrasound biofeedback 5 weeks preoperatively and for 12 weeks postoperatively (*n* = 50)	Preoperative PFMT (3 sets/day) 5 weeks preoperatively and for 12 weeks postoperatively (*n* = 47)	2, 6, 12 weeks	Continent at 6 weeks: intervention: 32%; control: 11% ($P < 0.05$); continent at 12 weeks: intervention: 74%; control: 43% ($P < 0.05$); continence defined using 24-h pad weight	Small study Control group also received preoperative care, but a less intense programme	An intensive PFMT programme commenced before RP improved postoperative PFM function and urinary continence
Aydin Sayilan and Ozbas (2018)[229]	RCT	Supervised and unsupervised 6-month Kegel exercise programme with transabdominal ultrasound biofeedback starting 1 week preoperatively (*n* = 30)	No PFME (only breathing exercises) (*n* = 30)	1, 3, 6 months	ICIQ-UI at 3 months, mean (s.d.). intervention: 9.0 (3.6); control: 14.3 (3.3) ($P < 0.01$); ICIQ-UI at 6 months: intervention: 6.2 (2.9); control: 14.6 (3.0) ($P < 0.01$); no pads Pad use at 1/3/6 months: intervention: 20%/23.3%/50%; control: 6.7%/3.3%/3.3% Primary definition of continence: ICIQ-UI = 0; secondary definition = pad use	Small study No exercises at all in the control group	PFMEs are suitable for patients experiencing incontinence after RP
Dijkstra-Eshuis et al. (2015)[230]	RCT	PFMT with biofeedback for a minimum of 4 weeks preoperatively (*n* = 65)	Standard of care (*n* = 56)	6 weeks, 3, 6, 9,12 months	1 year: intervention: 65.5% continent; control: 80%; continence defined as 0 g on 24-h pad weight test ($P > 0.05$)	In all patient groups, continence was achieved in 72% at 1 year postoperatively	No significant difference between groups at 1 year
Ocampo-Trujillo et al. (2014)[231]	RCT	Supervised PFMT, 3 times/day for 4 weeks preoperatively with biofeedback (*n* = 8)	Routine pre-surgical education (dietary and general health measures) (*n* = 8)	8 weeks	No pads at the time of catheter removal postoperatively: intervention: 75%; control: 25% (*P* = NS); continence defined as 0 g on 3 consecutive 24-h pad tests	Small study (*n* = 16); short follow-up period	No significant difference between groups at the time of catheter removal, but changes in the histology and function of the PFMs were identified
Patel et al. (2013)[190]	Retrospective	Physiotherapist-guided PFMT with verbal and visual biofeedback for up to 4 weeks preoperatively (*n* = 152)	Verbal instruction about PFME by the surgeon (historical control) (*n* = 132)	6 weeks and 3 months	6 weeks: mean 24-h pad weight; intervention: 9 g; control: 17 g ($P < 0.001$) 3 months: intervention: 4 g; control: 2 g ($P = 0.18$); continence defined as <2 g on 24-h pad weight test	Non-randomized	Starting physiotherapist-led PFMT preoperatively reduces the duration and severity of early urinary incontinence
Geraerts et al. (2013)[232]	RCT	Physiotherapist-guided PFMT with digital or EMG biofeedback for 3 weeks preoperatively (*n* = 91)	PFME after catheter removal (*n* = 89)	1, 3, 6, 12 months	Median time to continence: intervention: 30 days; control: 31 days ($P = 0.88$); time to continence main outcome measure	Short preoperative training period focused on teaching awareness of the PFMs	Standard postoperative continence rehabilitation could not be improved by adding 3 preoperative training sessions of PFME

Table 3 (cont.) | **Trials of prehabilitative PFME programmes versus standard of care**

Refs	Study design	Intervention	Control	Time of postoperative evaluation	Outcomes	Limitations	Authors' conclusions
Tienforti et al. (2012)[233]	RCT	One physiotherapist-guided PFMT session the day before surgery with verbal and visual biofeedback and one session upon catheter removal; monthly sessions thereafter (*n* = 16)	Oral and written instructions on Kegel exercises after catheter removal (*n* = 16)	1, 3, 6 months	6 months: intervention: 10/16 patients continent; control: 1/16 patients continent ($P = 0.002$); continence defined as ICIQ-UI score = 0	Only one preoperative session and on the day before surgery	Preoperative PFMT with monthly postoperative PFME sessions is significantly more effective than the standard of care in improving continence recovery
Centemero et al. (2010)[169]	RCT	Physiotherapist-guided PFMT with verbal and visual feedback starting 30 days preoperatively (*n* = 59)	Postoperative PFME (*n* = 59)	1 and 3 months	1 month: intervention: 44.1% continent; control: 20.3% ($P = 0.018$); 3 months: intervention: 59.3% continent; control: 37.3% ($P = 0.028$); continence defined as no urinary leakage reported in patient's bladder diary and a negative stress test	Short follow-up	Preoperative PFME may improve early continence and QoL after RP but might not change the long-term outcome
Dubbelman et al. (2010)[234]	RCT	Information folder 1 day preoperatively and 9 physiotherapist-guided PFMT sessions postop (*n* = 34)	Information folder only (*n* = 36)	1, 4, 6, 12, 26 weeks	6 months: intervention: 30% continent; control: 27% continent; continence defined as urine loss of <1 g at 1-h pad test and <4 g on 24 h pad test	Information starting 1 day preoperatively	No significant difference between trial arms
Burgio et al. (2006)[235]	RCT	Single preoperative session of physiotherapist-guided PFMT with visual biofeedback and rectal probe (*n* = 63)	Postoperatively PFME (*n* = 62)	6 weeks, 3 and 6 months	Intervention: median time to continence 3.5 months; control: median time to continence >6 months ($P = 0.04$); 6 months; intervention: severe/continual leakage; intervention: 5.9%; control: 19.6% ($P = 0.04$); continence defined as 3 consecutive weekly 1-day diaries that showed no leakage, or a completed 7-day diary with no leakage	Single preoperative session	Preoperative behavioural training can increase the recovery or urinary control and decrease the severity of incontinence following RP
Parekh et al. (2003)[236]	RCT	Physiotherapist-guided PFMT (2 sessions preoperatively, every 3 weeks for 3 months postoperatively after catheter removal) with verbal cues, visual biofeedback, digital palpation and EMG rectal probes (*n* = 19)	No formal PFME instructions	6, 12, 16, 20, 28, 52 weeks	12 weeks: intervention: 13 (68%) continent; control: 7 (37%) ($P < 0.05$); median time to continence: intervention: 12 weeks; control: 16 weeks ($P < 0.05$); continence defined as needing 0 to 1 pad/day	Small sample size	Starting physiotherapist-led PFMT preoperatively leads to earlier return of urinary control
Bales et al. (2000)[237]	RCT	Graded PFMT before and after surgery and with biofeedback by a trained nurse (anal pressure probe or perineal patch electromyography) for 2–4 weeks preoperatively (*n* = 50)	Written and brief verbal instructions in PFME before and after surgery (*n* = 50)	1, 2, 3, 4, 6 months	6 months: intervention: 94% continent; control: 96% ($P = 0.596$); continence defined as ≤1 pad/day	Patients received only one preoperative biofeedback session. Method of biofeedback (surface electrodes)	Preoperative biofeedback training did not improve urinary continence overall or the rate of return of continence in men undergoing RP

EMG, electromyography; ICIQ-UI, International Consultation on Incontinence–Urinary Incontinence; NS, not significant; PFME, pelvic floor muscle exercise; PFMs, pelvic floor muscles; PFMT, pelvic floor muscle training; QoL, quality of life; RCT, randomized controlled trial; RP, radical prostatectomy; TPUS, transperineal ultrasound.

with training programmes starting more than 4 weeks before surgery (TABLE 3). Two systematic reviews and meta-analyses have pooled the results from these studies: Chang et al. (7 studies of preoperative PFMEs)[38] and Hall et al. (15 studies: 5 preoperative PFMEs, 10 postoperative PFMEs)[156]. In the 2016 review of seven studies, Chang et al. reported a 36% improvement in continence at 3 months in men who performed preoperative PFMEs compared with control patients, most of whom received usual care (OR for incontinence 0.64; 95% CI 0.47–0.88, $P = 0.005$). However, no significant difference was observed in the continence recovery outcomes between intervention and control groups 6 months after surgery[38]. These data suggest that the types of preoperative PFME and the way in which PMFT is delivered in these studies might be critical to hastening the recovery of continence and decreasing the duration and severity of the postprostatectomy incontinence symptoms[38,170]. The time taken to return to continence is critical for the patients' perceived quality of life and psychosocial functioning after radical prostatectomy[58]. Similarly, a 2020 systematic review and meta-analysis that included 15 RCTs of PFMT delivered preoperatively or postoperatively concluded that commencing PFMT preoperatively reduced incontinence at 3 months (RR 0.76, 95% CI 0.63–0.92, $P = 0.006$), whereas postoperative PFMT was not significantly associated with reduced incontinence (RR 0.90, 95% CI 0.79–1.02, $P = 0.10$)[156]. Deconstructing the details of the PFME or PFMT programme design of the included studies showed that the PFME training was particularly efficacious if commenced preoperatively (as opposed to postoperatively), if it included some form of biofeedback as an adjunct and if the training instructions focused on the urethra (striated urethral sphincter), as opposed to the anus (anal sphincter and puborectalis)[156]. Taken together, the evidence to date would suggest that preoperative delivery of a PFMT programme can reduce the time to continence where the potential benefits outweigh the risks. To provide further evidence, a randomized trial (MaTchUP) comprising 363 men has commenced in Australia. The study compares three groups who receive treatment supervised by a physiotherapist commencing 1–2 weeks prior to surgery and postoperatively after removal of the urinary catheter. The first group will receive an individualized PFMT programme, including urethral instruction and training strategies incorporating transperineal ultrasonography visual biofeedback. The second group will receive conventional PFME training focused on muscles around the anus with digital rectal examination and biofeedback. The third group is a control group that will receive no specific training and will be provided with written educational material and online resources only[170]. This trial is expected to be completed in 2022.

Patient instruction, training and biofeedback

PFMT programmes can be delivered by health-care professionals, for example, physiotherapists with a special interest and training in men's health and a scope of practice that includes continence management. A 2019 meta-analysis comprising 22 studies reported that PFMT delivered by a health professional and/or physiotherapist led to faster recovery and increased odds of becoming continent at 1, 3, 4 and 12 months after radical prostatectomy, compared with controls (most control groups comprised either verbally instructed PFMEs starting postoperatively or no PFMEs): OR and 95% CI at 1, 3, 4, 6, 12 months postoperatively: 1 month 2.79 (1.53–5.07), $P = 0.0008$ (10 studies), 3 months 2.80 (1.87–4.19), $P < 0.0001$ (19 studies), 4 months 2.93 (1.19–7.22), $P = 0.02$ (7 studies), 6 months 4.11 (2.24–7.55), $P < 0.0001$ (17 studies) and 12 months 2.41 (1.33–4.36), $P = 0.004$ (11 studies)[171].

PFMT currently consists of intermittent, voluntary contractions of the striated urethral sphincter, levator ani and bulbospongiosus (also known as bulbocavernosus) muscles[172]. Three synergistic voluntary pelvic floor muscle activation strategies can contribute to increased urethral pressure: striated urethral sphincter-dominant, levator ani-dominant, and both striated urethral sphincter and levator ani[85,173]. Whether a particular pelvic floor synergistic strategy is associated with a differential risk of postprostatectomy incontinence is not known. However, the extent of the shortening of the striated urethral sphincter during voluntary contractions is reported to be important for managing postprostatectomy incontinence[85,157]. Traditionally, PFMT programmes have targeted global activation of the pelvic floor musculature, often with a focus on the anal sphincter area rather than specific striated urethral sphincter activation and training strategies[139]. It has been suggested that a greater focus should be placed on striated urethral sphincter activation and training strategies to compensate for any loss of smooth and striated muscle after prostatectomy[157].

Voluntarily contracting and training the pelvic floor musculature is a novel task for most men, as it involves anatomically remote musculature that are not often contracted or specifically trained in an isolated voluntary manner. Biofeedback has become an important component of comprehensive instruction for pelvic floor muscle activation. Biofeedback involves the use of visual, auditory and/or tactile strategies designed to increase the patient's awareness and understanding of pelvic floor muscle function. A 2016 systematic review and meta-analysis of RCTs reported that biofeedback-assisted PFME training led to statistically significant improvements in urinary continence at 3 and 6 months and beyond 6 months, compared with PFMT without biofeedback (mean effect size −0.23, 95% CI −0.44 to −0.02, $P = 0.034$ and −0.28, 95% CI −0.47 to −0.08, $P = 0.005$, respectively, where 0.20 is considered a small effect size and 0.50 a medium effect size)[174]. Including biofeedback in PFME instruction and training is important to enable the patient to correctly learn how to contract the pelvic floor muscles and acquire the necessary motor skills to practise correctly. Learning to contract the pelvic floor muscles voluntarily can occur in three main phases that include the following: a cognitive phase whereby the patient understands what needs to occur, an associative phase where improved voluntary pelvic floor muscle performance occurs through instruction, feedback and correct practice and an autonomous phase whereby each patient correctly trains the pelvic floor muscles with the

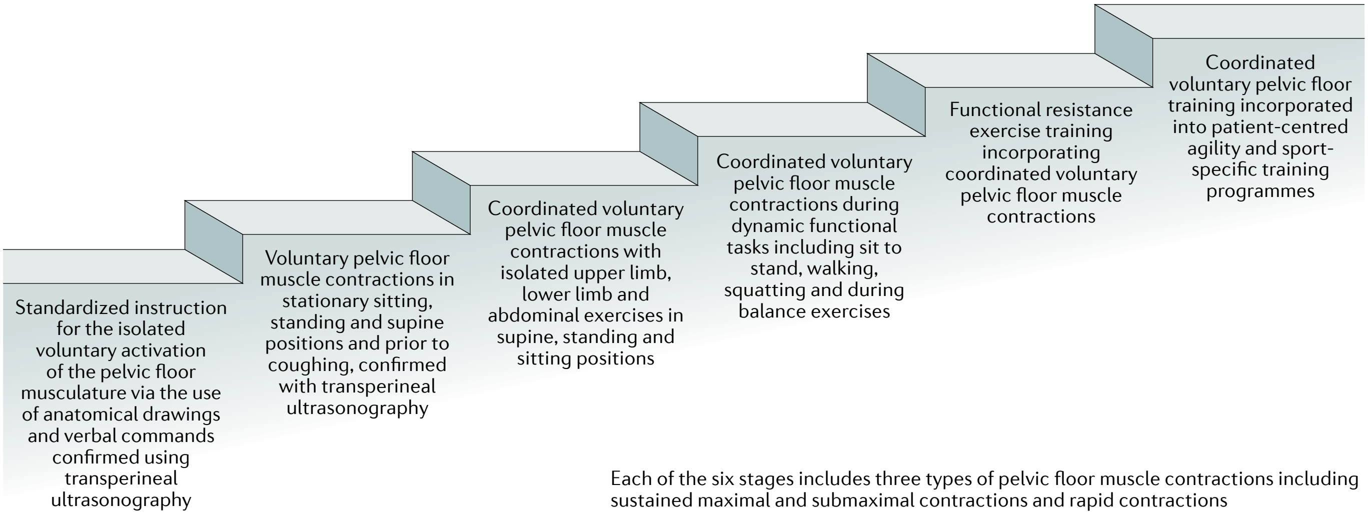


Fig. 4 | **Components of a progressive pelvic floor exercise training programme.** The stepwise approach of a muscle training programme before radical prostatectomy.

expectation that improved motor performance transfers into functional tasks, facilitating the return to continence following radical prostatectomy[175].

Many health-care professionals falsely assume that patients will correctly contract the pelvic floor musculature when given verbal instructions and/or written materials to do so. Clinical trials have used a range of different verbal instructions to teach patients how to contract the pelvic floor muscles[139]. Different verbal instructions given to patients can alter the activation patterns of the individual pelvic floor muscles and in turn the efficacy of prescribed PFMT programmes[176]. Instructions focusing on dorsal retraction of the penis such as 'shorten your penis', and urethral closure such as 'imagine you are stopping the flow of urine midstream' encourage improved activation of the striated urethral sphincter[176]. Instructions that target anal structures such as 'tighten around your anus' predominantly induce anal sphincter activity with accompanying puborectalis activation[176]. Targeted verbal instructions together with tactile cues can facilitate relaxation of the superficial abdominal muscles. Relaxing the superficial abdominal muscles can optimize the isolated voluntary activation of the pelvic floor muscles and to minimize any increase in bladder pressure caused by contraction of abdominal and diaphragm muscles; for example, breath holding[157]. The physiotherapist could place their hand on the patient's abdominal musculature to ensure that the patient does not rely on the contraction of their abdominal musculature and breath holding during voluntary activation and training of the pelvic floor musculature.

Traditional methods of providing instruction and biofeedback for pelvic floor muscle instruction and training to reduce urinary incontinence have limitations. One commonly used set of instructions and training biofeedback strategy involves patients observing their urinary flow when voluntarily and repeatedly starting and stopping urination[158]. This biofeedback method for pelvic floor muscle instruction and training is not recommended and can result in incomplete bladder voiding, increased post-void residual volume and risk of urinary tract infection[177]. Perineometry incorporates the use of an anal pressor sensor to teach and confirm the correct activation of the pelvic floor muscles. Digital rectal examination also continues to be used to assess pelvic floor activation and function. The most commonly used assessment scale during a digital rectal examination is the Modified Oxford Scale (0 = no contraction, 1 = flicker, 2 = weak, 3 = moderate, 4 = good, 5 = strong). However, the subjective nature of clinicians' evaluation and use of the scale has led to measurement bias. Evidence does not support the Modified Oxford Scale as a reliable and valid method of measuring and differentiating pelvic floor muscle activation, strength and function[178]. Although perineometry and digital rectal examination are used to measure pelvic floor muscle strength, neither provides a valid and reliable measure of striated urethral sphincter and bulbocavernosus function[157]. In addition, perineometry and digital rectal examinations are invasive and typically not well tolerated and the measurements are often unreliable[168,179,180]. The limitations of perineometry and digital rectal examination have led to the development of non-invasive real-time transabdominal and transperineal ultrasonography for instruction and training of the pelvic floor musculature.

A progressive patient-centred PFMT programme can incorporate a stepwise approach (FIG. 4). Teaching and training pelvic floor muscle function preoperatively can commence with isolated pelvic floor muscle contractions in stationary positions (supine, sitting and standing). The patient can progress to training the pelvic floor musculature during more complex dynamic tasks where men are likely to experience postprostatectomy incontinence symptoms including coughing, lifting weighted objects, sitting to standing and when walking[49,157,170]. Training men to consciously activate, coordinate and correctly time voluntary pelvic floor muscle contractions is essential to increase and maintain urethral closure pressure in order to avoid urinary leakage following radical prostatectomy[157].

Activation of the pelvic floor musculature opposes the increase in the intra-abdominal and bladder pressure. An increase in intra-abdominal pressure increases bladder pressure and displaces the bladder base, including the urethrovesical junction, prostate and anorectal junction[85,181]. Striated urethral sphincter function also increases proportionally with intra-abdominal pressure to increase urethral pressure[182]. Thus, preoperative PFMT specifically includes an anticipatory contraction of the pelvic floor musculature before the predictable increase in intra-abdominal pressure with functional tasks. Hypertrophy of the striated pelvic floor musculature and/or the increased strength, endurance and coordination of the muscles is suggested to improve urethral sphincter constriction[157–159].

The efficacy of PFME and PFMT programmes can depend on the standardization and quality of verbal instructions given to the patients. For example, instructions such as 'retract your penis' and 'elevate your bladder' will predominantly activate the striated urethral sphincter and puborectalis muscles, respectively[176]. The effect of different PFMT verbal instructions has been reported in healthy continent men aged 28–44 years in a sitting position, rather than in patients prior to prostatectomy and patients with postprostatectomy incontinence, potentially limiting the applicability of these data[176]. Furthermore, using the phrase 'shorten your penis' might be insensitive wording for men who are affected by postoperative penile shortening, which occurs in 15–68% of men following prostatectomy[183] and can affect self-esteem and quality of life[184]. Relying on the use of terms encouraging penile shortening to facilitate striated urethral sphincter function can be stress-inducing and, potentially, less effective. Alternative patient-centred instructions such as 'draw your penis towards you as if you are stopping the flow of urine' or 'lift your scrotum upwards and retract your penis towards your stomach' might be more suitable. The delivery and effectiveness of verbal instructions given to each patient by clinicians can be assessed using a non-invasive real-time transperineal ultrasonography examination. Transperineal ultrasonography will visually determine the translation of patient-centred instructions given by clinicians for the patient to perform the required pelvic floor muscle activation strategy. Although instructions can be standardized, patient-specific characteristics may require refinement to achieve the required pelvic floor muscle activation strategy.

Application of transperineal ultrasonography

Until 2012 (REF.[185]), assessing the components of the male continence mechanism simultaneously and instructing patients to correctly activate the pelvic floor musculature with biofeedback was not possible in routine clinical practice (FIG. 1). Access was restricted anatomically, owing to the deep position of the muscles within the pelvis, and practically, because of a lack of appropriate imaging technologies in routine clinical practice. Although imaging modalities, such as transrectal ultrasonography for anorectal junction movement (puborectalis), transurethral ultrasonography for striated urethral sphincter muscle contraction[78,186] and transabdominal ultrasonography for bladder base elevation (levator ani)[187] have been used to observe the movement of single structures during voluntary pelvic floor muscle contractions, the invasiveness of transrectal and transurethral ultrasonography has resulted in limited use in routine clinical practice. However, transperineal ultrasonography enables clinicians to view the dynamic contraction and motion of the striated muscles of the pelvic floor non-invasively in real time both at rest and during voluntary (Supplementary videos 1–3) and involuntary (Supplementary video 4) pelvic floor muscle contractions. Transperineal ultrasonography provides visual biofeedback to patients and clinicians during PFMT instruction and exercise, potentially improving patient learning and increasing the effectiveness of PFMT and PFME programmes. One prospective study reported that transperineal ultrasonography-guided PFMT led to faster recovery time to continence (time to continence in days, transperineal ultrasonography-guided PFMT mean ± s.d., 76 ± 100 versus no transperineal ultrasonography-guided PFMT 122 ± 132, $P = 0.037$)[188].

Assessment of pelvic floor muscle function

Pelvic floor muscle function can be assessed non-invasively using ultrasonography both preoperatively and postoperatively. Transabdominal ultrasonography has now been superseded by the transperineal approach. The transperineal approach provides visualization of the coordinated function of the striated urethral sphincter, levator ani and bulbocavernosus, and also provides access to the pubic symphysis, which serves as a stable reference landmark for measurements of pelvic floor muscle function[189] (FIG. 5; Supplementary video 1). By contrast, non-invasive transabdominal ultrasonography visualizes the function of the levator ani musculature only (bladder base elevation) with no stable reference landmark for reliable measurements of bladder base displacements during voluntary pelvic floor muscle contractions[190,191].

Transperineal ultrasonography has been used in patients to assess and measure pelvic floor muscle function, provide non-invasive visual biofeedback during PFMT and for the measurement of MUL[85,173,181,185,192]. Transperineal ultrasonography is a well-established, non-invasive imaging modality with multiple applications in urological clinical practice and research, including the assessment of pelvic floor disorders in women[193]. Transperineal ultrasonography enables static and dynamic assessment of the lower urinary tract system, including anorectal structures and for the measurement of MUL[173,185,192] (FIG. 3). Transperineal ultrasonography can assess the real-time coordinated function of the pelvic floor muscles simultaneously in supine, sitting and standing positions[194], for example, striated urethral sphincter, puborectalis and bulbocavernosus muscles, which influence urethral pressure (Supplementary videos 1 and 2). Furthermore, transperineal ultrasonography is less expensive than MRI investigations for the routine measurement of MUL and is used when MRI is contraindicated[192]. Transperineal ultrasonography examinations can be performed at rest (FIG. 5a), during voluntary PFM contractions (FIG. 5b) (Supplementary videos 1–3) and during other tasks such as coughing (Supplementary video 4) and Valsalva manoeuvres, where timing of the pelvic floor muscle contraction prior to an increase in intra-abdominal pressure can be assessed and specific training strategies for the patient developed[56,157,181].

Performing transperineal ultrasonography

Patient preparation for transperineal ultrasonography is minimal. Men should generally consume 300–450 ml of water 30–60 min before the transperineal ultrasonography examination to ensure standardization of bladder volumes and to optimize the ultrasound image[173,181,192]. A B-mode-capable diagnostic 2D ultrasonography system with cineloop functionality is required to successfully capture the dynamic nature of the contraction and relaxation phases of pelvic floor muscle contractions in real time and store for subsequent analysis[173,181,189]. Transperineal ultrasonography is usually performed with conventional curved array probes with frequencies from 3.5 to 7 Hz (REFS[173,189]) (Supplementary videos 1 and 2). However, a higher frequency linear probe transducer can provide a more focused image of the action and function of the striated urethral sphincter (Supplementary videos 3 and 4).

Minimizing exposure of the genitalia and ensuring that incontinent patients are protected in case of an incontinence episode is essential for patient comfort, privacy and to minimize anxiety. Patients can be dressed in either a hospital gown or a pair of loose-fitting shorts that provide sufficient access for the placement of the probe onto the perineum. Transperineal ultrasonography examinations can be performed while incontinent patients are wearing an absorbent pad. The absorbent pad can be moved laterally at the perineum to permit access for the placement of the probe. Alternatively, a uridome adhesive sheath, which covers the penis and is connected to a drainage bag, can be considered.

The transperineal ultrasonography probe is covered with ultrasonic gel. For hygiene purposes, non-powdered gloves and plastic wrap cellophane sheets can be used as clinically accessible and cost-effective probe cover options. The transperineal ultrasonography probe cover can be secured around the neck of the probe with an elastic band or adhesive tape. Commercially available non-sterile probe covers can be used. Powdered gloves are not advised, as the powder can cause reverberation, resulting in reduced quality of the transperineal ultrasonography image.

The transperineal ultrasonography probe is aligned and subsequently positioned on the perineum in the midsagittal plane. The patient can assist the clinician with the probe placement on the perineum by manually lifting the scrotum. Once the probe is positioned, the scrotum is then released by the patient. Transperineal ultrasonography imaging can be performed with the patient in a standing position, in a semi-seated position with the legs extended, in a supine position with knees extended or with the knees flexed to 70° (REFS[173,191,192,194]).

No consensus has been reached regarding the standardized orientation of the transperineal ultrasonography image on the screen. The default ultrasonography image usually appears with the probe at the top of the screen. Inverting the default transperineal ultrasonography image on the screen 180° places the probe and the perineum at the bottom of the screen, with the head of the patient orientated towards the top of the screen (FIG. 5). A caudal (inferior) to cephalad (superior) orientation of the lower urinary tract from the bottom to the top of the screen can assist clinicians and patients with verbal instructions and in the interpretation of the movement of the anatomical structures of interest in real time. For example, the antero-superior elevation of the bladder base and the anorectal junction with a verbal command such as 'elevate your bladder' during a voluntary pelvic floor muscle contraction would occur in an upward direction towards the top of the screen (see Supplementary videos 1 and 2). The left-sided or right-sided orientation of the transperineal ultrasonography image on the screen should be determined and clearly designated by each clinical facility to ensure consistency with any anatomical sketches that patients receive in their educational materials.

The main axis of the probe is maintained in the midsagittal plane throughout the transperineal ultrasonography examination. A lateral left-to-right sweep of the transducer is then conducted to obtain a clear image for the identification of the anatomical structures of interest, including the pubic symphysis anteriorly, the bladder, prostate, prostatic and membranous urethra, the penile bulb and anorectal junction (FIG. 3b; supplementary videos 1 and 2).

During voluntary pelvic floor contractions, transperineal ultrasonography shows the coordinated

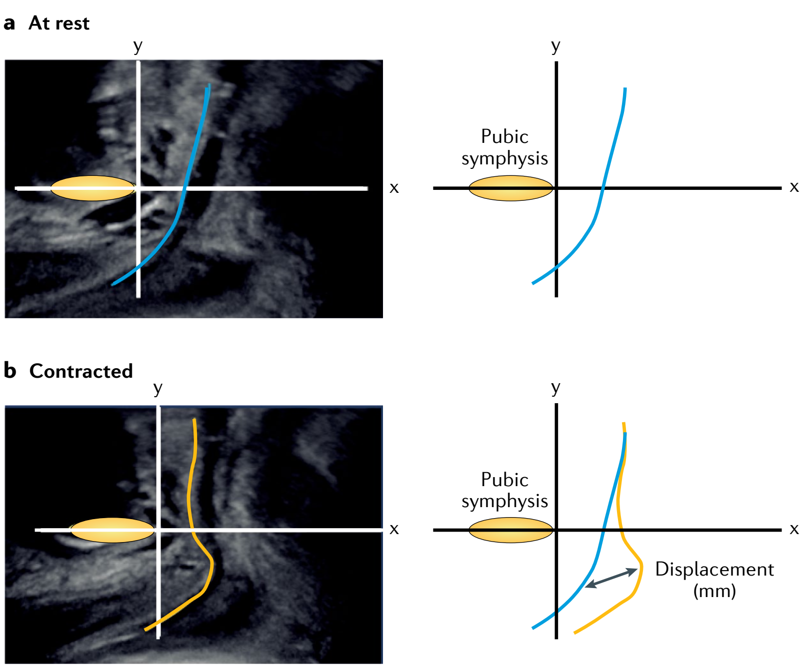


Fig. 5 | **Transperineal ultrasonography of the striated urethral sphincter.** Mid-sagittal 2D cineloop transperineal imaging is used to capture images of the membranous urethra during voluntary pelvic floor muscle contractions. The pubic symphysis is used as a stable bony reference landmark for the position of an x–y axis system to interpret the activity of the striated urethral sphincter as visualized by the displacement of the mid-membranous urethra. **a** | The membranous urethra at rest. **b** | The membranous urethra contracted. The same approach is used for the assessment of the displacement of the anorectal junction (puborectalis muscle) and the penile bulb (bulbocavernosus).

Table 4 | **Pelvic floor muscle function observed on transperineal ultrasonography**

Muscle	Observed TPUS movement	TPUS link
Striated urethral sphincter (rhabdosphincter)	Posterior displacement of the mid-membranous urethra	Supplementary videos 1, 2, 3 and 4
Levator ani: encompassing puborectalis, iliococcygeus, pubococcygeus and pubovisceralis	Antero-superior displacement the bladder base (UVJ)	Supplementary videos 1 and 2
Puborectalis	Antero-superior displacement of the ARJ	Supplementary videos 1 and 2
Bulbocavernosus	Anterior compression of the penile bulb	Supplementary videos 1 and 2

ARJ, anorectal junction; TPUS, transperineal ultrasound; UVJ, urethrovesical junction.

function of the striated pelvic floor muscles in one image, including the striated urethral sphincter, levator ani, puborectalis and bulbocavernosus (Supplementary videos 1 and 2). The functional interrelationship of the action of these pelvic floor muscles can be captured in a single sagittal plane image sequence of each voluntary pelvic floor muscle contraction. Transperineal ultrasonography can clearly display the antero-superior elevation of the bladder base (specifically the urethrovesical junction) and the anorectal junction, dorsal displacement of the membranous urethra and compression of the bulb of the penis during voluntary pelvic floor muscle contractions. The synchronized movement of the anatomical structures during voluntary pelvic floor muscle contractions has been validated against electromyography (EMG) recordings of the pelvic floor musculature[56] (TABLE 4; Supplementary videos 1–4).

The relative contribution of each striated muscle group during voluntary pelvic floor muscle contractions can be determined and quantified (TABLE 4; FIG. 5; Supplementary videos 1 and 2). Specifically, capturing the pubic symphysis in the midsagittal images provides a stable bony reference landmark that can be used by a coordinate x, y axis system to measure the displacement of anatomical landmarks[189] (FIG. 5). Studies have reported the use of purpose-built software to analyse and measure the displacement of relevant anatomical landmarks[173,189]. However, accessible Digital Imaging and Communications in Medicine (DICOM) viewer software packages have the necessary capability and can be used[192].

Measurement of membranous urethral length

MRI is the gold standard for measuring MUL. The clear visualization and cross-referencing of standard sagittal, axial and coronal T2-weighted MR images enables the identification of the apex of the prostate, membranous urethra and penile bulb[88,195]. However, obtaining preoperative MUL measurements using MRI is not routine in urological practices outside of large-volume centres. MRI investigations are costly, time consuming and resource intensive, requiring specialist technicians and radiologists to perform and evaluate the images. Furthermore, not all patients can undergo MRI owing to claustrophobia or the presence of metal implants. However, a 2018 investigation reported that preoperative MUL can be accurately and reliably measured by transperineal ultrasonography[192] (Supplementary videos 1 and 2). In this study, transperineal ultrasonography-measured MUL demonstrated excellent agreement with MRI measurements (intra-class correlation in the supine position: 0.93, 95% CI 0.76–0.98), excellent test–retest reliability (intra-class correlation in the supine position 0.97, 95% CI 0.91–0.99) and minimal difference between the two supine position measurements (mean difference of 0.03 mm, limits of agreement 95%: −1.2 to 1.3 mm)[192]. Visualization of the MUL in the same patient using transperineal ultrasonography and MRI illustrates the excellent agreement between the two measurements (FIG. 3).

Assessing urinary function outcomes

A variety of methods can be used to assess urinary function in men undergoing radical prostatectomy. When assessing postoperative outcomes, the patient's preoperative baseline function must be considered, in particular the presence of pre-existing preoperative voiding dysfunction. For example, intrinsic sphincter dysfunction or overactive bladder symptoms can be identified and treatment interventions commenced in the prehabilitation period[52,196,197]. Studies report that patients with poor urinary incontinence and overactive bladder symptom scores before radical prostatectomy also had worsening of symptom scores at all time points after radical prostatectomy[95,198–200].

Pad weight is an objective method recommended by the International Continence Society (ICS) to identify and quantify the severity of urinary incontinence symptoms preoperatively and during the postoperative period[201]. Ideally, 24-h pad weight is assessed for 3 consecutive days coupled with either a voiding diary, in which the patient records his voiding pattern during normal activities, and/or a frequency–volume chart, whereby patients void into a measurement container and the volume and time of each voiding episode is recorded[202]. The standardized pad weight testing procedures can be explained to patients preoperatively in preparation for the required postoperative testing requirements.

A broadly accepted conservative definition of urinary continence after radical prostatectomy has been pad-free status (no pad use per 24 h in the past week)[91,203]. Alternative definitions of continence include 'social continence' where pad use is ≤1 pad per day[91,108]. The evaluation of urinary function directly by clinicians is often inadequate[204], requiring the use of validated questionnaires to obtain patient-reported outcome measures[205]. Validated questionnaires, such as the International Consultation on Incontinence Questionnaire (ICIQ) on Male Lower Urinary Tract Symptoms (ICIQ-MLUTS)[206,207], a short form thereof (ICIQ-SF)[49,203,208], the Expanded Prostate Cancer Index Composite (EPIC)[205,209] urinary incontinence domain and the University of California Los Angeles Prostate Cancer Index (UCLA-PCI), have been used[210].

Patient motivation and compliance

Establishing a regular and consistent pattern of exercise prior to surgery, especially for patients with an inactive lifestyle, can be challenging for patients and clinicians.

Understanding each patient's behavioural and psychosocial enablers, influencers and barriers to exercise is important. Involving the patient in the development of the preoperative treatment plan including exercise interventions and discussing treatment goals enables the patient to be an active participant in the preparation for surgery. As a result, patient compliance with the prescribed management plan is likely to be increased[211,212]. Patients are similarly motivated to work towards a deadline, in this case the date of surgery when motivation to engage in positive behaviour change is increased[213,214].

If the patient is unmotivated, the cause of any physical or psychosocial barriers to participation in the preoperative programme should be investigated and discussed. For example, the ability to undertake weight-bearing aerobic exercise or resistance training could be limited by comorbid degenerative joint disease. Providing patients with specific solution-focused alternatives — such as non-weight-bearing exercise including arm cranking and cycling, modified non-weight-bearing resistance exercise and training options while still using weights and resistance bands — can overcome barriers to participation. A range of approaches, including supervised, group-based, home-based and web-based interventions, have been reported to improve exercise adherence in cancer survivors. Strategies to improve the uptake of preoperative exercise-based interventions include the use of self-reported exercise behaviours supported by objective self-monitoring measurements. The setting of specific measurable goals and a graded patient-centred approach to increasing the exercise duration and intensity can improve exercise adherence before radical prostatectomy[215].

The efficacy of verbal and written instructions to promote behavioural change during the preoperative period can depend on how the instructions are framed: messages that stress the benefits of engaging in physical exercise interventions and PFMT programmes before surgery (gain-framed messages) can be more effective than messages that focus on the disadvantages of non-participation (loss-framed messages)[216,217]. According to health behaviour change theory, an increase in the belief that exercise can deliver greater positive outcomes (a more rapid return to continence and a greater ability to cope with surgery) can lead to positive changes in a person's behaviour[218,219]. In populations that do not have a cancer diagnosis, those who expect more positive and fewer negative outcomes from exercise have a stronger commitment to engage in exercise and increase the amount of physical activity they undertake[220]. Clinicians could use gain-framed scripted phrases, such as "Increasing your physical activity levels and doing PFMT correctly and effectively before surgery will give the surgeon the best possible patient to operate on and improve your recovery" and "the preoperative PFMT programme will give you peace of mind knowing that you are doing everything you can to prepare well for surgery, which can reduce the impact of the predictable urinary incontinence symptoms".

Technology has increasingly become part of aerobic exercise training programmes and PFMT programmes, in particular the use of patient-friendly smartphone applications and wearable devices. Accessible activity-tracking devices can be recommended to patients to enable the quantification of their physical activity and habitual exercise. These smartphone and wearable devices can also provide clinicians with objective data with which to assess patient compliance, the effects of different interventions, to adjust the exercise prescription and as a motivator for positive behaviour change[221,222]. In a non-randomized study of 112 patients undergoing prostatectomy, a communication tool between the patient and the health-care professional replaced in-person clinical follow-up visits with an instructional PFMT video and automated reminders to do the exercise programme. This change in communication mode led to a significant decrease in urinary leakage at 1–3 months compared with PFME alone (24-h pad test (g): mean ± s.d. 254 ± 76 in the intervention group versus 293 ± 86 in the control group at 1 month, $P < 0.05$, and mean 76 ± 47 versus 98 ± 58 at 3 months, $P < 0.05$)[223].

A culture of multidisciplinary prehabilitation

When a patient presents with newly diagnosed localized prostate cancer and meets with the surgeon to discuss the available treatment options, the conversation often focuses on cancer control and long-term mortality rather than the risks and management of postoperative complications. Shared decision-making consultations that discuss the management plan to proceed with radical prostatectomy can be an important teachable moment, whereby the surgeon and their multidisciplinary team can inform the patient about the risk profile for postprostatectomy incontinence, the positive effect of preoperative PFMT programmes and the importance of engaging in physical exercise in the lead-up to and after surgery. The date of surgery presents the patient with a clearly defined timeline, from the start of the preoperative intervention to the day of surgery, and can act as a motivator for positive behaviour change during the preoperative period and after surgery[214].

When the surgeon informs and reinforces the requirement for the patient to participate in the defined preoperative programme to reduce postprostatectomy incontinence, they become an important enabler for the commitment to, and delivery of, preoperative PFMT, and act as a key motivating factor[224,225]. Patients need to be informed by the surgeon and their multidisciplinary team about the benefits of structured exercise programmes on continence and oncological outcomes. For example, obesity (BMI ≥30) is significantly associated with additional risk of urinary incontinence at 12 months after prostatectomy (OR 2.43, 95% CI 1.57–2.56)[106]. A qualitative interview study with urological oncology surgeons, patients and physiotherapists reported that a recommendation for preoperative PFMT from the surgeon, and a referral to a specific provider, were key enablers for the acceptance, commitment to and delivery of preoperative PFMT[225]. Effective verbal communication of information about the preoperative plan, supplemented with written materials, can assist the transfer of knowledge to the patient during consultations and throughout the preoperative period. The use of a preoperative checklist can facilitate patient engagement in the preoperative phase of care and the surgeon's specific plan of management[224].

Establishing and maintaining a culture of multidisciplinary health-care delivery can benefit patients who are participating in an effective 'team-based approach' to surgical cancer care[226]. By consistently reinforcing the surgeon's referral for preoperative exercise interventions, including PFMT and exercise, the multidisciplinary team can continue to build a culture of prehabilitation and facilitate the defined preoperative surgical pathway[227]. To establish a culture of evidence-based prehabilitation, the multidisciplinary team members can be presented with a summary of the evidence that identifies the effectiveness of preoperative PFME and/or PFMT on postprostatectomy incontinence. An evidence-based summary can be an important starting point for discussions with patients when proposing the change to a preparatory preoperative prehabilitation model of care rather than a reactionary postoperative rehabilitation model of care[224].

Despite committing to a multidisciplinary team approach, the surgeon is key to the success of the preoperative and postoperative interventions[224,225]. Patients report that referral to preoperative PFMT programmes should be the domain of the surgeon[225]. The advice, recommendation and/or mandate of the surgeon influences the patient's decision-making prior to radical prostatectomy[225]. Surgeons are well placed to assume the leadership role for determining and reinforcing a comprehensive model of care that incorporates preoperative exercise-based strategies, including preoperative PFMT programmes[225]. Urology practices and departments should be able to refer patients to providers of preoperative PFMT programmes, for example, physiotherapists, who have a scope of practice to deliver a level of care expected by the surgeon and achieve the goals set for each patient[225].

Conclusions

Physical exercise interventions including aerobic exercise, resistance training and preoperative PFME and/or PFMT programmes can positively influence physical and psychosocial outcomes in patients who have undergone radical prostatectomy. The intent of designing and prescribing an appropriate preoperative exercise stimulus is to impose a sustained physiological challenge that will result in beneficial physiological adaptations at the individual muscle level and across the urological, cardiovascular, respiratory, musculoskeletal, neurological, metabolic and endocrine body systems. Establishing a consistent pattern of exercise before surgery can be challenging for both patients and clinicians. Thus, understanding individual patient behavioural and psychosocial enablers, influencers and barriers to exercise makes an important contribution to the success of the preoperative programme. A structured and coordinated prehabilitation model of care that is led by the surgeon and delivered through their multidisciplinary team can act as an extension of the care provided by the surgeon. A strong recommendation and mandate by the surgeon and referral to specific providers with the required scope of practice is an important enabler for the success of preoperative PFME and/or PFMT interventions. The implementation of transperineal ultrasonography provides a non-invasive and validated method to improve the quality and effectiveness of the delivery of PFME and/or PFMT interventions in men before radical prostatectomy. Collectively, exercise-based interventions before and after prostatectomy have the potential to extend the care that is provided by the surgeon to facilitate optimal preoperative and postoperative functional outcomes for the patient.

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