ORIGINAL ARTICLE

Exercises for Spine Stabilization: Motion/Motor Patterns, Stability Progressions, and Clinical Technique

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Objective: To quantify several forms of the curl-up, side-bridge, and birddog exercises (muscle activity and 3-dimensional [3D] spine position) including some corrective techniques to assist clinical decision-making.

Design: A basic science study of a convenience sample with a retest of expert intervention.

Setting: Spine Biomechanics Laboratory/Research Clinic.

Participants: Healthy men (N=8) performed the exercises, and 5 subjects repeated the exercises as an expert applied corrective techniques.

Interventions: Not applicable.

Main Outcome Measures: Surface electromyography of selected trunk and hip muscles together with video analysis and 3D spine posture were collected.

Results: Comparison of muscle activation levels showed there were justifiable progressions in each exercise form. In general, bracing of the abdominal wall enhanced activation of the obliques, but different techniques caused migration of muscle activity to other muscles. Examples of specific findings include the following. Movement during these traditionally isometric exercises such as drawing squares with the hand/foot while in the birddog posture enhances activation of many muscle groups. Breathing while holding the isometric exercises had differing effects on muscle activation which was exercise dependent. Some corrective exercise techniques, such as fascial raking, substantially changed relative activation between muscles in the abdominal wall.

Conclusions: The data presented in this study may be used to guide the clinical decision process when choosing a specific exercise form together with selecting the correct starting level, a logical progression, suitable dosage, and possible corrective technique to enhance tolerance of a patient.

Key Words: Clinical laboratory techniques; Exercise; Rehabilitation.

MANY EXERCISES HAVE BEEN named as, or proposed as, spine stabilization exercises. Sufficient spine stability requires involvement of all muscles in the torso.[1] When muscles contract, they create both force and stiffness. Force may or may not be stabilizing, whereas stiffness is always stabilizing.[2] However, muscle forces also create moments about the 3 orthopedic axes at all spine levels. This constraint demands constant migration of activity between many muscles, requiring a responsive motor control system, endurable muscles, and sufficient tolerance of the spine to support the resulting loads. A few studies have attempted to quantify exercises for their ability to stabilize while challenging the muscles to an appropriate level.[3,4] Furthermore, because these exercises are usually used with clinical populations with backs that have compromised load-bearing capacity, exercises are preferred that impose minimal spine load. A series of studies showed that 3 forms of exercise produced stabilizing patterns, specifically for flexion dominant challenges using a form of the curl-up,[5] frontal plane challenges using the side-bridge,[6,7] and extensor dominant challenges using the birddog[8] (referred to as the *big 3* in this article).[9] These resulted in relatively lower spine loads than other exercises and have become components in several back exercise programs and trials. Further, specific techniques within these exercise forms have been developed to minimize oxygen related muscle fatigue,[10] to measure endurance,[11] and to evaluate changes in mechanics when combined with labile surfaces such as gym balls.[12]

Several groups have claimed that training specific muscles has been effective for patients needing stabilization. However, none of the studies were designed to isolate specific muscles but rather evaluated exercises that challenged many groups of muscles. Thus, any report of efficacy pertains to the exercises chosen rather than the training of a specific muscle. One exception was a study by Koumantakis et al,[13] who assessed the clinical efficacy of different forms of the big 3 together with a few other exercises (eg, bridging). These were compared with another exercise group who performed similar exercise forms, but who also employed specific techniques to try and activate the transverse abdominis and multifidus at the onset of the trial. This patient group had a delayed recovery, suggesting that specific transverse abdominis and multifidus training was not as effective and that patients should engage in multimuscle therapeutic exercises. More recently, Suni et al[14] showed that the position of the spine (neutral in this case) when performing exercise resulted in better outcome. Finally, not all back patients do well with stabilization exercise approaches. For example, Fritz et al[15] showed that those patients with stiff backs did better with mobilizing approaches, whereas those with unstable backs did better with stabilization exercise. Hicks et al[16] have shown that testing for shear instability (using the test described by Magee[17]) was a good predictor of those who would do well with stabilization exercise approaches. It is a constraint of all clinical trials using manual therapy that clinical

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List of Abbreviations

EMG	electromyography
MVC	maximum voluntary contraction

skill is not accounted for. For example, a good clinician may be able to judge better the starting challenge of a particular exercise progression. Good clinicians adjust particular body postures to spare painful joints, know when to engage in corrective exercise, and know when to adjust muscle coactivation patterns to make an exercise more tolerable and suitable for a patient. However, there are few data in the literature to guide these clinical decisions.

The purpose of this study was to quantify progressions of the big 3 exercises further in terms of muscle activation level to provide guidance for clinical decisions. In addition, some more performance-based modifications of these exercises were quantified for those interested in transitioning the progression from rehabilitation into performance training. Progressing isometric forms of the exercises to incorporate limb movement may enhance muscle challenge and cause migration of activity to other muscle groups. In addition, many athletic events require extremely rapid contraction, then relaxation, of the torso muscles.[18] It may be that the big 3 exercises can be adapted to train this ability. Finally, because clinicians make adjustments in patient posture and correct muscle activation patterns, another element was added to this study. Specifically, once the data had been collected, another expert clinician was recruited to fine-tune technique with each patient to see whether measurable changes in mechanics were observed as a result of a verbally expressed, and manual, corrective technique. It was hypothesized that subtle changes in technique would alter spine posture and muscle activation patterns. Obviously altered patterns change the stress distribution among tissues and variables such as spine stability, thus altering pain.

METHODS

Recruitment procedures and experimental methods were approved by the university human research ethics committee.

Electromyographic signals and spine posture were collected from 8 healthy men age 21.6±4.1 years, 1.82±0.06m tall, with a mass of 74.6±10.7kg. Five of these subjects were reassessed by an expert clinician who performed some technique corrections to see whether technique in exercise form had any effect. This was conducted 3 months after the original study, and 3 of the original subjects were not available.

Fifteen channels of EMG were collected from electrode pairs placed bilaterally over the following muscles: rectus abdominis lateral to the navel; external oblique about 3cm lateral to the linea semilunaris but on the same level of rectus abdominis electrodes; internal oblique caudal to the external oblique electrodes and the anterior superior iliac spine and still cranial to the inguinal ligament; latissimus dorsi over the muscle belly when the arm was positioned in the shoulder mid-range; thoracic erector spinae approximately 5cm lateral to the spinous process (actually longissimus thoracis and iliocostalis at T9); lumbar erector spinae approximately 3cm lateral to the spinous process (actually longissimus and iliocostalis at L3); right gluteus medius in the muscle belly found by placing the thumb on the anterior superior iliac spine and reaching with the fingertips around to the gluteus medius; gluteus maximus in the middle of the muscle belly approximately 4cm lateral to the gluteal fold; and rectus femoris approximately 5cm caudal to the inguinal ligament and biceps femoris over the muscle belly midway between the knee and hip. The skin was shaved and cleansed with a 50/50 water and ethanol solution. Ag-AgCl surface electrode pairs were positioned with an interelectrode distance of about 2.5cm. The EMG signals were amplified and then A/D converted with a 12-bit, 16-channel analog to digital converter at 1024Hz. Each subject was required to perform a maximal contraction of each measured muscle for normalization of each channel. Subjects were instructed to ramp up to full exertion, which usually occurred within 3 to 5 seconds, although trials were recorded for 10 seconds. For the abdominal muscles, each subject adopted a sit-up position and was manually braced by a research assistant. The subject then produced a maximal isometric flexor moment followed sequentially by a right and left lateral bend moment and then a right and left twist moment. Little motion took place. Participants also performed an isometric reverse curl-up by adopting a supine position where they attempted to lift the pelvis off the table while a research assistant restrained the knees. Subjects were further instructed to attempt to twist right and left. For the spine extensors and gluteal muscles, a resisted maximum extension in the Biering-Sorensen position was performed.[19] A specific gluteus medius normalizing contraction was also attempted with resisted side-lying abduction (ie, the clam). Participants lay on their left side with the hips and knees flexed. Keeping their feet together, they abducted their right thigh to parallel and a research assistant restricted further movement. Normalizing contractions for rectus femoris were attempted with isometric knee extension performed from a seated position with simultaneous hip flexion on the instrumented side. The

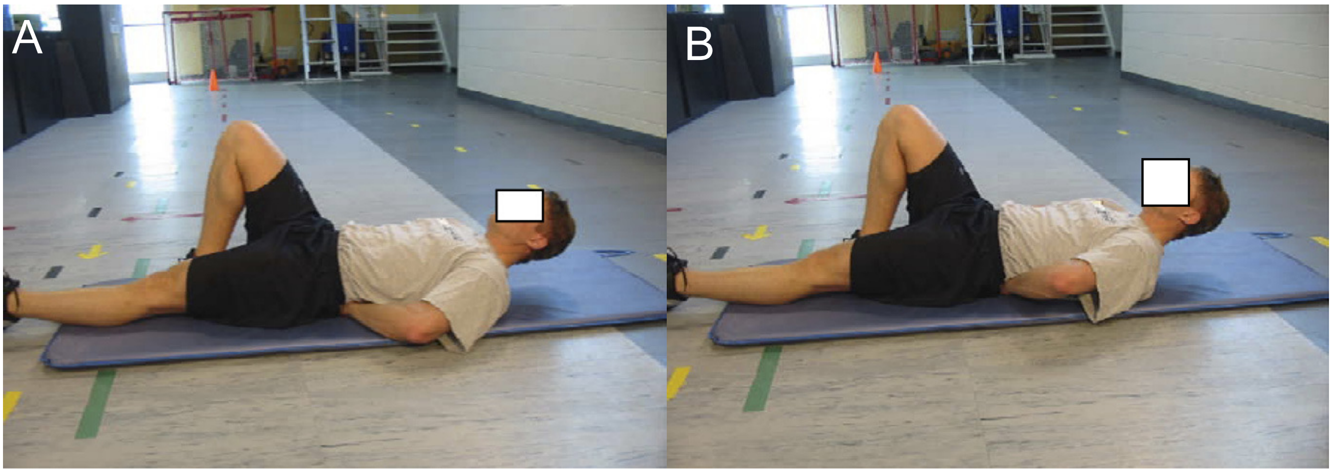

Fig 1. Examples of the curl up. (A) Elbow on the mat, and curl up. (B) Elbows off the mat.

maximal amplitude observed in any normalizing contraction for a specific muscle was taken as the maximum for that particular muscle. The EMG signals were normalized to these maximal contractions, after full wave rectification and low-pass filtering with a second-order Butterworth filter. A cut-off frequency of 2.5Hz was used to mimic the EMG to force frequency response of the torso muscles.[20]

Lumbar spine position was measured about 3 orthogonal axes using an electromagnetic tracking instrument.[a] This instrument consists of a single transmitter that was strapped to the pelvis over the sacrum and a receiver strapped across the ribcage, over the T12 spinous process. For the curl-up exercises, the transmitter was reversed and strapped over the anterior pelvis. Thus, the position of the ribcage relative to the pelvis was measured (lumbar motion). Spine posture was normalized to that obtained during standing (thus corresponding to 0° of flexion-extension, lateral bend, and twist). A second transmitter was strapped to the lateral femoral condyle of the right leg to track hip motion.

Description of Exercises

Exercises are shown in figures 1 through 7.

Curl-Up

Participants were supine with both hands placed under the lumbar spine supporting a neutral curve. They were instructed to pivot about the sternum and lift the shoulder blades off of the mat while maintaining a neutral neck position for 5 seconds. This exercise progressed with technique alterations that included elevating the elbows from the table, prebracing the abdominal wall (stiffening), and deep breathing during the exercise. The instruction for bracing was the same in all exercises (see fig 1). Specifically, when standing, subjects were asked to contract and stiffen the abdominal wall. All subjects found this easy to perform. In the clinic, once in a while when subjects do not seem to understand what is meant, we simply state, "Stiffen as though you will be hit in the belly." Facilitation of the abdominal wall was achieved with fascial raking.[18] Here the clinician rakes the obliques, carefully to not encroach on the rectus, with the ends of the fingers so that the subjects contract the abdominal wall, neither drawing in nor pushing out (see fig 2).

Fig 2. Raking of the fascia with 2 hands. Note that stimulation is to the obliques and not the rectus.

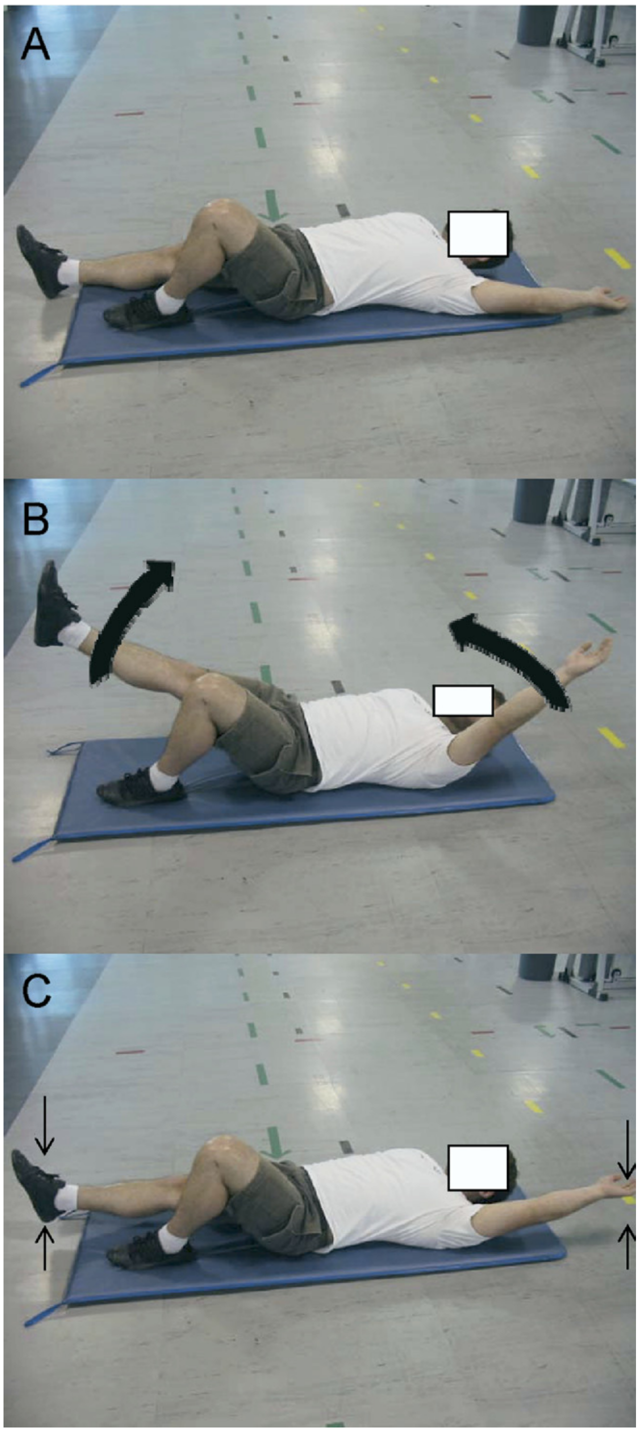

Fig 3. Illustration of rapid contraction, plyometric dead bug. (A) Relaxed, (B) large amplitude slow motion, and (C) short range (see arrows).

Dead Bug

Participants were supine with the right hand placed under the lumbar spine. They started with the hips, knees, and shoulders flexed to 90° and slowly extended the right hip and left shoulder until both were completely extended level to horizontal but still slightly elevated off the table (see fig 3). The extended

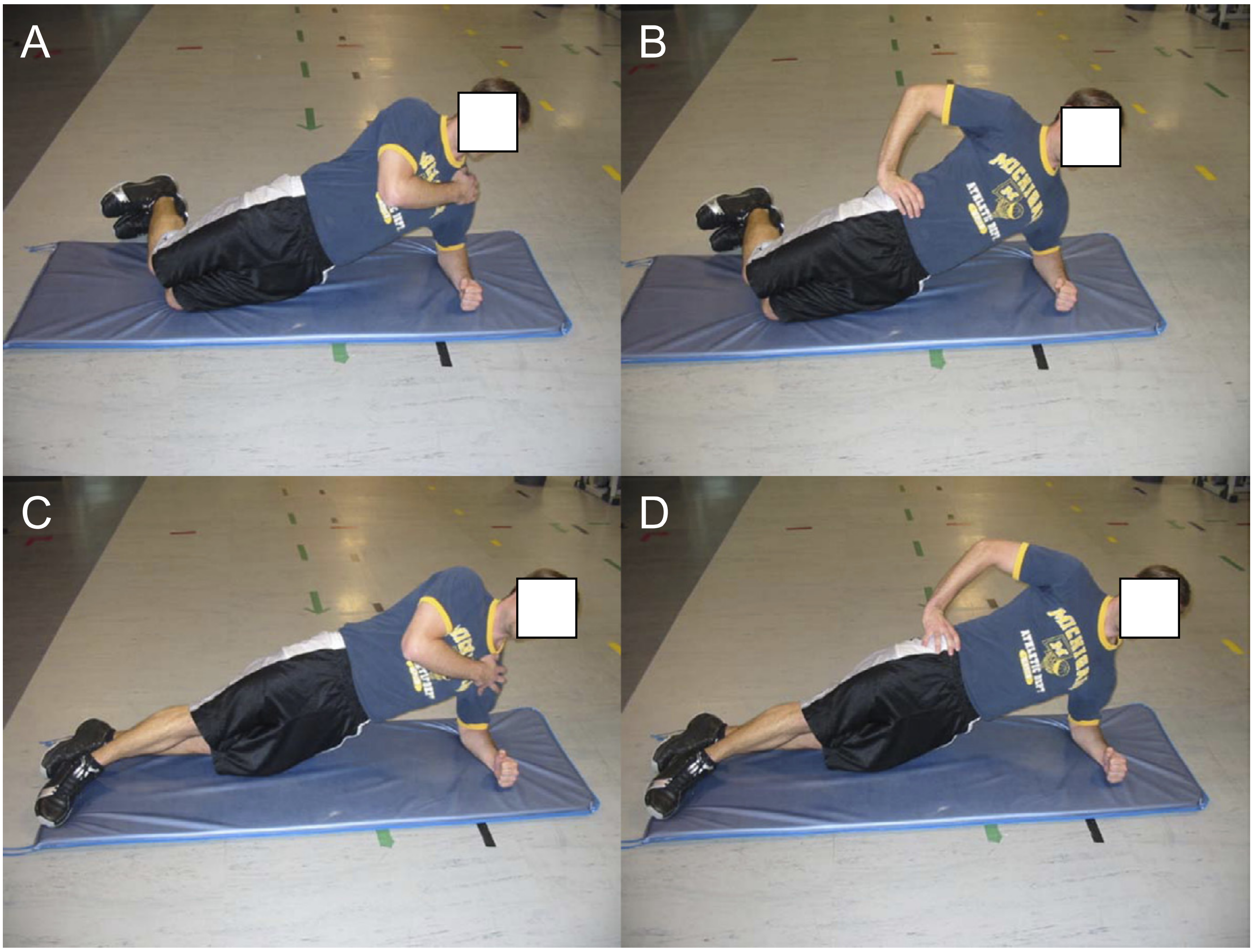

Fig 4. Illustration of 4 variations of the side-bridge. (A) Side-bridge with knees on the ground and the hand on shoulder. (B) Side-bridge with the hand on the waist/pelvis. (C) Side-bridge with feet on the ground and the hand on the shoulder. (D) Side-bridge with hand on waist/pelvis. Note the alignment of the ribcage and pelvis so that the spine is in a neutral posture.

posture was held for 5 seconds, and participants returned to the starting position. A plyometric trial in which participants (from the extended posture) rapidly flexed the left shoulder and right hip was also conducted. Here the intention was first to stiffen the torso, then to contract ballistically to create motion only at the shoulder and hip, not the torso. The motion was very short-range with the emphasis placed on the quickness of muscle contraction and relaxation. This was considered an athletic variation of the progression only.

Side-Bridge

The mildest form of the side-bridge was knees: participants lay on the right side supported by the right hip and elbow (flexed to 90°) (see fig 4A). The hips were extended in a squatlike manner to neutral as the hips were elevated off the table and support shifted from the right hip to the right knee. The left hand was positioned over the right deltoid and the arm drawn across the chest to stabilize the shoulder. Participants progressed by removing the hand from the deltoid and placing the left arm over the torso and the hand on the waist (see fig 4B). In the full side-bridge, legs were extended, and the top foot was placed in front of the lower foot for support. Subjects support themselves on the right elbow and on their feet while lifting their hips off the floor to create a straight line over the length of their body (see fig 4C). The right hand was placed on the waist. The full side-bridge was also performed while participants engaged in heavy breathing (slow, deep breaths) (see fig 4D). In the final progression, participants were instructed to roll from the side-bridge (see fig 5A) into the plank (see fig 5B) (prone, supported on elbows and toes), and out of the plank into a left side-bridge (see fig 5C). Corrections were made to cue the subject to eliminate twisting between the ribcage and pelvis (see fig 6).

Birddog

Participants began in a quadruped position (see fig 7A). Initially, participants lifted only the left arm, then progressed to the right leg only. Next, the left arm and right leg were lifted simultaneously both without and with an abdominal brace. An additional reach with the arm was added, and finally participants performed the active birddog by drawing squares with the hand and foot, constraining motion to the shoulder and hip only (see fig 7B). Note that as the hand was abducted, so was the foot; as the hand dropped toward the floor, so did the foot. In

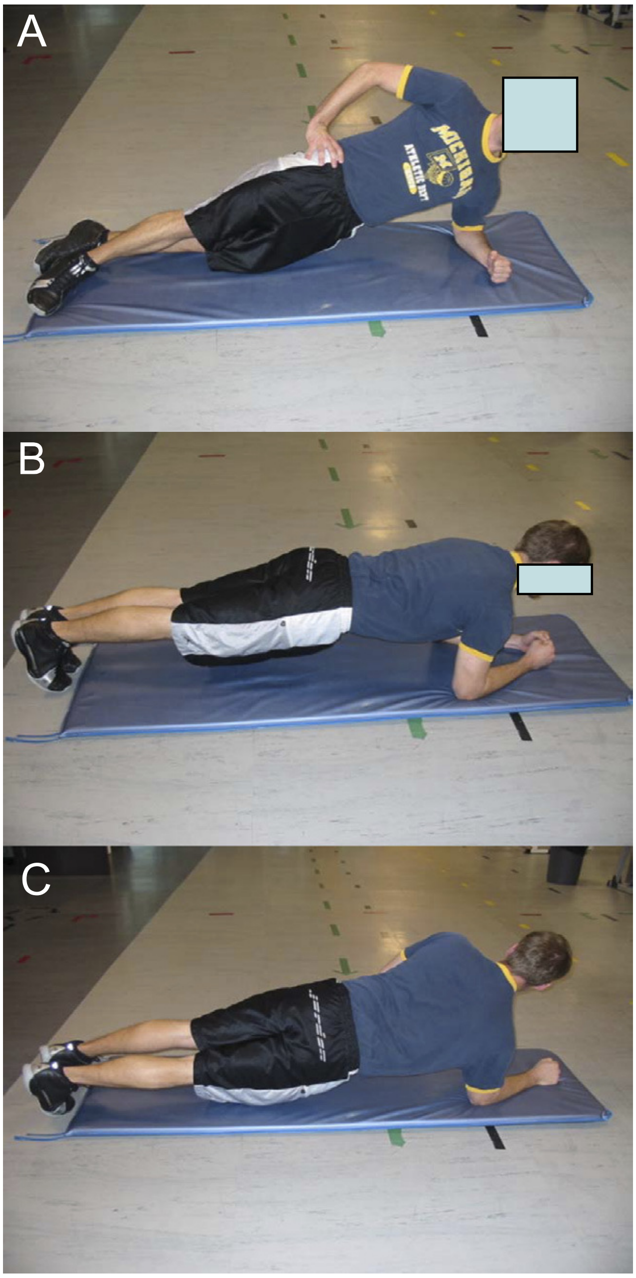

Fig 5. Illustration of the (A) left side-bridge, (B) roll to plank, and (C) rolling from the plank to right side-bridge (this photo captures the roll midway). Note that the ribcage is locked to the pelvis, resulting in minimal spine twist.

this way, the hand and foot were abducted and adducted, and raised and lowered, in unison.

Expert Correction

A clinician who is known for therapeutic exercise technique corrections retested 5 subjects 3 months after the original data collection. Corrections were directed toward removing asymmetries in spine lateral or twist axis posture, and toward neutral in the sagittal plane. These subjective corrections were to mimic clinical corrections intended to seek less pain. Fascia raking of the abdominal obliques was also employed to progress to more challenging forms of the exercises. Here the fingertips dig and rake across the fascia of the obliques with an intensity between "hurt" and "tickle." For example, in the curl-up, if more abdominal contraction occurred, the greater stiffness would produce more internal resistance.

Statistical Analysis

A 1-way repeated-measures analysis of variance (α=.05) was performed followed by a least-squared means post hoc analysis, in which significant main effect differences were tested.

RESULTS

The results are organized to examine the effects of technique on each exercise, followed by an examination of the effect of expert correction.

Curl-Up

In this style of the curl-up, very little motion takes place in an effort to protect the disks from damage or pain exacerbation. A progression in abdominal challenge began with a curl just to elevate the head/neck/shoulders slightly while the elbows were on the mat. The progression continued with raising the elbows off the mat. Raising the elbows caused a trend to increase rectus abdominis activity while decreasing the upper erector spinae activity (P=.17), demonstrating more flexor torque challenge (fig 8). While stiffening the torso with an abdominal brace, both external and internal obliques increased their activation (P=.003), with the internal oblique approaching 30% of MVC during the brace. The addition of simultaneous heavy breathing did not further increase abdominal activity, but in some cases, it reduced activity. For example, during inspiration, the activity in the right internal oblique was reduced compared with the breath held and braced condition (P=.004). Interestingly, there was relatively more activity in the rectus abdominis during inspiration compared with the obliques, and relatively higher activation in the obliques during expiration. However, 2 distinct patterns were noted among the subjects, because some entrained abdominal wall activity to breathing in this way, whereas others did not. Those who did not presumably used the diaphragm to breathe. This difference in muscle migration was eliminated with expert correction. Although probably not functionally significant, the gluteus medius also increased its activity from 3.5% to 6% of MVC (P=.01) with the addition of the brace.

An athletic form of abdominal exercise consisted of the plyometric dead bug, which produced much higher peak muscle activation (fig 9) in all muscles. For example, in the normal dead bug hold, the right side rectus abdominis, external oblique, and internal oblique were activated to 6%, 8%, and 5% MVC, respectively. Ballistic contraction caused an increase in peak activity to 53%, 26%, and 42% MVC (all P<.01), respectively. There was an interesting interplay between the muscles on both sides of the torso, probably because of the twisting moment caused by the left arm extension and shoulder flexor moment. For example, the left side internal oblique was higher for the static hold, but the right side internal oblique was higher during the dynamic activity burst. The emphasis here was placed on very short-range motion but with contraction and relaxation of the muscles performed as quickly as possible. Participants were instructed to focus all motion at the shoulder and hip.

Side-Bridge

A clear progression emerged as the side-bridge performed from the knees caused the lowest torso muscle challenge (ie,

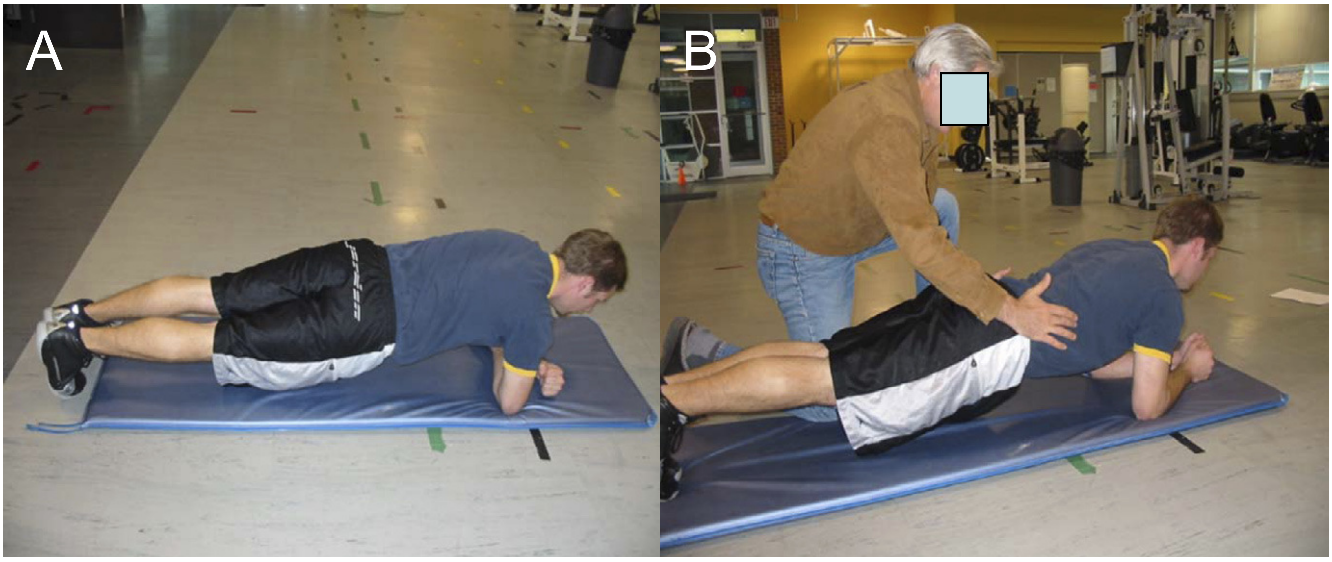

Fig 6. Illustration of (A) an incorrect roll out of the plank because the pelvis is leading the ribcage, resulting in spine twist, and (B) the therapist correcting the patient with manual contact and cues to the iliac crest and ribcage.

less than 20% MVC in the right oblique wall and 12% and 15% in the right upper and lower erector spinae, respectively) (fig 10). The left side was below 10% MVC. Supporting the side-bridge with the feet elevated the activity in all muscles, making it a more challenging exercise. Rolling into a plank, pausing, and continuing to the other side for a bridge was the most demanding, with activity approaching 50% MVC in the rectus abdominis and the obliques, and approaching 30% MVC in latissimus dorsi. Significant increases ($P<.001$) were observed in both obliques, rectus abdominis, latissimus dorsi, and both upper and lower spine extensors. There was no difference in oblique activity with the addition of challenged breathing.

Birddog

The challenge according to the activity in various muscles appears to progress as follows: just arm elevation, just leg elevation, both arm and leg (full birddog), then the addition of a conscious abdominal brace, and finally a deliberate slight abduction of the shoulder with further elevation (fig 11). This final maneuver elevates the left upper back extensors from 23% to 35% MVC.

When in a full birddog posture, drawing squares with the hand and foot creating, shoulder and hip motion, significantly changes activation levels in the right external oblique, latissimus dorsi, and lumbar erector spinae, but in particular the gluteus medius and maximus (fig 12). The activity may increase or it may decrease, simply demonstrating the migration of activity among the torso muscles.

Expert Correction

Expert correction appears to make some subtle changes. For example, when performing the curl-up while breathing, raking

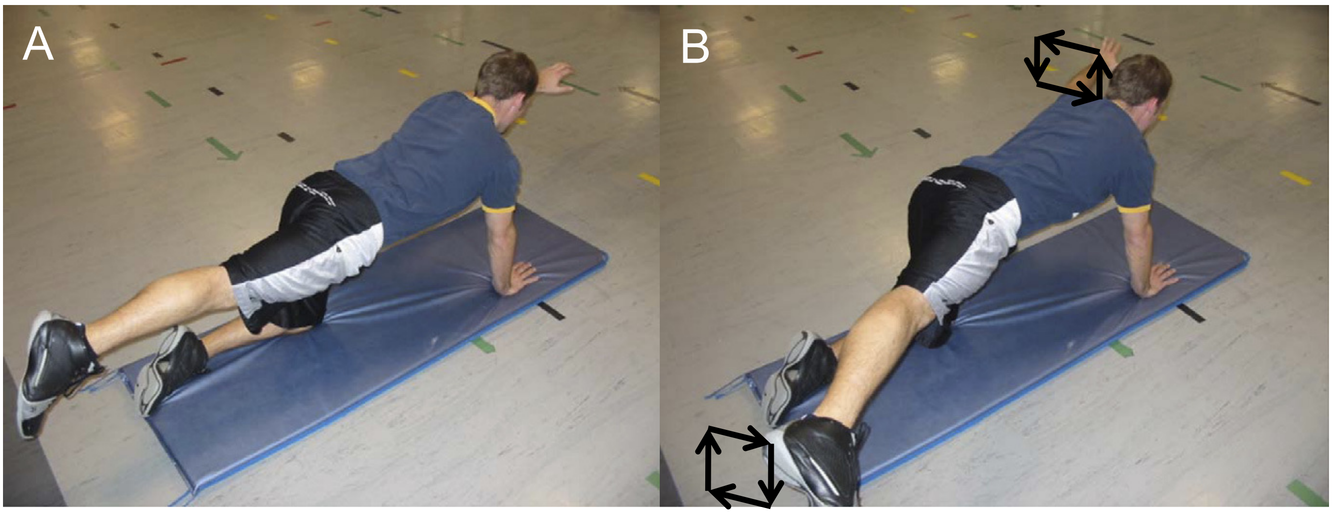

Fig 7. Illustration of the birddog with the hand and foot drawing squares at the (A) starting position and (B) square out, square down, then square in. Note all motion takes place about the shoulder and hip. No motion occurs in the spine.

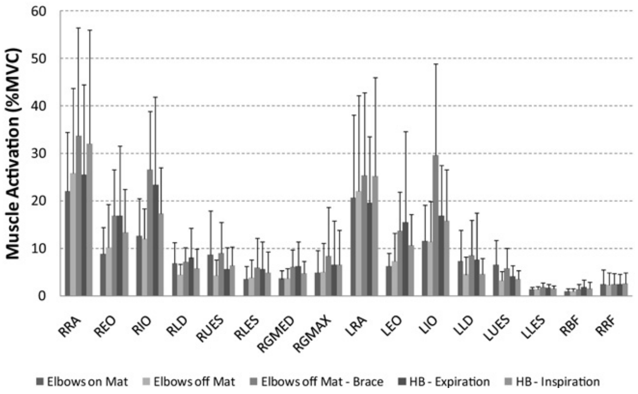

Fig 8. Curl up: average EMG in static postures and during the heavy breathing variation. Muscle activation levels during the different variations of the curl-up exercise. Raising the elbows tends to enhance rectus abdominis activity while reducing upper extensor activity. This is because the elbows and shoulders cannot pry the elevation of the head/neck/shoulders. Bracing enhances the internal obliques in particular. During heavy breathing, more muscle activity was observed in the inspiration phase of rectus abdominis, whereas less was observed in the obliques. Abbreviations: RRA, right rectus abdominis; REO, right external obique; RIO, right internal oblique; RLD, right latissimus dorsi; RUES, right upper erector spinae; RLES, right lower erector spinae; RGMED, right gluteus medius; RGMAX, right gluteus maximus; LRA, left rectus abdominis; LEO, left external oblique; LIO, left internal oblique; LLD, left latissimus dorsi; LUES, left upper erector spinae; LLES, left lower erector spinae; RBF, right biceps femoris; RRF, right rectus femoris.

of the fascia overlying the obliques causes less rectus abdominis activity (34% to 17% MVC on average) and more activity in the internal oblique (36% to 50% MVC; $P=.002$) and latissimus dorsi (4% to 11% MVC; $P=.004$). The amount of spine flexion decreased from 9° to 2°, indicating a more neutral spine. The corrected technique during the side-bridge with the rolling action emphasized locking the ribcage to the pelvis to eliminate spine twist. This correction significantly increased activity in both obliques and the latissimus dorsi (ie, 18% to 35% MVC in latissimus when minimal torso twist was emphasized). Torso twisting was reduced from 11° to 4° with corrected instruction. Expert instruction during the birddog, in which the hand and foot drew squares, significantly increased activity in the left internal oblique and latissimus dorsi. The correction also resulted in a more neutral spine (spine flexion decreasing from 16° to 0° with expert correction).

DISCUSSION

Clinicians choose techniques to help make an exercise tolerable for a patient that include muscle activation and posture changes. The corollary is that failure to do so can make the same exercise painful. The data presented here may be used to assist clinical decisions regarding the starting challenge, progression, corrective technique, and exercise selection. Basic features of these exercises have been assessed in the past for stability and spine load,[3,4] but more variations have been presented here. Interestingly, although exercises performed in upright postures are able to achieve high stability indices, none have been found to achieve the levels of muscle activation reported here with such low spine loads reported before.[3,5,8] Perhaps this is why various forms have become preferred for inclusion in trials of efficacy.[13]

The addition of heavy breathing did not increase abdominal activity over the brace condition, but it is considered more challenging from a control perspective. Some of the subjects showed varying muscle activity linked to inspiration or expiration. Others did not show any link, suggesting that they were able to transform the muscles into isometric stabilizers, ensuring that the diaphragm and possibly other ventilatory muscles are trained to perform their function independently of any spine-stabilizing role. It is clear that once a muscle moves in eccentric or concentric contraction, that stiffness is lost,[21] and by default causes a compromise for stability.

The side-bridge is an interesting exercise in that one half of the torso musculature is much less active, reducing total spine load, yet stability is ensured by the need to maintain the torque to support the bridge.[3] Progressive forms of the exercise introduce twisting torques, which may be appropriate for some. The rolling action into and out of the plank is obviously more challenging given the substantial increases in muscle activity needed to control the isometric bending and twisting torque in the torso. This is an interesting exercise because the addition of deliberate ventilation does not allow entrainment of the stabilizing musculature to the breathing cycle. These muscles must support the torques necessary to maintain the bridge posture. Perhaps this helps explain why some have found this useful when intentionally attempting to train the diaphragm independently of the abdominal wall during challenged breathing in athletes and occupational athletes.[18]

The birddog progression showed that arm abduction and further elevation of the raised arm is an effective technique to enhance activity in the upper back extensors. Furthermore, the technique of the hand and foot drawing imaginary squares, in which the emphasis is placed on hip and shoulder motion, being sure to not allow any spine or torso motion, also appears to migrate activity throughout the spine, torso, and hip muscles. This may be considered by those wishing to train control in both the hip and torso musculature.

Expert correction is a difficult concept in that the real issue is the insistence of good form by the clinician/patient. Generally, good form means trying to reduce the spine postural deviations that exacerbate pain, or allow more challenging forms of exercise to be performed pain-free. In this study, an experienced clinician instructed each subject to perform the exercises, and the data were collected. This was thought to represent competent practice. The first clinician had no knowledge that the expert (S.M.M.) would repeat the study in an attempt to correct technique. In general, more activation was achieved in the obliques during the curl-up, and in the upper erector spinae during the birddog, for example. In addition,

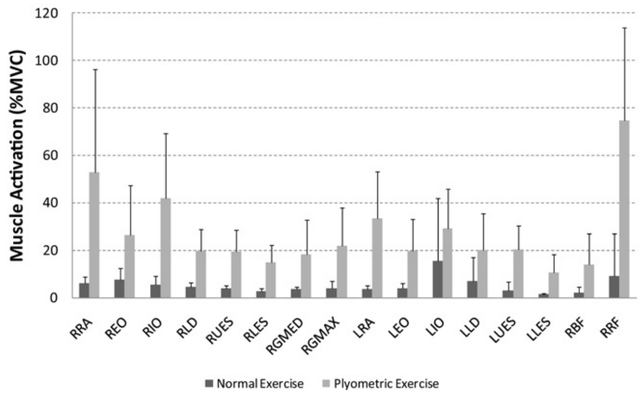

Fig 9. Dead bug EMG: normal (average) versus plyometric (peak). The plyometric dead bug, in which the right and left arm were raised, caused higher peak muscle activity levels. Abbreviations: (see fig 8).

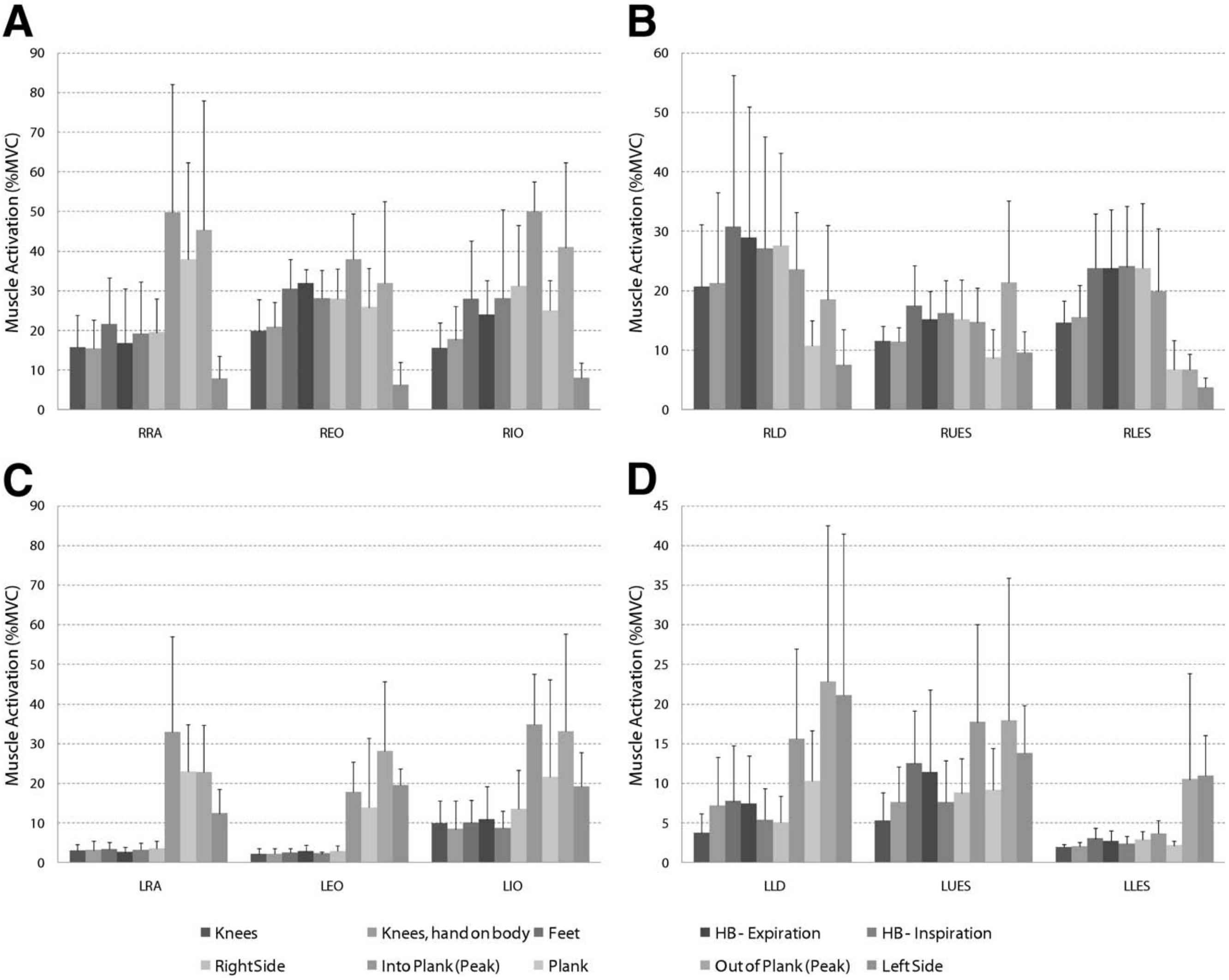

Fig 10. Comparison of the activation levels of the (A) right abdominals (rectus abdominis, external oblique, internal oblique), (B) right back extensors (latissimus dorsi, upper erector spinae, lower erector spinae), (C) left abdominals, and (D) left back extensors, during the different variations of the side-bridge exercise. Rolling into and out of the plank appears to substantially challenge all muscles. Abbreviations: HB; heavy breathing (see fig 8 for remaining definitions).

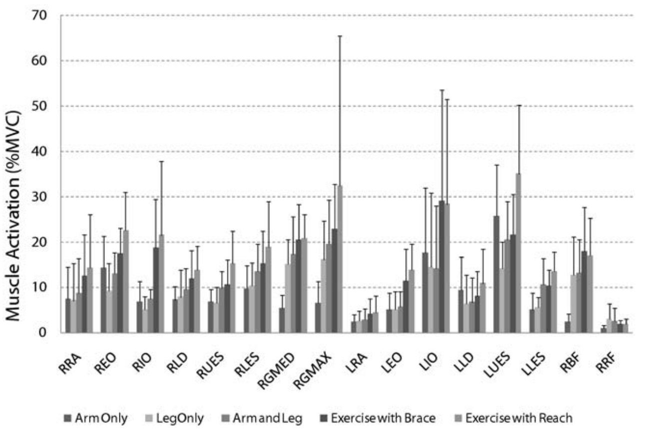

Fig 11. Birddog comparison: average EMG values. Comparison of the muscle activation levels for all muscles during the different variations of the birddog exercise. Abbreviations: (see fig 8).

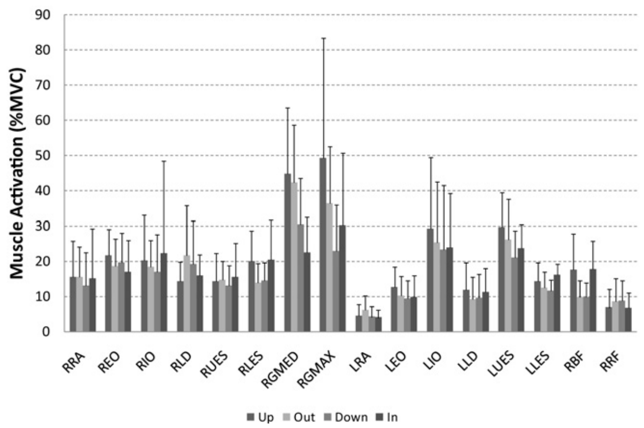

Fig 12. Birddog: squares peak EMG. Comparison of the muscle activation levels for the birddog exercise during the different phase of hand and opposite foot squares up, out, down, and in. Abbreviations: (see fig 8).

spine posture and motion were better controlled keeping the spine closer toward elastic equilibrium, or a neutral spine. It is commonplace for a patient to report that a certain exercise hurts, and many clinicians will either discontinue the exercise or draw back to a less challenging form. This may be quite appropriate. However, subtle correction may often take the pain away. For example, consider a patient with pain from a single facet joint during a side bridge. Here, a small correction about the twist axis may immediately eliminate pain. The point to be made here is that vigilant clinicians can instruct and correct patients to fine-tune muscle activity and spine posture, often resulting in better pain control and tolerance of more challenging exercise.[19]

Study Limitations

Several limitations influence the interpretation of the results reported here. These were healthy subjects, and patients in pain may respond differently. However, although we have not performed a selected cohort study, our case studies suggest that corrections of technique can change painful exercise into pain-free. Certainly every clinician adjusts therapeutic exercise form to reduce pain. However, much work remains in this regard. The possibility exists that the expert was not skilled but nonetheless the interventions did make a measurable change in normal mechanics, which may explain how these approaches reduce pain in many patients.

CONCLUSIONS

The big 3 spine stabilization exercises have been quantified before to enhance spine stability in an environment that imposes low loads on the spine. The data presented here document progressions of these forms of exercise that can assist clinical decision-making. Further, some techniques to modify spine posture and muscle use were also described that will assist finding techniques to minimize pain and maximize function.

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