Masterclass

Functional load abdominal training: part 2

C. M. Norris

This article discusses current abdominal training by analysing the sit-up and leg-raise actions, and body segment alignment is emphasized with reference to the lumbar spine. A new approach to abdominal training based on the principles of spinal stabilization is proposed, consisting of three overlapping stages. In stage one, the stabilizing function of the deep abdominal muscles is re-educated, and several practical suggestions are made to assist this process. In stage two, static stability is built emphasizing isometric control of the lumbar spine neutral position. In stage three, apparatus is introduced for traditional exercises that are appropriate to functional training of the trunk. © 2001 Harcourt Publishers Ltd

Analysis of current abdominal exercise technique

To be able to develop more appropriate exercises for the trunk it is essential to firstly understand what the traditional exercises for this region actually achieve. To this end the two major categories of abdominal exercises, the 'sit-up' and 'leg-raise' will be briefly analysed (Norris 1994).

The sit-up

The sit-up is essentially an action where the subject moves from a supine lying position to a long-sitting position by performing hip flexion (trunk moving on a fixed leg), usually with trunk flexion. There are several modifications of this action, which will be dealt with below.

In a classic sit-up, as soon as the head lifts, activity is seen in the rectus abdominis (Walters & Partridge 1957), and as a consequence the rib cage is depressed anteriorly. The rectus is acting here to stabilize the ribcage and hold it down against the pull of the neck flexors attempting to lift the head. The initial period of trunk flexion emphasizes the supra-umbilical portion of the rectus, the infra-umbilical portion and the internal oblique contracting later in the movement (Kendall & McCreary 1993). As the internal oblique contracts, it pulls on the lower ribs, causing the ribs to flare out and so increasing the infrasternal angle.

One of the problems poorly toned individuals face is 'bow stringing' of the abdominals, which is often seen at the initiation of the sit-up action. For rectus abdominis to pull flat, the deep abdominals (transversus abdominis and internal oblique) must be able to pull on the rectus sheath to hold the abdominal wall down. This movement demands a coordinated action of both the superficial and deep abdominals, which is often lost. Where an imbalance exists with the deep abdominal muscles poorly recruited and the rectus abdominis lengthened, the abdominal wall will be seen to *dome* and the pelvis to anteriorly tilt. As a consequence the athlete may lift the trunk with the lumbar spine extended or flat rather than flexed.

Fixation of the pelvis is provided by the hip flexors, especially iliacus through its attachment to the pelvic rim. The strong pull of hip flexors is partially counteracted by the pull of the lateral fibres of external oblique and the infra-umbilical portion of the rectus abdominis which tend to tilt the pelvic posteriorly. Action of the external oblique, if powerful enough, will compress the ribs and reduce the infrasternal angle once more (Kendall et al. 1993).

In a poorly conditioned subject exercising at speed, the initial movement in a sit-up may be a

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momentary posterior tilting of the pelvis by action of the hip extensors. This will pre-stretch the hip flexors, giving them a mechanical advantage before hip flexion occurs (Ricci et al. 1981).

Effects of foot fixation

If the sit-up action is attempted from the supine lying position without allowing trunk flexion, there is a tendency for the legs to lift up from the supporting surface. This occurs because the legs constitute roughly one-third of the bodyweight and the trunk two-thirds.

As the abdominal muscles flex the spine, the centre of gravity of the upper body is moved caudally. Movement of the centre of gravity in this fashion reduces the lever arm of the trunk enabling the subject to sit up without the legs lifting (Fig. 1).

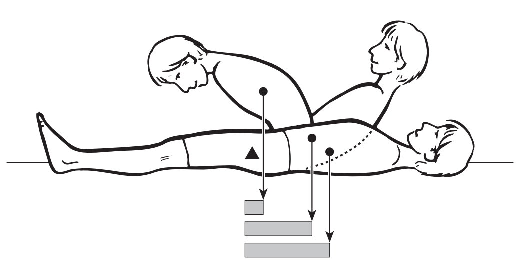


Fig. 1 Movement of the centre of gravity of the upper body during a sit-up exercise.

In cases where the abdominal muscles are weak and lengthened, maximum spinal flexion will not occur because the muscles are unable to pull the lumbar spine into full inner range. In this case the lever arm of the trunk remains long and the legs are seen to lift. The exact point at which this occurs in the movement will depend on a subject's bodyweight and stature.

If the feet are fixed, the hip flexors can now pull powerfully without causing the legs to lift. In addition, the act of foot fixation itself may facilitate the iliopsoas (Janda & Schmid 1980). Foot fixation requires the subject to pull against the fixation point by active dorsiflexion. This process stimulates the gait pattern at heel contact increasing activity in the tibialis anterior, quadriceps and iliopsoas, a pattern known as flexor synergy (Atkinson 1986).

Modifications of the sit-up include the bent knee sit-up and the trunk curl. The bent knee sit-up is performed from the crook lying starting position, with the knees flexed to 90° and hips flexed to 45°. The action is one of the trunk flexion followed by, or performed with, hip flexion. The trunk curl is performed from the same starting position, but no hip flexion occurs, the lumbar spine remaining in contact with the supporting surface. The bench-curl ('crunch' exercise) is performed from a starting position of 90° hip flexion and 90° knee flexion, the shin being supported on a bench or chair. Bending the knees and hips to alter the starting position of the sit-up will affect both the passive and the active actions of the hip flexors, and the biomechanics of the lumbar spine. In supine lying, the iliopsoas is on stretch, and aligned with the horizontal (Fig. 2). In this position, vertebral compression is at its greatest as the muscle contracts, and trunk lifting is at a mechanical disadvantage. The ratio of lifting to compression is, therefore, approximately 1:10 (Watson 1983). As the knees are flexed, the iliopsoas is pulled more vertically and so the ratio of trunk lifting to vertebral compression reduced to 2:5 in crook lying and 1:1 in bench lying.

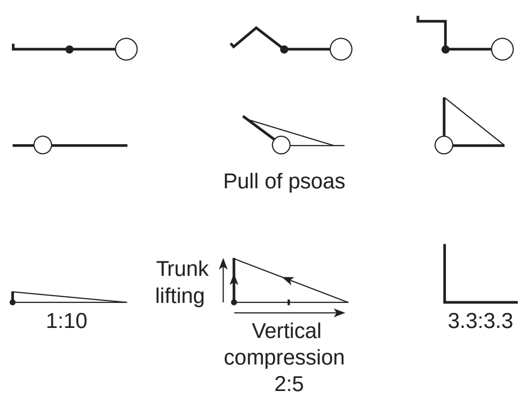


Fig. 2 Ratio of trunk lifting to vertebral compression forces due to the pull of iliopsoas in a sit-up.

With 45° hip flexion, tension development in the iliopsoas has been shown to be 70–80% of its maximum, while with the hips and knees flexed to 90° this figure reduces to between 40% and 50% (Johnson & Reid 1991).

However, passive tension developed by the iliopsoas due to elastic recoil must also be considered. If the hips are flexed, the iliopsoas will not be fully stretched, and will not be able to passively limit the posterior tilt of the pelvis. Instead, to fix the pelvis and provide a stable base for the abdominals to pull on, the hip flexors will contract earlier in the sit-up action. This contraction although occurring earlier, will be of reduced intensity (Walters & Partridge 1957) due to the length–tension relationship of the muscle.

With the legs straight in the traditional sit-up position, the iliopsoas is stretched, and can passively limit posterior tilting of the pelvis. However, in this stretched position, the iliopsoas is capable of exerting greater force during hip flexion. If the abdominal muscles are too weak to maintain the position of the pelvis to tilt anteriorly, lengthening the abdominals, and hyperextending the lumbar spine. This type of action is, therefore, unsuitable for postural re-education if the aim is to shorten posturally lengthened abdominal muscles.

Straight leg raising

The bilateral straight leg raise has been shown to create only slight activity in the upper rectus, although the lower rectus contributes a greater proportion of the total abdominal work than with the sit-up (Lipetz & Gutin 1970). The rectus works isometrically to fix the pelvis against the strong pull of iliopsoas (Silvermetz 1990). The force of contraction of the iliopsoas is maximum when the lever arm of the leg is greatest, near the horizontal, and reduces as the leg is lifted towards the vertical.

In subjects with weaker abdominals, the pelvis will tilt and the lumbar spine hyperextend. This forced hyperextension will dramatically increase stress on the facet joints in the lumbar spine. The movement is likely to be limited by impaction of the inferior articular processes on the laminae of the vertebrae below, or in some cases by contact between the spinous processes (Twomey & Taylor 1987). Where this action occurs rapidly, damage may result to the facet joint structures. Once contact has occurred between the facet and lamina, further loading will cause axial rotation of the superior vertebrae (Yang & King 1984). The superior vertebra pivots, causing the inferior articular process to move backwards overstretching the joint capsule.

Abdominal training based on spinal stabilization principles

Because one of the prime functions of the trunk is stability, the Functional Load Abdominal Training (FLAT) programme follows an exercise progression based on spinal stabilization principles (Norris 1995). Initially the stabilizing function of the deep abdominal muscles is re-educated. Once this has been achieved, the endurance of these muscles is built up and static stability is enhanced. Only when these two aims have been achieved are exercises used to enhance the performance of the trunk mobilisor muscles and complex multijoint movements are begun. The first action to be mastered in the back stability process is *abdominal hollowing*, a technique which has been shown to be especially useful in the early stages of stability control (Richardson et al. 1992). This movement emphasizes the internal oblique and transversus abdominis muscle (Lacote et al. 1987) while reducing the dominance of the upper rectus (O'Sullivan et al. 1998). Muscle re-education of this type may be achieved in a number of starting positions, with four point kneeling and standing (wall support) being the two most effective positions.

Stability muscles have been described as better suited to endurance (postural holding) and better recruited at low resistance levels (Norris 1998). In the clinic, it is often found that subjects begin with little control over the intensity of contraction which these muscles produce. Often, the contraction begins minimally and then builds to high intensities (60–70% maximum voluntary contraction [MVC]). This is acceptable during the early stages of learning as it enables the subject to 'feel the muscle working'. However, accurate control must be gained, and in all hollowing exercises the subject should be instructed to master changing the intensity of the muscle contraction. This is achieved by asking for a 'maximal contraction' and then relaxing by half, and half again. Once the minimal contraction is achieved, the intensity is then built up again in steps to reach the maximum. Only when hollowing can be controlled with minimal muscle intensity over a period of time (10 repetitions each of 30–40% MVC) can exercises be progressed. The position in which the

Box 1 Neutral position of the lumbar spine – a working definition

The neutral position of the lumbar spine is midway between end range flexion and end range extension. In a neutral position the discs and facet joints are minimally loaded and the soft tissues surrounding the lumbar spine reach a state of elastic equilibrium. In the normal (non-pathological) subject, the neutral position will correspond to lumbar alignment in an optimal posture. In subjects with a sub-optimal posture, pelvic tilt may be increased or reduced giving corresponding changes in the depth of the lumbar lordosis. In either case, the neutral position remains mid-way between end range flexion and end range extension. However, in such cases of postural malalignment, part of the treatment aim must be to restore optimal posture by re-balancing the length of the surrounding soft tissue elements. Neutral position may be found either passively (therapist moving the subject's pelvis) or actively (subject moving his/her own pelvis through muscle action).

movements are performed is important. The neutral position of the spine (Box 1) should be used whenever possible, and initially the subject will need to be positioned correctly by the therapist.

As the transversus has horizontally aligned fibres, four point kneeling allows the abdominal muscles to sag, giving stretch facilitation (Fig. 3). The subject is positioned with their lumbar spine in a neutral position, and the head looking at the floor, between the hands rather than forwards. Head position should reflect optimal alignment with the ear horizontally aligned to the shoulder joint. The hip should be directly above the knee, and the shoulder directly above the wrist. The hands and knees are shoulder width apart.

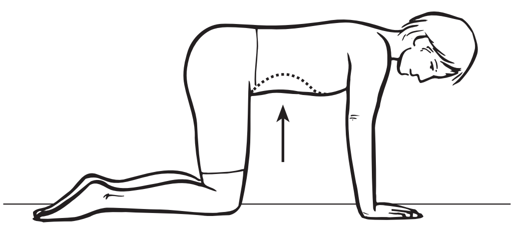


Fig. 3 Abdominal hollowing in four point kneeling.

The subject focuses their attention on their umbilicus and is instructed to pull the umbilicus 'in and up' while breathing normally. This action has been shown to dissociate activity in the internal obliques and transversus from that of rectus abdominis (Richardson et al. 1992). Dissociation itself makes the exercise useful for re-educating the stabilizing function of the abdominals where rectus abdominis has become the dominant muscle of the abdominal group.

To facilitate learning multisensory cueing is used (Miller & Medeiros 1987) to increase the sensory input to the subject. Auditory cues can be provided by the therapist speaking to the subject and giving feedback about performance. Visual cues are given by encouraging the subject to look at the muscles as they function, and by using a mirror placed on the floor/couch below the abdomen. Kinaesthetic cueing is accomplished by encouraging the subject to 'feel' the particular action, for example asking them to 'feel the stomach being pulled in'.

Tactile cues are provided by the therapist and/or belt touching the subject's abdomen. The abdominal region below the umbilicus is palpated. The therapist places the heel of their hand over the patient's anterior superior iliac spine and points their fingers towards the patient's pubic bone. The therapist's finger tips will then fall over the retro-aponeurotic triangle (Walters & Partridge 1957). The muscles are sheet like and will flatten rather than bulge when they contract. To facilitate the contraction the therapist instructs the subject to 'stop me pushing in' as they palpate the abdominal wall. A second method of facilitation is to instruct the subject to cough (visceral compression) and hold the muscle contraction they feel beneath the therapists palpating fingers. This 'cough and hold' procedure is also useful when used in conjunction with surface EMG. As the muscle contraction shows on the EMG unit, the subject is encouraged to maintain the contraction while breathing normally, The contraction time is built up to a single 30 seconds hold or 10 repetitions of 10 seconds holding. The subject should be encouraged to reduce the contraction intensity of the muscle to the minimum required to maintain the hollow abdomen position.

A webbing belt may be fastened around the abdomen below the umbilicus, with the muscles relaxed and sagging. The belt should be tight enough to touch the skin but not so tight as to pull the muscles in. The desired action is to hollow the abdomen and pull the muscles away from the belt, and then to relax them completely to fill the belt again. Two errors are common here: firstly, an inability to draw the muscles away from the belt; secondly, a contraction which is too strong and makes the abdominal wall rigid, seen as an inability to relax the muscles to fill the belt once more. With full muscle control both actions should be attainable. Once the contraction is achieved, the holding time is built up to 10–30 seconds while breathing normally.

Visualization of correct exercise technique is used following demonstration by the therapist. Visualization or 'mental practice' involves the subject relaxing, and 'seeing' themselves performing the exercise in their imagination. Visualization of this type has been shown to benefit both motor skill acquisition (Fransler et al. 1985) and strength development (Cornwall et al. 1991).

Some subjects find four point kneeling difficult to control and tend to round their spine as they attempt abdominal hollowing. Where this is the case, wall support standing is a more appropriate starting position (Fig. 4). The subject stands with their feet 6 inches from a wall and their back flat onto the wall surface. A neutral spinal position should be maintained. In an obese or poorly toned subject, the weight of the digestive organs will pull the abdominal wall out and down (visceral ptosis). Again a belt is used and positioned below the umbilicus and the action is to contract the lateral abdominals and to pull the abdominal wall 'in and up' trying to create a space between the abdomen and the belt. Since lateral abdominal action and pelvic floor action are linked through motor programming as part of the intra-abdominal pressure mechanism, pelvic floor contractions are also useful to aid learning of abdominal hollowing. The instruction is to pull the pelvic floor in as though trying to 'stop yourself passing water' or 'gripping'. In men

Fig. 4 Abdominal hollowing in wall support standing.

the action of 'lifting the penis' is also useful imagery.

The abdominal hollowing action must be differentiated from pelvic tilting, and care should be taken to ensure that the subject does not flatten their back against the wall indicating posterior-pelvic tilting through the action of the rectus abdominis. Once the abdominal hollowing action has been performed correctly to repetition, the subject should move forward from the wall and repeat the action without wall support. No spinal or pelvic movement should occur.

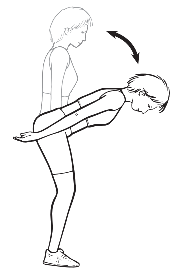
Building static stability

The crook lying position is used as the starting position for isolated limb movements to build static stability. The neutral position of the lumbar spine is found and abdominal hollowing is performed to stabilize the spine. One leg is then slowly straightened keeping the heel resting on the ground to perform a *heel slide* action (Fig. 5). This movement is made easier if the heel is on a slippery surface (a cloth if on a polished floor or a piece of shiny paper if on a carpet). As the leg is straightened, abdominal hollowing must be continued and stability maintained. The moment the pelvis anteriorly tilts and the lordosis increases, the movement must stop and the leg be drawn back into flexion once more. The exercise is progressed by using full limb weight, and

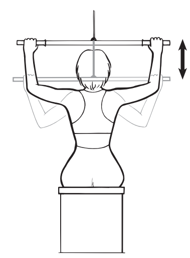
Box 2 Exercises to strengthen secondary stabilizing muscles

In each of the following exercise examples the movement is slow and controlled. At the mid-point of the action the position is held and the weight slowly lowered back to its starting position. The emphasis is on both strength and endurance. Perform each exercise for 8–12 repetitions taking a full 4–5 seconds to complete the full movement. Medium (not heavy) poundages are used.

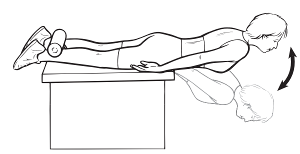
<u>Hip Hinge</u>
(*Gluteals and erector spinae*)
The subject stands with the knees slightly bent to relax the hamstrings and allow free pelvic tilting. The action is to angle the trunk forward by moving the pelvis on the fixed hip, keeping the spine straight. The trunk moves to 45° and then returns to the upright position.



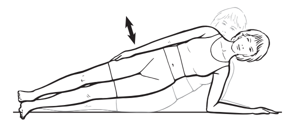
<u>Lateral pulldown</u>
(*lattisimus dorsi*)
The subject sits beneath a high pulley machine and grasps a wide bar. The action is to pull down until the bar rests either across the shoulders or at the top of sternum.



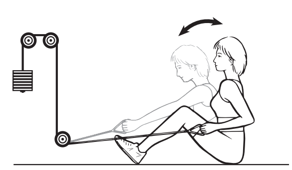
<u>Spinal extension</u>
(*erector spinae and gluteals*)
The subject rests prone on an extension frame with the pelvis supported on the low pad and the lower legs beneath fixation rollers. The action is to straighten the body by moving the trunk on the fixed leg until the body is horizontal.



<u>Horizontal side support</u>
(*quadratus lumborum*)
The subject begins in side lying with the body resting on the underneath forearm. The action is to lift the pelvis until the body forms a straight line from foot to shoulder.



<u>Seated rowing</u>
(*Shoulder retractors*)
The subject sits in front of a low pulley machine with the knees slightly flexed to allow a neutral spine position to be maintained. The action is to pull the machine handle in towards the chest (lower sternum) while retracting and depressing the scapulae.



performing *leg lowering* (Fig. 6). In supine lying, the hips are flexed to 90° and the knees are relaxed. The neutral position of the lumbar spine is found and abdominal hollowing performed. The abdominal contraction is maintained as one hip is extended to allow the foot to contact the ground. Initially, the foot rests on the ground near the buttock and gradually the movement is performed with greater knee extension to allow the foot to touch the ground further from the buttock, increasing the limb leverage and, therefore, progressing the resistance. Eventually, single leg raises are performed with the other leg still supported in the crook lying position. The movement is performed with alternating legs initially allowing one leg to rest on the ground before the other leg is lifted. As a progression on this

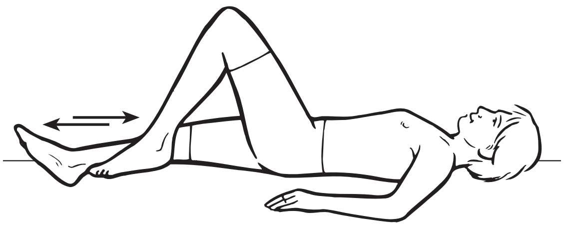


Fig. 5 Heel slide action.

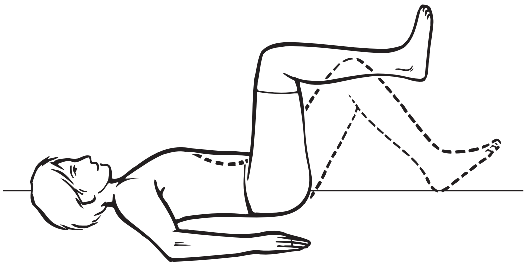


Fig. 6 Leg lowering action.

action, the limbs are again moved alternately but the leg lifts after the other limb has moved from the ground. Finally, both legs may be lifted and lowered together initially with minimal limb leverage and finally with increasing leverage. Some authors recommend the use of bilateral straight-leg raises as a final progression of this exercise, but the compression and shear forces imposed by the psoas muscle upon the lumbar spine make this unsuitable for use in rehabilitation following low-back pain.

In the third stage of training, when muscle re-education and static stability have been achieved, apparatus may be used. The aim is now to use appropriate traditional exercises to re-strengthen secondary stabilizing muscles and to build relevant mobilisors. The muscles which assist in stability, including the latissimus dorsi, erector spinae (Vleeming et al. 1990) quadratus lumborum (McGill et al. 1996) and the shoulder retractors (Janda 1994), are enhanced together with the gluteals as they provide power during lifting. Suitable exercises are shown in Box 2.

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