Received: 16 May 2022 | Accepted: 21 July 2022

DOI: 10.1002/nau.25034

CLINICAL ARTICLE

Neurourology Urodynamics | SUFU | WILEY

# The relationship between pre- and postprostatectomy measures of pelvic floor muscle function and development of early incontinence after surgery

**Ryan E. Stafford PhD**[1,2] | **Stuart Doorbar-Baptist MSc**[3] | **Paul W. Hodges PhD**[1]

[1]The University of Queensland, School of Health and Rehabilitation Sciences, Brisbane, QLD, Australia

[2]School of Human Sciences (Exercise Science), The University of Western Australia, Perth, WA, Australia

[3]Sydney Physiotherapy Solutions, Sydney, NSW, Australia

**Correspondence**
Paul W. Hodges, PhD, School of Health and Rehabilitation Sciences, The University of Queensland, Brisbane, QLD 4072, Australia.
Email: p.hodges@uq.edu.au

**Funding information**
National Health and Medical Research Council

## Abstract

**Aims:** The aim of this study is to investigate (i) whether pelvic floor muscle (PFM) shortening can be enhanced by provision of training focused on striated urethral sphincter (SUS) with feedback before prostatectomy, (ii) whether PFM shortening during voluntary efforts and coughing before and after prostatectomy differs between men who do and do not report symptoms of urinary incontinence 1 month after prostatectomy, and (iii) the relationship between severity of incontinence after prostatectomy and features of pelvic floor function (muscle shortening) and urethral length before and after prostatectomy.

**Methods:** Sixty men referred for preoperative PFM training before radical prostatectomy participated. The International Continence Society Male Short Form questionnaire was used to quantify continence status. Transperineal ultrasound (US) imaging was used to record pelvic displacements related to activation of striated urethral sphincter, bulbocavernosus (BC) and puborectalis muscles during cough, “natural” voluntary contraction following pamphlet instruction, and trained voluntary contraction after formal physiotherapist instruction including US feedback.

**Results:** Pelvic floor displacements following training differed between continent and incontinent men; continent participants demonstrated increased SUS shortening after training (compared with “natural”), but no difference was observed between trained and “natural” contractions for incontinent participants. Motion at ano-rectal junction during cough was reduced following surgery, but voluntary and involuntary activation of SUS or BC was not consistently affected by surgery.

**Conclusions:** Participants' capacity to improve function of the SUS with training appears related to postprostatectomy continence outcome.

**KEYWORDS**

pelvic floor, postprostatectomy incontinence, prostate cancer, prostatectomy, ultrasound imaging

## 1 | INTRODUCTION

Urinary incontinence after prostatectomy negatively impacts quality of life.[1] Why these symptoms develop for some men and not others remains poorly understood. Previous work highlights the impact of prostate size,[2] age,[3] and pre-[4] and postsurgery membranous urethral length.[2] Recently, function of the striated pelvic floor muscle (PFM) has been shown to relate to recovery of continence.[5,6] Unlike the other factors, this is potentially modifiable with exercise.

Continence is controlled by contributions from urethral smooth muscle, fibro-elastic properties of urethral/periurethral connective tissues, vascular tissue, and striated PFM.[7–9] These striated muscles include the striated urethral sphincter (SUS), puborectalis (PR) (part of levator ani), and bulbocavernosus (BC) muscles.[9,10] Activity of these muscles can be assessed reliably[11] with transperineal ultrasound imaging (TPUS)[10] and recent investigations in healthy men[12] provide new insight into their contribution to continence during voluntary and automatic (e.g., cough) tasks. Prostatectomy removes much of the smooth muscle of the proximal urethra with the prostate[13] and surrounding connective tissues are cut. Removal and/or damage to elements of the continence mechanisms increases demand on the remaining mechanisms. Measures made with TPUS show greater SUS shortening during coughing in men who are continent after surgery than men without prostate cancer or incontinence.[5]

It is unresolved whether preoperative PFM function differs between men who do and do not develop incontinence after prostatectomy. Systematic reviews support the commencement of PFM training before surgery.[14] This assumes enhanced PFM function before surgery improves muscle recovery, and continence, after surgery. There are two issues. First, although PFM function after prostatectomy relates to continence recovery,[6] whether postprostatectomy continence also depends on PFM function preprostatectomy is unclear. Second, the types of PFM exercise can vary from a pamphlet to formal one-on-one physiotherapist training. Studies of presurgery PFM training have conflicting outcomes,[14] but none have included dynamic assessment of PFM function or investigated the influence of the intervention on function of the PFMs.

This study aimed to (i) investigate whether PFM shortening is enhanced by training focused on SUS with TPUS feedback preprostatectomy, (ii) investigate whether PFM shortening (voluntary efforts, coughing) pre- and postprostatectomy differs between men who are or are not incontinent 2 weeks postprostatectomy, and (iii) investigate relationships between incontinence severity and PFM function or urethral length pre- and postprostatectomy.

## 2 | METHODS

### 2.1 | Participants

Sixty men referred for preoperative PFM training before radical prostatectomy for treatment of prostate cancer participated. Men were included if they were aged between 30 and 75 years, understood spoken English, and were able to attend physiotherapy sessions. Participants were excluded if they described any symptoms of incontinence before surgery, underwent any previous pelvic surgeries that might affect PFM function, or had previously received pelvic radiation treatment. This cohort study comparing PFM function in men before and after prostatectomy was approved by the University of Queensland Human Research Ethics Committee. Participants provided written informed consent.

### 2.2 | Measurement

A curved ultrasound (US) transducer (35C50, DP50 Mindray) was placed on the perineum in the midsagittal plane such that the pubic symphysis, urethra, ano-rectal junction (ARJ), and bulb of the penis (BP) were visible (Figure 1), using a technique previously described[10] and validated[15] for assessment of PFM function. US data were recorded in video format (frame rate: 25 Hz) via a digital video converter between the US and personal computer. Data were recorded at two timepoints: (i) first pre-op physiotherapy appointment ~2 weeks preprostatectomy and (ii) first post-op physiotherapy appointment ~2 weeks postprostatectomy (i.e., 1 week after catheter removal). Before each session, participants completed the International Continence Society Male Short Form questionnaire (ICSMaleSF), which is a valid and reliable scoring system for evaluating men with lower urinary tract symptoms.[16] Data were collected by a single assessor.

### 2.3 | Procedure

Participants sat semireclined on a plinth (backrest reclined to ~30° from vertical) and performed three tasks. First, men performed a strong voluntary cough with effort of 8/10 where "10" was equal to maximum effort using the modified Borg scale (shown to be a valid and reliable tool for assessment of respiratory effort[17])

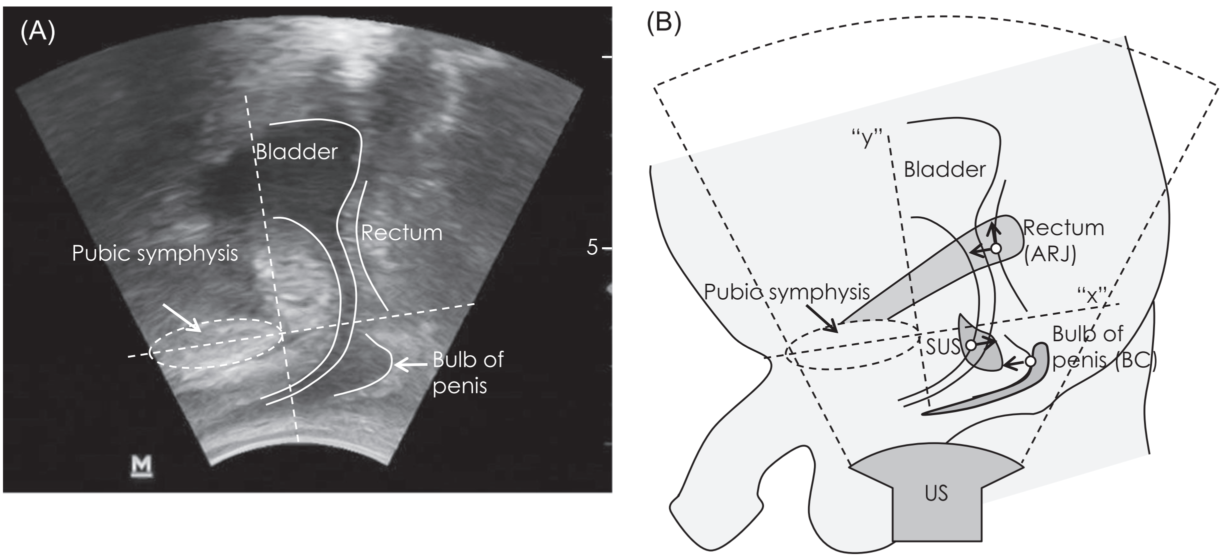


**FIGURE 1** (A) Transperineal ultrasound image from a participant following prostatectomy. (B) Graphical depiction of the male pelvic floor showing landmarks used for displacement calculations (white circles) with arrows indicating directions of motion. ARJ, ano-rectal junction; BC, bulbocavernosus; SUS, striated urethral sphincter; US, ultrasound.

without education regarding PFMs. Second, they performed an untrained "natural" maximum voluntary contraction (MVC) in response to written instruction to "contract your PFMs as hard as you can as if you are attempting to stop wind escaping and hold for 3 s" provided via pamphlet.[18] This task was used to investigate how men contract their PFMs before any formal training and without additional PFM education. Finally, a "trained" MVC held for up to 30 s was performed following instruction to "contract the PFMs as hard as you can as if you are attempting to shorten the penis" including visual feedback from TPUS, which followed a 30 min one-on-one training session with a pelvic floor physiotherapist that prioritized the SUS muscle and followed the principles outlined by Hodges et al.[19] for optimization of PFM exercise to maintain or restore continence following prostatectomy. Participants were naïve to performing PFM contractions (apart from any understanding they had before attending the session) during the preoperative session but not the postoperative session.

## 2.4 | Data analysis

Measures of continence were considered in two ways. First, for comparison between men with and without incontinence after prostatectomy, participants were grouped according to their answer to the Item 3 from the ICSMaleSF: "Does urine leak when you cough or sneeze?" This question was chosen, as it relates to a specific feature of incontinence, which is strongly associated with the function the PFM—urine leakage during tasks with elevated intra-abdominal pressure that requires PFM contraction. Men who answered "never" were classified as continent and men who answered "occasionally," "sometimes," "most of the time," or "all of the time" were classified as incontinent. Second, for investigation of the relationship between incontinence severity and each measure, we used the composite sum of values within the "incontinence" section of the ICSMaleSF (range: 0–24).

To quantify striated muscle contribution to continence, single image frames were exported from video data for analysis of pelvic floor landmark motion as described previously.[11] Displacement at each landmark was calculated using a custom-written graphical user interface (Matlab r2018a, The Mathworks), which compared landmark position at rest and during specific timepoints during tasks. The landmarks were as follows: mid-urethra (MU), ARJ, and BP, which represent contraction of the SUS, PR, and BP muscles, respectively. For cough analysis, three images were exported: (i) rest (within 5 s before cough onset), (ii) time of maximum descent of ARJ during the pressurization phase, and (iii) maximum ventral/cranial displacement of ARJ during expulsion. During this task, ARJ displacement was calculated in two phases: lengthening (displacement between rest and maximum descent) and shortening (displacement between maximum descent and elevation). MU and BP displacements were monophasic and calculated between rest and peak shortening. For the MVC tasks, displacement was measured between two exported images: (i) rest within 5 s before contraction and (ii) during the hold phase with maximal displacement. The postoperative membranous urethral length was calculated as the distance between the bladder neck and the urethra at the penile bulb.[20]

## 2.5 | Statistical analysis

To investigate whether PFM shortening is modified by provision of training focused on SUS before prostatectomy (Aim 1), a repeated-measures analysis of variance (ANOVA) compared PFM displacements between untrained and trained efforts (repeated measure) preprostatectomy. To investigate whether PFM function pre- and postprostatectomy differs between men with and without incontinence at ~2 weeks postprostatectomy (Aim 2), repeated-measures ANOVAs compared landmark displacements between sessions before and after prostatectomy (repeated measure), between trained and untrained efforts (repeated measure), and between men with and without incontinence (Item 3, ICSMaleSF) postprostatectomy (categorical variable) for each measure during the three tasks. Pearson's correlation investigated the relationship between PFM displacement/urethral length and incontinence severity (composite incontinence score, ICSMaleSF) postprostatectomy (Aim 3) and between PFM displacements and urethral length. Posthoc testing used Duncan's multiple range test. Significance was set at $p < 0.05$.

# 3 | RESULTS

## 3.1 | Effect of PFM training focused on SUS preprostatectomy

Preprostatectomy, SUS shortening during an MVC effort was greater following training focused on this muscle (3.6[1.9] mm) than a "natural" contraction that followed written instruction (3.1[1.4] mm; main effect, $p = 0.020$, Figure 2 and Table 1). Training did not change in shortening of BC (main effect: $p = 0.52$) or PR (main effect, ARJx: $p = 0.95$; ARJy: $p = 0.26$).

## 3.2 | Relationship between continence status at 2 weeks and PFM measures pre- and postprostatectomy

Based on Item 3 of the ICSMaleSF at ~2 weeks postprostatectomy, 23 participants were continent and 37 were incontinent. The average (SD) age, height, and weight for continent men was 62(9) years, 179(5) cm, and 84(9) kg, respectively, and 63(7) years, 177(7) cm, and 85(17) kg for incontinent men. Ninety-one percent (21/23) of continent men and 84% (31/37) of incontinent men underwent robot-assisted laparoscopic radical prostatectomy and the remainder in each group underwent open laparoscopic radical prostatectomy. For SUS, there was a significant interaction between incontinence and

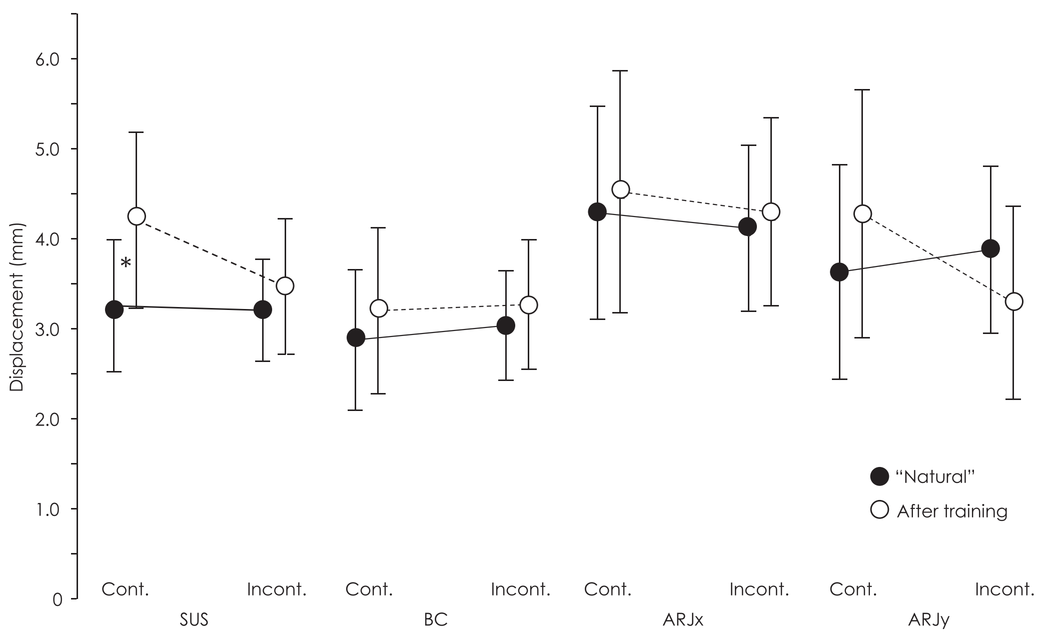


**FIGURE 2** Displacements at each landmark during "natural" contractions and contractions after training for continent and incontinent men. ARJx, ano-rectal junction motion "*x*" direction; ARJy, ano-rectal junction motion "*y*" direction; BC, bulbocavernosus; Cont., continent; Incont., incontinent; SUS, striated urethral sphincter. *Significance $p < 0.05$.

**TABLE 1** Pelvic floor landmark displacements during voluntary contractions

| | SUS (mm) | | BC (mm) | | ARJx (mm) | | ARJy (mm) | |
|---|---|---|---|---|---|---|---|---|
| | "Natural" | After training | "Natural" | After training | "Natural" | After training | "Natural" | After training |
| Pre-op | | | | | | | | |
| Group mean (SD) | 3.1 (1.4) | 3.6 (1.9) | 3.0 (1.8) | 3.1 (2.1) | 5.3 (3.1) | 5.2 (3.1) | 4.7 (2.4) | 4.2 (2.5) |
| Continent group mean (SD) | 3.0 (1.4) | 3.9 (2.1) | 2.8 (1.7) | 3.3 (1.7) | 5.2 (2.9) | 5.2 (2.4) | 4.7 (2.4) | 5.0 (2.5) |
| Incontinent group mean (SD) | 3.2 (1.4) | 3.4 (1.8) | 3.0 (1.8) | 3.0 (2.3) | 5.3 (3.2) | 5.3 (3.5) | 4.7 (2.4) | 3.7 (2.4) |
| Post-op | | | | | | | | |
| Group mean (SD) | 3.4 (1.6) | 3.9 (1.8) | 2.9 (1.5) | 3.2 (1.7) | 4.2 (1.9) | 4.6 (2.5) | 3.3 (2.2) | 3.6 (2.7) |
| Continent group mean (SD) | 3.6 (1.6) | 4.4 (1.9) | 2.9 (1.6) | 3.0 (1.6) | 4.4 (2.3) | 4.8 (2.2) | 3.0 (2.3) | 3.9 (3.0) |
| Incontinent group mean (SD) | 3.2 (1.6) | 3.5 (1.7) | 2.9 (1.5) | 3.4 (1.7) | 4.2 (1.7) | 4.5 (2.7) | 3.5 (2.3) | 3.3 (2.6) |

Abbreviations: ARJx, ano-rectal junction "*x*" coordinate; ARJy, ano-rectal junction "*y*" coordinate; BC, bulbocavernosus; SUS, striated urethral sphincter.

**TABLE 2** Pelvic floor landmark displacements during coughing

| | | | Pressurization phase | | Expulsion phase | |
|---|---|---|---|---|---|---|
| | SUS | BC | ARJx | ARJy | ARJx | ARJy |
| Pre-op | | | | | | |
| Group mean (SD) | 3.7 (1.6) | 1.9 (1.0) | −1.9 (1.5) | −1.8 (1.4) | 2.6 (1.0) | 2.3 (1.1) |
| Continent group mean (SD) | 3.7 (1.6) | 2.0 (0.7) | −1.7 (1.6) | −1.3 (1.3) | 2.8 (0.9) | 2.3 (1.2) |
| Incontinent group mean (SD) | 3.7 (1.7) | 1.8 (1.1) | −2.1 (1.5) | −2.1 (1.4) | 2.5 (1.1) | 2.3 (1.1) |
| Post-op | | | | | | |
| Group mean (SD) | 3.5 (1.2) | 2.0 (1.0) | −0.7 (1.0) | −1.0 (1.1) | 1.7 (1.0) | 1.8 (1.1) |
| Continent group mean (SD) | 3.9 (1.0) | 2.3 (0.9) | −0.5 (0.9) | −0.9 (1.0) | 1.8 (1.2) | 2.0 (0.9) |
| Incontinent group mean (SD) | 3.3 (1.3) | 1.8 (1.1) | −0.9 (1.1) | −1.1 (1.1) | 1.6 (0.9) | 1.8 (1.2) |

Abbreviations: ARJx, ano-rectal junction "*x*" coordinate; ARJy, ano-rectal junction "*y*" coordinate; BC, bulbocavernosus; SUS, striated urethral sphincter.

contraction task ($p = 0.039$). Although continent men achieved greater SUS shortening after training focused on this muscle than the "natural" contraction pre- and postprostatectomy (posthoc $p < 0.001$), incontinent men did not (posthoc $p = 0.29$). SUS displacements during "natural" efforts did not differ between continent and incontinent men (posthoc $p = 0.90$). Postprostatectomy and after training, continent men shortened SUS by 4.4(1.9) mm, whereas this was 3.5(1.7) mm for incontinent men. This difference was not significant (posthoc $p = 0.059$). Elevation of the ARJy landmark (PR shortening) was less postprostatectomy for both continent and incontinent men (main effect $p = 0.004$) and not changed by training focused on SUS (main effect $p = 0.91$). Although there was a significant interaction between continence and contraction type for ARJy displacement (interaction $p = 0.017$), no posthoc comparison was significant. Compression of the penile bulb by BC did not differ between continent and incontinent men pre- or post-prostatectomy (interaction $p = 0.60$) and not changed by training focused on SUS (main effect $p = 0.16$).

During cough, there was no difference between continent and incontinent men pre- or postprostatectomy for displacement related to SUS (interaction $p = 0.15$) or BC (interaction $p = 0.29$), and displacement at these landmarks was not affected by surgery (SUS: main effect $p = 0.58$; BC: main effect $p = 0.30$). ARJ displacement was less postprostatectomy in the cranio-caudal (ARJy) and anterior–posterior (ARJx) directions during both the lengthening and shortening phases of cough (main effect: all $p < 0.050$, Table 2), but did not differ between men who were continent or incontinent (main effect: all

$p > 0.050$). Postprostatectomy urethral length was greater for continent than incontinent men ($p = 0.014$).

### 3.3 | Correlation between PFM displacement/urethral length and incontinence severity

There was a significant negative correlation between post-prostatectomy incontinence severity (composite ICSMaleSF) and SUS shortening during cough (less severe incontinence in those with greater SUS shortening; $R = 0.48$, $p = 0.001$). Preoperative SUS shortening during cough did not correlate with incontinence severity ($R = 0.16$, $p = 0.24$). Incontinence severity was negatively correlated with urethral length (less incontinence in men with longer urethral length postprostatectomy; $R = 0.28$, $p = 0.033$). There was no correlation between urethral length and postprostatectomy SUS shortening with cough ($R = 0.14$, $p = 0.30$) or with voluntary contraction (natural and after training; $R < 0.14$, $p > 0.27$). No other significant relationships were observed between landmark displacement postprostatectomy and severity of incontinence. Shortening of BC (but not SUS or PR) during cough preprostatectomy (after training focused on SUS) was negatively associated with incontinence postprostatectomy (less incontinence men in men with greater shortening postprostatectomy; $R = 0.34$, $p = 0.008$).

## 4 | DISCUSSION

These data provide several novel insights into PFM contraction pre- and postprostatectomy, and the association with incontinence after surgery. First, both pre- and postprostatectomy, SUS shortening was greater after a single session of training focused on this muscle for men who regained early continence, but not for men who were incontinent after prostatectomy. Second, SUS shortening (post-, but not pre-prostatectomy) and urethral length (postprostatectomy) correlated with incontinence. Third, urethral length was not correlated with SUS shortening, which suggests these factors independently related to incontinence. These observations have implications for PFM training.

### 4.1 | Effect of PFM training

This study is the first to investigate the effect of PFM exercise instruction on pattern of PFM shortening in men with prostate cancer. Dorsal MU displacement was greater after SUS-focused training with feedback provided by TPUS than in response to the typical instruction[18] to contract "as if you are attempting to stop wind escaping." Greater SUS shortening in young healthy men has also been identified with instructions that focus on the "urethra" than the "anus."[12] Enhancement of SUS shortening without changed displacement of BC or PR suggests it is possible to selectively augment activation of this muscle. This has potential clinical utility for management of incontinence postprostatectomy as previous work has shown that shortening of SUS is a stronger determinant of continence than other muscles.[6] If enhanced shortening of PR and/or BC is required to regain continence (e.g., if SUS is unable to meet the demands of continence because of denervated or surgical damage[21]), these data suggest other instructions and feedback to target those muscles would be required.

### 4.2 | Differences between men with and without incontinence postprostatectomy

In this cohort of 60 men, SUS shortening improved with a single session of training in those who were continent at 2 weeks, but not those who were incontinent, both pre- and postprostatectomy. This implies that even preprostatectomy, men who regain continence quickly after surgery have better capacity to enhance SUS shortening with training than incontinent men. This suggests men who develop incontinence have less capacity to modify the pattern of activity and it seems reasonable to speculate that these men might require additional preoperative training. This should be explored further.

Despite enhanced SUS shortening after training (compared with before training) for continent men, there was no difference in SUS measures between continent and incontinent men during coughing or MVC. This contrasts earlier observations of greater SUS shortening in men who regain continence postprostatectomy than those who do not.[5,6] This difference might be explained by the very early timepoint (~2 weeks vs. months/years postprostatectomy[5,6]) used for this study, for several reasons. First, incontinence early postprostatectomy would include some different mechanisms (e.g., detrusor instability,[22] neuropraxia,[23] and edema) than long-term incontinence (e.g., failure to recover capacity of striated muscles). Second, later measures would enable greater time for recovery and/or adaptation of the PFMs to compensate for smooth muscle loss.[19] Third, participants in this study received detailed instruction regarding SUS contraction preprostatectomy and continued home-based training. This should reduce impaired SUS contraction postprostatectomy and differs from earlier studies, which are unlikely to have involved PFM training. It is plausible that this reduced differences between groups, but implies that SUS function is not the only determinant of early continence/incontinence, as highlighted above. Current studies are investigating PFM function at later timepoints after early PFM rehabilitation.[24] Fourth, the absence of difference between continence groups might be related to how it was defined (see below).

## 4.3 | Correlation between PFM contraction and incontinence severity

Although there was no difference in SUS shortening with groups defined dichotomously as continent/incontinent based on a single feature, there was a negative correlation between incontinence severity (continuous measure from composite score) and SUS shortening during coughing postprostatectomy. This concurs with modeling data that show SUS shortening determines continence after prostatectomy[6] and systematic review evidence of sphincter incompetence as a determinant of postprostatectomy incontinence.[25] Other factors must contribute to early incontinence postprostatectomy.

The negative correlation between postoperative urethral length and incontinence severity agrees with reports of a shorter membranous urethra in incontinent men pre-[20] and postprostatectomy.[26] Although plausible that shorter urethral length could impact SUS function and underpin an assumption that length is the principal determinant of incontinence, the absence of correlation between SUS and urethral length measures suggests an independent contribution. It is notable that urethral length report here are longer than those reported earlier[20] (~20 mm vs. ~13 mm). At shorter urethral lengths, the correlation with SUS function might be greater.

BC shortening during coughing was the only feature measured preprostatectomy that significantly correlated with incontinence. This was largely explained by poor BC function in four participants who developed severe incontinence. Those men were incontinent despite improvement of BC function after surgery, which implies BC function is unlikely to explain continence outcome.

## 4.4 | Impact of prostatectomy on ARJ motion

Consistent with previous data,[11] prostatectomy changed some features of ARJ, but not SUS or BC, motion. Reduced ARJ motion during coughing postprostatectomy might be explained by structural changes with prostatectomy. After surgical removal of the prostate, the urethra is sutured to the bladder neck. In some cases, the Denonvilliers fascia is anchored to the bladder base via suture to reduce tension at the anastomosis.[27] Bladder neck "funneling"[28] is common postprostatectomy with reduced height of the bladder base relative to the pubic symphysis and ARJ.[5] The change in position and other structural changes are likely to explain reduced motion at ARJ after surgery.

## 4.5 | Clinical implications

These data support the notion that continence recovery depends on SUS[5,6] and adds that other factors also contribute to early incontinence. Although this supports the proposal that SUS should be the primary target for PFM exercise programs pre- and postprostatectomy, men who developed incontinence did not improve SUS function despite training. This might be explained by differences in capacity of the participants to control of the PFMs and suggests that some men might require additional training to improve SUS contraction. Training including a motor control component with a primary focus on the SUS might be beneficial,[19] but with individual programs are guided/progressed by findings of assessment.

## 4.6 | Methodological limitations

Several issues require consideration. We used the self-reported ICSMaleSF Questionnaire to classify continent and incontinent participants, and quantify incontinence severity. Although we did not quantify urine loss, other studies have reported a strong association between questionnaire responses and pad-weight data.[29] For the continuous measure of incontinence severity, we used the composite score of the ICSMaleSF, which includes multiple urinary symptoms (e.g., nocturia, urgency, and so on) as a better representation of overall symptom "severity" than the response to the single item with relevance to stress urinary incontinence. We cannot be certain that the differences in contraction between "natural" and "trained" tasks are explained by the cues used to instruct the contraction, the method of instruction delivery or by the presence of visual feedback on US imaging. All features are likely to contribute. Finally, 8 participants out of 60 underwent open procedures (and the remainder underwent robotic procedures); after surgery 2 were continent and 6 were incontinent. This is unlikely to have influenced the data given randomised control trial evidence of similar outcomes between groups,[30] and that some of the observations (e.g., improved SUS function with training) were present before surgery.

## 5 | CONCLUSIONS

Men who are continent postprostatectomy demonstrate better capacity to improve SUS function with training both pre- and postprostatectomy than incontinent men. SUS shortening is suggested as the primary target for PFM exercise. ARJ motion during cough and voluntary contraction is reduced postprostatectomy, but SUS or BC shortening is not.


### ACKNOWLEDGMENTS

Funding for this study was provided by the National Health and Medical Research Council (NHMRC) of Australia (APP1146267) and a Physiotherapy Research Fellowship from Queensland Health. Paul W. Hodges is funded by a Leadership Fellowship from the NHMRC (APP1194937). The study was approved by the University of Queensland Human Research Ethics Committee and participants provided written informed consent. University ethical approval number: 2017001736. Open access publishing facilitated by The University of Queensland, as part of the Wiley-The University of Queensland agreement via the Council of Australian University Librarians.


### CONFLICT OF INTEREST

The authors declare no conflict of interest.

### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

### ETHICS STATEMENT

This longitudinal investigation of a cohort of men scheduled to undergo prostatectomy was not a clinical trial and therefore did not require clinical trial registration. Participants received standard care and we compared this with their natural, untrained strategy of muscle contraction.


### ORCID

*Ryan E. Stafford* http://orcid.org/0000-0002-5444-477X
*Paul W. Hodges* http://orcid.org/0000-0002-1206-9107


### REFERENCES


1. Novara G, Ficarra V, D'Elia C, Secco S, Cavalleri S, Artibani W. Trifecta outcomes after robot-assisted laparoscopic radical prostatectomy. *BJU Int*. 2011;107(1):100-104.
2. Hou GL, Luo Y, Di JM, et al. Predictors of urinary continence recovery after modified radical prostatectomy for clinically high-risk prostate cancer. *Urol J*. 2015;12(1):2021-2027.
3. Lavigueur-Blouin H, Noriega AC, Valdivieso R, et al. Predictors of early continence following robot-assisted radical prostatectomy. *Can Urol Assoc J*. 2015;9(1-2):e93-e97.
4. Mungovan SF, Sandhu JS, Akin O, Smart NA, Graham PL, Patel MI. Preoperative membranous urethral length measurement and continence recovery following radical prostatectomy: a systematic review and meta-analysis. *Eur Urol*. 2017;71(3):368-78.
5. Stafford RE, Coughlin G, Hodges PW. Comparison of dynamic features of pelvic floor muscle contraction between men with and without incontinence after prostatectomy and men with no history of prostate cancer. *Neurourol Urodyn*. 2020;39(1):170-80.
6. Stafford RE, van den Hoorn W, Coughlin G, Hodges PW. Postprostatectomy incontinence is related to pelvic floor displacements observed with trans-perineal ultrasound imaging. *Neurourol Urodyn*. 2018;37(2):658-65.
7. Elbadawi A. Functional anatomy of the organs of micturition. *Urol Clin North Am*. 1996;23(2):177-210.
8. Elbadawi A, Mathews R, Light JK, Wheeler TM. Immunohistochemical and ultrastructural study of rhabdosphincter component of the prostatic capsule. *J Urol*. 1997;158(5):1819-1828.
9. Stafford RE, Ashton-Miller JA, Constantinou CE, Hodges PW. Novel insight into the dynamics of male pelvic floor contractions through transperineal ultrasound imaging. *J Urol*. 2012;188(4):1224-1230.
10. Stafford RE, Ashton-Miller JA, Constantinou CE, Hodges PW. A new method to quantify male pelvic floor displacement from 2D transperineal ultrasound images. *Urol*. 2013;81(3):685-689.
11. Cowley D, Stafford RE, Hodges PW. The repeatability of measurements of male pelvic floor anatomy and function made from transperineal ultrasound images of healthy men and those before and after prostatectomy. *Neurourol Urodyn*. 2021;40:1539-1549.
12. Stafford RE, Ashton-Miller JA, Constantinou C, Coughlin G, Lutton NJ, Hodges PW. Pattern of activation of pelvic floor muscles in men differs with verbal instructions. *Neurourol Urodyn*. 2016;35(4):457-463.
13. Myers RP, Cahill DR, Devine RM, King BF. Anatomy of radical prostatectomy as defined by magnetic resonance imaging. *J Urol*. 1998;159(6):2148-2158.
14. Chang JI, Lam V, Patel MI. Preoperative pelvic floor muscle exercise and postprostatectomy incontinence: a systematic review and meta-analysis. *Eur Urol*. 2016;69(3):460-467.
15. Stafford RE, Coughlin G, Lutton NJ, Hodges PW. Validity of estimation of pelvic floor muscle activity from transperineal ultrasound imaging in men. *PLoS One*. 2015;10(12):e0144342.
16. Donovan JL, Peters TJ, Abrams P, Brookes ST, de aa Rosette JJ, Schafer W. Scoring the short form ICSmaleSF questionnaire. International Continence Society. *J Urol*. 2000;164(6):1948-55.
17. Kendrick KR, Baxi SC, Smith RM. Usefulness of the modified 0-10 Borg scale in assessing the degree of dyspnea in patients with COPD and asthma. *J Emerg Nurs*. 2000;26(3):216-222.
18. Dorey G, Glazener C, Buckley B, Cochran C, Moore K. Developing a pelvic floor muscle training regimen for use in a trial intervention. *Physiotherapy*. 2009;95(3):199-209.
19. Hodges PW, Stafford RE, Hall L, et al. Reconsideration of pelvic floor muscle training to prevent and treat incontinence after radical prostatectomy. *Urol Oncol*. 2020;38(5):354-71.
20. Cameron A, Suskind A, Neer C, et al. Functional and anatomical differences between continent and incontinent men post radical prostatectomy on urodynamics and 3T MRI. *Neurourol Urodyn*. 2014;33(2):169.

21. Desautel MG, Kapoor R, Badlani GH. Sphincteric incontinence: the primary cause of post-prostatectomy incontinence in patients with prostate cancer. *Neurourol Urodyn*. 1997; 16(3):153-160.
22. Lee H, Kim KB, Lee S, et al. Urodynamic assessment of bladder and urethral function among men with lower urinary tract symptoms after radical prostatectomy: A comparison between men with and without urinary incontinence. *Korean J Urol*. 2015;56(12):803-810.
23. Weyne E, Mulhall J, Albersen M. Molecular pathophysiology of cavernous nerve injury and identification of strategies for nerve function recovery after radical prostatectomy. *Curr Drug Targets*. 2015;16(5):459-473.
24. Hodges P, Stafford R, Coughlin GD, et al. Efficacy of a personalised pelvic floor muscle training programme on urinary incontinence after radical prostatectomy (MaTchUP): protocol for a randomised controlled trial. *BMJ Open*. 2019;9(5):e028288.
25. Hoyland K, Vasdev N, Abrof A, Boustead G. Post-radical prostatectomy incontinence: etiology and prevention. *Rev Urol*. 2014;16(4):181-188.
26. Muñoz-Calahorro C, García-Sánchez C, Barrero-Candau R, García-Ramos JB, Rodríguez-Pérez AJ, Medina-López RA. Anatomical predictors of long-term urinary incontinence after robot-assisted laparoscopic prostatectomy: a systematic review. *Neurourol Urodyn*. 2021;40(5):1089-1097.
27. Rocco B, Gregori A, Stener S, et al. Posterior reconstruction of the rhabdosphincter allows a rapid recovery of continence after transperitoneal videolaparoscopic radical prostatectomy. *Eur Urol*. 2007;51(4):996-1003.
28. Kirschner-Hermanns R, Najjari L, Brehmer B, et al. Two- and three-/four dimensional perineal ultrasonography in men with urinary incontinence after radical prostatectomy. *BJU Int*. 2012;109(1):46-51.
29. Tienza A, Graham PL, Robles JE, et al. Daily pad usage versus the international consultation on incontinence questionnaire short form for continence assessment following radical prostatectomy. *Int Neurourol J*. 2020;24(2):156-62.
30. Coughlin GD, Yaxley JW, Chambers SK, et al. Robot-assisted laparoscopic prostatectomy versus open radical retropubic prostatectomy: 24-month outcomes from a randomised controlled study. *Lancet Oncol*. 2018;19(8):1051-60.


## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

**How to cite this article:** Stafford RE, Doorbar-Baptist S, Hodges PW. The relationship between pre- and postprostatectomy measures of pelvic floor muscle function and development of early incontinence after surgery. *Neurourol Urodyn*. 2022;41:1722-1730. doi:10.1002/nau.25034