Key Words
Pelvic floor muscles, abdominal muscles, automatic function, dysfunction, rehabilitation.

by Ruth Sapsford

The Pelvic Floor

A clinical model for function and rehabilitation

Summary The pelvic floor forms the inferior boundary of the abdomino-pelvic cavity. The co-ordinated action of the muscles which surround this cavity generates intra-abdominal pressure, with the pelvic floor muscles acting before the pressure rise to maintain organ support and urinary and faecal continence. When the pelvic floor muscles lose their automatic co-ordinated function, it is the timing of muscle recruitment, as well as the endurance and strength, which is deficient. This paper presents a theory on how automatic pelvic floor muscle activity operates in healthy women, discusses how it is lost, suggests a non-invasive way of testing it, and proposes a programme to restore the automatic recruitment timing of the muscles, as well as their endurance and strength, to optimise rehabilitation outcomes.

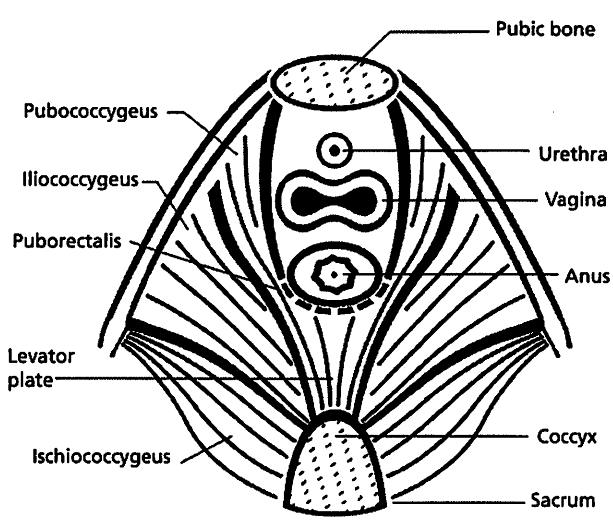

Fig 1: Diagrammatic view of the levator ani and ischiococcygeus viewed from the pelvic surface.
Puborectalis forms a U-shaped sling which is incorporated into and functions with the external anal sphincter; pubococcygeus (PC), the principal component, supports and compresses the vagina and rectum and fuses posteriorly to form the levator plate between the anorectal junction and the coccyx; iliococcygeus fuses with PC into the levator plate which supports the upper vagina and the rectum; ischiococcygeus provides further rectal support. Slow-twitch fibre content in these muscles ranges from 67% to 76% (Gilpin *et al*, 1989)

Introduction

The role of the pelvic floor (PF) is generally understood to be that of support for the pelvic viscera under all circumstances, and control of their outlets – both to close and release.

This paper briefly reviews what is already known about voluntary and spontaneous functioning of the pelvic floor muscles (PFM). In addition it explains a theory based on clinical observation, integration of concepts from various scientific and medical disciplines and some initial research on optimum methods for physiotherapists to restore PFM function. This theory has been developed through an understanding of how the PFM are controlled for automatic function.

When the integrity of the PFM support and control mechanisms is compromised, pelvic organ dysfunction may result. The disruption of support can occur in urethrovesical, uterovaginal or anorectal systems, and frequently in all three simultaneously (Maglinte *et al*, 1999). Interventions aimed at restoring support are either surgical or conservative, focusing on fascial or muscular elements respectively. Surgical interventions in cases of fascial laxity may successfully restore organ position within the pelvis in cases of prolapse (Koduri and Sand, 2000). Where organ function is compromised, however, restoration of position does not necessarily restore that function. In obstructed defecation, due to a descending perineum, surgical correction of the rectal defect may cure the prolapse but the evacuation problem usually persists (Pemberton, 1990). In cases of urinary incontinence, the most common form of dysfunction, many different surgical interventions have been used with variable outcomes (Black and Downs, 1996). This has led to a push for the initial approach of management of urinary incontinence to be conservative, aimed at improving muscle control, as this is not invasive and is beneficial in many cases (Berghmans *et al*, 1998; Bo, 1995).

Pelvic Organ Support

Muscles as well as fascia are potentially supportive elements. There have been differences of opinion over the years as to what forms the principal supporting mechanism of the pelvic organs. The levator ani are the principal supporting muscles of the pelvic floor and are considered in four sections (fig 1).

Berglas and Rubin (1953) demonstrated the supporting mechanism of the uterus using radiography. At rest in standing, the barium defined rectum and vagina were seen to be positioned over the levator plate with the cervix near the coccyx. On straining, the organs were pressed against the plate. They deduced that it was muscle, not fascia and ligaments, that provided organ support during increases in intra-abdominal pressure (IAP). They also commented that the PFM were an intrinsic part of the physiological complex of muscles of the abdominal wall. Other investigations noted significantly increased muscle bundles from pubococcygeus (PC) to the vaginal wall and perineal body in black women, as well as strong pelvic connective tissue (Nichols and Randall, 1989).

Organ support during coughing was investigated using perineal ultrasound to record bladder neck position, in two groups of women – one with genuine stress incontinence (GSI) and one without (Wijma *et al*, 1991). Both groups had similar bladder neck extensibility on voluntary PFM contraction and straining. However, in those with incontinence the bladder neck descended with coughing, whereas in the continent group it maintained a constant position.

In healthy subjects, pelvic organ support is automatic during activity, but in symptomatic women the PFM do not respond functionally, despite voluntary activation.

Anorectal Function

Faecal continence is dependent on anal pressure being greater than rectal pressure, when contents are present. The smooth muscle internal anal sphincter (IAS) and striated muscle external anal sphincter (EAS) both contribute to anal closure at rest with the EAS contributing approximately 15% of that closing pressure. With rectal filling the IAS relaxes, in anticipation of evacuation, and activity in the EAS increases to maintain anal closure until a suitable time and place for evacuation is found (Pemberton, 1990). Voluntary activity in EAS can double the anal resting pressure, and the pressure increase with coughing is greater still (Meagher *et al*, 1993). Increases in anal pressure and EMG activity have also been shown with isometric abdominal exercises (Sapsford and Hodges, 2001).

Defecation requires rectal support, anal outlet release and an effective expulsive effort (Markwell and Sapsford, 1995). On sitting to evacuate, the PF and abdominal wall relax, the anorectal junction descends 1-2 cm (Shorvon *et al*, 1989), and the anal sphincter relaxes. Rectal emptying is initiated either by rectal contractions or by increasing the IAP with an expulsive effort. Expulsive IAP forces are generated by activity in all the abdominal muscles (De Troyer *et al*, 1990) in combination with diaphragmatic descent. An isometric hold of the PF muscles in their lowered position provides rectal support against the increased IAP, while the anal outlet opens. It has been shown that PC EMG activity occurs during the defecatory attempt in healthy subjects but does not occur in patients with obstructed defecation (Lubowski *et al*, 1992).

Thus abdominal and PFM co-ordinated activity is required for anal release, rectal support, expulsive effort and continence.

Urinary Function, Continence and Incontinence

For urinary continence to be maintained, urethral pressure must be greater than bladder pressure at all times. The rise in urethral pressure *before* the increase in IAP during a cough indicates that factors other than IAP are responsible for those increases. The pressure rise has been attributed to intra-urethral and peri-urethral structures (Constantinou and Govan, 1982; Thind *et al*, 1990). Urethral pressure increases have also been demonstrated with voluntary PFM contractions, and with isometric abdominal holds (Sapsford *et al*, 1998).

Reports of a low incidence of GSI

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in Chinese women led to dissection of Chinese female cadavers, from low socio-economic groups, in Hong Kong (Zacharin, 1977). The findings showed that the levator ani muscle complex was much better developed than in occidentals, with a thicker muscle mass that extended further laterally. Connective tissue binding the vagina and anal canal to the muscle margins was noticeably dense and strong. It was concluded that the low incidence of stress incontinence was due to tissue quality, possibly due to hard work, minimal obesity and squatting.

The initial conservative approach for treatment of GSI is voluntary exercise for the PFM and was developed by Kegel (1948). Since that time, voluntary exercise, with variations in the programmes used, and sometimes with adjunctive interventions such as neuromuscular stimulation (Knight *et al*, 1998) vaginal weights (Peattie *et al*, 1988) or biofeedback (Berghmans *et al*, 1996) has been used by physiotherapists, nurses, and medical practitioners (Bo and Talseth, 1996; Mantle and Versi, 1991; Dougherty *et al*, 1989).

The aim of exercise in these conditions has been to improve the strength of the PFM and the endurance of strong contractions (Knight *et al*, 1998; Bo, 1995). It is generally advocated that this should be done by exercise of those muscles in isolation, without obvious participation of adjacent hip or abdominal muscles (Knight and Laycock, 1994; Bo, 1995; Bump *et al*, 1996).

PFM Function

While the increased strength of the PFM is reportedly measured objectively using a vaginal pressure device (Knight *et al*, 1998), how and whether that increased strength confers automatic function with increases in IAP is not known.

Using electromyography (EMG) Deindl *et al* (1994) showed bilateral PC tonic activity at rest in seven out of ten nulliparae, and either unsustained or no activity in the others. Yet on voluntary activation, coughing and valsalva all subjects showed a strong phasic response, whereas parous women with stress incontinence showed unsustained tonic patterns, with asymmetrical recruitment and paradoxical inhibition in response to some activities.

Christensen *et al* (1995) used magnetic resonance imaging (MRI) to demonstrate elevation of pelvic organs from rest with a sustained submaximal PFM hold. Areas of change at the anterior and lateral abdominal walls indicated abdominal muscle activity during the PFM hold. The elevation of the bladder neck during a PFM contraction, descent during straining and return to the resting position on cessation of each action has been demonstrated with MRI (Bo *et al*, 1997).

This type of response can also be seen on images from videodefecograms of a patient with descending perineum syndrome and pain (Markwell, 1998). They demonstrate elevation of the rectum with voluntary activation of the PFM, yet on attempted evacuation the rectum loses its muscular support and marked perineal descent occurs, rising to its former resting position at the end of the defecatory attempt.

There is some evidence that PFM activity is associated with abdominal muscle activity. The effect of posture on PFM activity has been studied by EMG, in relation to voiding dysfunction in young girls (Wennergren *et al*, 1991). Sitting perched on the rim of the toilet seat or sinking into the 'hole' resulted in urethral, anal and abdominal muscle activity. These two postures required trunk muscle activity for stability. Relaxation of the PFM was achieved using a smaller diameter toilet seat, which provided body support, and a foot support. Some functional activities have been shown to recruit PFM. Puborectalis was active during lifting (Hemborg *et al*, 1985). Bo and Stein (1994) showed that PC EMG activity increased with valsalva, or a cough, during sit-ups and with backward pelvic tilting (lumbar flexion).

Support for the idea of a close association between the PFM and abdominal muscles comes from Power (1948) who described a direct continuation of puborectalis with rectus abdominis in an imperfectly developed fetus. Neurological evidence adds to this. A motor neuronal pathway from the nucleus retroambiguous to the lumbosacral cord in the cat was shown to project densely to both the abdominal wall and pelvic floor motor neurones in Onuf's nuclei (the S2-S4 nuclei which control PFM function) (Vanderhorst and Holstege, 1997). It is likely that a similar pathway occurs in man (personal communication, G Holstege, 1998).

Recent research (Sapsford *et al*, 2001; Gill and Neumann, 1999) indicates that abdominal muscle activity is a normal response to a PFM contraction and the position of the lumbar spine, either flexion, extension or neutral, varies the EMG response in each abdominal muscle. In flexion subjects perceived a diminished ability to perform a maximal PFM contraction and the palpated PC muscle contraction was less pronounced. Conversely, when specific isometric abdominal contractions were performed in lying, PC and EAS/EMG activity increased (Sapsford and Hodges, 2001).

Two other studies provide evidence of the synergistic action of the abdominal and PF muscles. They demonstrate similar effects with a strong isometric abdominal contraction and a maximal PFM contraction on urethral pressure increases (Sapsford *et al*, 1998) and the time taken for a midstream urine flow stop (Sapsford and Markwell, 1998).

Thus there seems to be enough evidence of PFM and abdominal muscle interaction to warrant a re-appraisal of PFM function as it is affected by IAP, trunk postures and trunk muscle activity.

A Clinical Model of PF Function

All the components of the PF constitute a musculoskeletal unit and it seems pertinent to consider how other musculoskeletal units function and relate these to concepts of the PF.

Panjabi (1992) suggests that a musculoskeletal unit has passive, active and neural subsystems of control, represented respectively by bones and ligaments, skeletal muscle, and both somatic and central nervous system components. Similarly, the term 'stress continence control system' has been suggested by Ashton-Miller (1996) to describe the ligaments, muscles and nerves involved in urinary continence during increases in IAP. Their co-ordinated action working as an integrated unit provides urethral support (DeLancey, 1996). Panjabi has focused his attention on the lumbar spine. Mechanical forces responsible for inter-segmental stability are provided by deep local trunk muscles – transversus abdominis (TrA) and multifidus.

Of all the abdominal muscles it is the TrA, the deepest corset-like muscle, which is recruited before rapid limb movement to help in stabilising the lumbar spine. Yet in patients with back pain this early recruitment does not occur and TrA acts phasically like the torque producing muscles which move the spine (Hodges and Richardson, 1996). Similar changes have been noticed in vastus medialis obliquus in relation to patellar pain syndromes (Richardson, 1987). It has been suggested that a delay in recruitment of muscle activity may also occur in the PFM (DeLancey, 1996)

The PFM are not an isolated unit, but part of the abdominal capsule (Richardson *et al*, 1999, page 95), surrounding the abdominal and pelvic organs (fig 2). The structures comprising this capsule are the lumbar vertebrae and multifidus muscles, the diaphragm, which has both postural and respiratory roles (Hodges *et al*, 1997), the TrA muscles

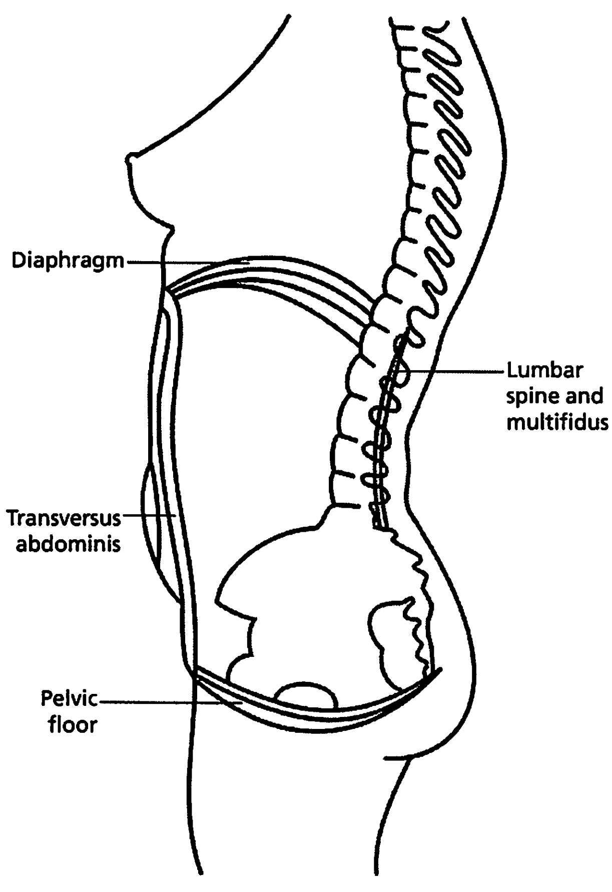

Fig 2: Diagrammatic representation of the abdomino-pelvic cavity surrounded by muscles which contribute to spinal stability, intra-abdominal pressure and continence.
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and the PFM complex. These muscles contribute to the maintenance of the trunk posture in an upright position and act synergistically. This has been demonstrated by a number of studies. Postural activity in the diaphragm occurs before rapid limb movement, irrespective of the phase of respiration, and coincides with the onset of activity in TrA (Hodges *et al*, 1997). Interactions between TrA and multifidus have also been demonstrated (Richardson *et al*, 1999, page 95). Pubococcygeal EMG activity occurs during specific abdominal manoeuvres and abdominal EMG activity has been demonstrated during a voluntary PFM muscle contraction (Sapsford *et al*, 2001). Other parts of the levator ani have not been tested. Further research is required to demonstrate all of these muscle interactions.

To enable an appropriate response to any potential disturbance a muscle must be ready to react. Wijma *et al* (1991) and Bo *et al* (1997) have shown that a functioning PF at rest is positioned somewhere in the middle of its range of movement, that is in a mid-zone. It returns to this mid-zone resting position on relaxation after voluntary contraction, straining and defecation (Shorvon *et al*, 1989). To maintain this mid-zone position against gravitational and abdominal forces, the PFM need to be tonically active at all times. The predominantly slow twitch PFM (Critchley *et al*, 1980; Gilpin *et al*, 1989; Dimpfl *et al*, 1998) are ideally suited to this role.

The PF needs to respond spontaneously to changes in posture, trunk muscle activity and IAP, to continue to support under light, heavy or sudden loading, and to keep the sphincters closed or to be able to release them as appropriate.

Automatic PF responses are acquired with the development of motor control, while muscle strength is gained from the demands placed upon that muscle (Gordon and Logue, 1985). Is there a simple means of detecting whether the PF responds automatically to increases in IAP? The author suggests that the spontaneity of PF support can be tested while a woman coughs forcefully when sitting upright. She reports a subjective awareness that the vagina bulges, flares, descends, opens or holds firm or lifts. In the first four it is hypothesised that the PF is not stabilised against the IAP increases, and in the latter the muscles hold firm in the mid-zone. Any perceived instability is greater in standing, and with a flexed spine in both sitting and standing. Research is currently under way to validate these subjective observations.

Spontaneous muscle activity cannot be assumed to be the same as voluntary activation (Deindl *et al*, 1994; Wijma *et al*, 1991; DeTroyer *et al*, 1990). Wijma *et al* (1991) showed that in all subjects the bladder neck was elevated by voluntary PF activation, but on coughing it maintained its mid-zone position in asymptomatic women, and descended in those with GSI. Whether the bladder neck needs to be elevated during coughing is not clear. DeLancey (1996) stated that the idea that the height of the urethra determines continence during stress needed to be looked at closely. If the timing and power of PFM activity can maintain the muscle within the mid-zone this may be what is needed to provide the necessary closing force.

Postural muscles require continuous activity to counteract gravitational forces. While large alpha motor neurones innervate skeletal muscle fibres, the muscle spindles within the muscles are innervated by two types of gamma motor efferents, which originate in the anterior horn and are controlled by the brainstem and cerebellum. The type of sensory stimulus relayed from the muscle spindle determines the type of motor response. With a sudden stretch of the muscle spindle the response is dynamic and short-lived, and with a slow stretch the response is a static and sustained hold (Guyton, 1991). It may be that the continuous tonic hold of the muscle establishes the sensitivity of the feedback system to the muscle, and enhances the muscle response to the demands placed upon it.

From this evidence it seems that the PFM act as part of an integrated abdomino-pelvic unit, under control of central nervous system programming that ensures appropriate timing of automatic responses to changes within that unit.

Causes of PFM Dysfunction

Morphological changes, such as variation in fibre diameter, fibrosis and centrally located nuclei, occur in the PFM in women who have had vaginal deliveries and with increasing age (Dimpfl *et al*, 1998). Partial denervation of the PC muscle, with evidence of re-innervation, occurs with the first vaginal delivery in the majority of women (Allen *et al*, 1990). In incontinent women PC voluntary holding times are shorter and vaginal surface EMG activity is less than in continent women (Deindl *et al*, 1994; Gunnarsson and Mattiasson, 1999). These changes may result in decreased feedback from the muscle to the motor control centre in the brain.

Reduced afferent inflow to the central nervous system has been shown to reverse the normal recruitment order of motor units, from slow-twitch (tonic) first, to fast-twitch units (phasic) being recruited first (Grimby and Hannerz, 1976).

Flexion of the lumbar spine affects the PFM response. Women find it harder to activate a PFM contraction in flexion (Sapsford *et al*, 2001). The author has noticed that the abdominal wall sags forward in flexion in standing in many women and this is known to lessen PFM activity (Sapsford and Hodges, 2001). Patients report that this forward-lean position aggravates urgency and the drag of a prolapse. Urine loss may occur with coughing and laughing when the abdominal wall is relaxed in sitting in an easy chair, but not when sitting upright. Many women flex the spine as they cough in standing and it is likely that this diminishes urethral closing pressure. In an experimental situation, bulging forward of the abdominal wall has been shown to lower urethral pressure in healthy women (Sapsford *et al*, 1998). This bulging action, however, is useful to facilitate voiding and defecation.

There is great variation in the extensibility of the bladder neck, ranging, in one study, from 21 to 38 mm (Bo *et al*, 1997). DeLancey (1996) suggested that it is not the height of the urethra but the stability of support that determines urinary continence during stress. Other musculoskeletal units within the body can exhibit hypermobility, but good motor control of muscle function maintains stability for daily activities. When excessive forces are applied, muscle strength may be inadequate to provide stability and external support is beneficial. Many women have found the use of a tampon during high impact activities provides bladder neck support and thus continence.

Long-term regular straining to empty the bowel has been associated with utero-vaginal prolapse and GSI (Spence-Jones *et al*, 1994). Defects in collagen cross-links in pubo-cervical fascia have been discovered in women with bladder neck prolapse with incontinence (Sayer, 1994). In some cases, stress-induced incontinence is due to tearing of passive elements, the para-vaginal fascial attachments, as well as inadequate muscle recruitment. Such fascial defects require surgical repair (DeLancey, 1996). However, co-ordinated muscle activity will ensure proper function once the anatomical defects have been corrected.

Nulliparous and parous subjects who had no PC tonic activity at rest (Deindl *et al*, 1994) may have had little postural activity in TrA. Young nulliparous women and athletes, who report urinary incontinence with effort, may also have low levels of postural activity in TrA and perhaps a timing deficit in PF recruitment despite their general fitness (Bo *et al*, 1994; Nygaard *et al*, 1994). This could be related to a previous back injury (Hodges and Richardson, 1996), or over-development of other abdominal muscles, especially rectus abdominis and the obliquus externus abdominis (EO).

Clinicians treating lumbar spine instability report that women comment on improved urinary control as their lumbar stability improves (Richardson *et al*, 1999, page 134). Symptoms associated with a loss of PFM tonic hold are urinary urgency and frequency, stress incontinence, obstructed defecation (poor rectal support as occurs in the descending perineum syndrome), vaginal dragging and pain.

Dysfunction also presents with over-activity of all the PFM. Voiding dysfunction, dyspareunia, obstructed defecation (sphincter non-release, sometimes called anismus) and perineal and perianal pain are associated problems. Many of these patients, frequently the young and very fit, have an over-active abdominal wall that is not released to allow PF relaxation.

It appears that changes to elements of the muscular capsule by pregnancy, parturition, inactivity, long-term straining at stool, back injury and over-activity can disrupt the orderly programmed recruitment of any of its components.

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Restoration of Function

In low back pain patients, it has been found that by repeatedly practising the specific action of a very low level isolated TrA contraction and increasing the length of hold of this contraction, the muscle can be retrained to act independently, thus improving stability and reducing pain (O'Sullivan *et al*, 1997; Richardson *et al*, 1999, page 97). Gentle periurethral PFM contractions are one of the most useful ways of facilitating TrA initially. In lying, patients learn to recognise a correct TrA contraction by palpating a slowly developing deep tension in the lower abdominal wall (Richardson *et al*, 1999, page 130). The exercise is progressed into more functional positions such as sitting and standing, and care is taken to minimise activation of obliquus internus abdominis (IO), before loading is added. Real time ultrasound provides biofeedback of TrA recruitment.

The author has noted clinically that gentle deep abdominal muscle isometric contractions can activate a low level PF response. Women in standing report a perception of periurethral, perivaginal and perianal tensing or tightening. This occurs in healthy women and in those with different types of dysfunction. In patients, initial attempts of gentle isometric abdominal muscle contractions in lying may recruit minimal activity in TrA and thus a very low level of PFM activity, which is not digitally detectable. A definite PC response can be palpated in those patients who have rehabilitated an independent TrA action. Abdominal activity, which probably includes IO with TrA, results in an obvious lift and closure around the perineal apertures.

If there is no observed perineal or palpable PC response to the abdominal action, yet it is known that PC can be activated voluntarily, it is reasonable to assume that the woman is recruiting abdominal muscles other than TrA. This has been detected in women who regularly do trunk curls. These favour activation of rectus abdominis and the EO muscles (Walters and Partridge, 1957).

Even in healthy subjects, the proportional recruitment of the different abdominal muscles during isometric exercise is very varied (personal communication, C Richardson, 1999). One study subject, who predominantly recruited EO with minimal activity in TrA during specific abdominal manoeuvres, showed only a small increase in EMG activity in PC. Another subject with greater recruitment of TrA showed a greater increase in PC activity (Sapsford *et al*, 2001). Perhaps this indicates the importance of TrA for good PC function.

PF neuropathy will limit muscle recruitment whatever the means used for activation. Failure, by the patient, to perceive a periurethral or perivaginal response to an appropriate abdominal contraction, when the PC response can be detected digitally at that time, is possibly due to disruption of sensory pathways. Sometimes this occurs after a vaginal repair. However a few women seem to have very poor PF kinaesthetic awareness.

The TrA/PF response appears to be enhanced by exercising with a good lumbosacral curve. A flexed starting position and spinal flexion during exercising tend to recruit torque producing abdominal muscles, such as EO and rectus abdominis, and these may restrict TrA muscle recruitment (Sapsford *et al*, 2001). There are indications that those who sit unsupported with a good lumbar curve, stand erect, and move with a firm lower abdomen, are facilitating low level PFM activity in synergy with the deep abdominal muscles, much of the time throughout the day. They have good postural control. It is only when these abdominal holds are automatic that PF support is maintained during trunk flexion.

Clinical experience indicates that retraining of prolonged gentle TrA tonic holds can restore the spontaneous PF support response before increases of IAP. Other approaches, which enhance PFM tonic activity, may also achieve this. The time required for this support response to become automatic varies, and may not be achieved by everyone. It probably depends on motivation, the ease with which the initial abdominal muscle response is gained, the state of endurance and strength of the muscles, both abdominal and PF, at the start of treatment and the time spent exercising. During the retraining period PF support prior to a cough can be facilitated by voluntarily tightening the lower abdomen, or using a voluntary PFM hold (Miller *et al*, 1998).

Strengthening has been the aim of most PFM rehabilitation in the past (Bo, 1995; Knight *et al*, 1998), but greater strength does not necessarily correlate with better function (Hextal *et al*, 1999; Knight *et al*, 1998). The amount of power needed to stabilise the PF position during effort will depend on the force generated during that effort. In the past, strengthening has generally been achieved by voluntary activation of the PFM, sometimes with adjunctive interventions. It is now known that strong abdominal isometric holds can be used to gain a strong PFM contraction (Sapsford and Hodges, 2001). However it is probable that retraining PFM tonic activity, achieved through prolonged gentle TrA activation, before increasing the strength, is an important factor in restoring the correct timing of the PF response.

Based on the foregoing theories the following PF rehabilitation programme, used by the author, is proposed.

Rehabilitation Programme

- Stand erect. Firmly palpate the lower abdomen. Slowly and gently draw in the lower abdomen (it must not push out), without breathing or moving the spine, until slight abdominal tension is detected. Hold, now breathe quietly without moving the abdomen, gradually increasing the hold time to 5, 10, 15, 20 and more seconds. Repeat 5 times. Do 5 sessions a day. Check for a subjective awareness of the periurethral and perivaginal tension. If there is no awareness an alternate approach to activation of the PF and TrA will be required (Richardson and Jull, 1995).
- When 15-second TrA holds are achieved with ease, incorporate the gentle long holds into many daily activities in upright standing, eg on phone, in shower, ironing, in queues, walking. The more the better.
- At this stage add strengthening. Always begin with a slow, gentle lower abdominal action and keep pulling to build to a strong isometric hold (TrA + obliques) for 6 seconds. Breathe while holding. Repeat 6 times, 2-3 times a day.
- Strong voluntary PF holds, with a neutral spine, can be incorporated now, but should not replace the abdominal holds. Maintain the tension that develops in the abdominal wall as you hold the PF.
- Use voluntary abdominal or PF holds for all effort activities, until the response is automatic.
- When the combined TrA and the pelvic floor tensioning response is automatic (without cognitive effort) ie in standing the abdominal wall holds firm in forward lean, and the vagina is subjectively perceived to hold firm during a cough in standing – reduce the prolonged gentle lower abdominal isometric holds to 2 or 3 a day.
- Maintain abdominal and PF strength and power by incorporating abdominal and PF holds into daily lifting and working activities.

Perhaps upright postures, with a good lumbar curve and associated TrA postural activity, and the added abdominal strength acquired from the demands of manual activities and load carrying, rather than racial characteristics, are the explanation for the good pelvic muscles and supporting tissues in black women and those Chinese cadavers dissected by Zacharin (1977). Increased strength of connective tissue also results from strong physical training (Stone, 1988). Westernisation of Chinese women in Hong Kong has occurred over the last 20 years and the reported incidence of prolapse and GSI now equals western levels (Brieger *et al*, 1996). It may be that decreased levels of synergistic abdominal and pelvic floor activity that occur with more sedentary lifestyles have contributed to this.

In summary, the author suggests that pelvic floor rehabilitation does not reach its optimum level until the muscles of the abdominal wall are rehabilitated as well.

Conclusion

The ideas presented in this paper challenge existing theory and practice and much research will be required to test these hypotheses. There is an increasing interest among physiotherapists around the world in the contribution of TrA to PF function. The few studies that have been published on this so far have been restricted to healthy subjects. It is recognised that the timing of a PFM response, in relation to increases in IAP, is a major factor in function and may be more important than the degree of strength (Deindl *et al*, 1993; DeLancey, 1996). If the findings in relation to other musculoskeletal units are taken into consideration, perhaps the rehabilitation of PF dysfunction can be further improved.

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Key Messages

- The timing of PFM recruitment before increases in abdominal pressure is essential for continence.
- Tonic PFM activity, to restore timing, needs to be rehabilitated before strengthening.
- Sustained tonic transversus abdominis activity is an ideal way to retain tonic PFM activity.
- Strengthening of PFM can be achieved by strong isometric abdominal holds or by strong PFM holds.
- PFM rehabilitation is not complete until the abdominal muscles are also rehabilitated.

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