Introduction to Pilates-Based Rehabilitation

Brent D. Anderson, PT, OCS and Aaron Spector, MSPT

Brent D. Anderson

fig. 1

Origins of Pilates-based work in rehabilitation

As a child, German-born Joseph H. Pilates (fig1) suffered from a multitude of illnesses resulting in muscular weakness. Determined to overcome his frailties, he dedicated his life to becoming physically stronger. He studied yoga, martial arts, Zen Meditation, and Greek and Roman exercises. He worked with medical professionals, including physicians and his wife Clara, a nurse. His experiences led to the development of his unique method of physical and mental conditioning, which he brought to the United States in 1923. In the early 1930s and 1940s, popular dance instructors and choreographers, such as Martha Graham, George Balanchine, and Jerome Robbins, embraced Pilates' exercise method. As elite performers, dancers often suffered from injuries

resulting in a long recovery period and an inability for peak performance. Unique at the time, Pilates' method allowed and encouraged movement early in the rehabilitation process, by providing needed assistance. It was found that reintroducing movement with nondestructive forces early in the rehabilitation process hastened the healing process. As a result, it was not long before the dance community at large adopted Pilates' work.

More than 70 years later, Pilates' techniques began to gain popularity in the rehabilitation setting. In the 1990s, many rehabilitation practitioners were using the method in multiple fields of rehabilitation, including general orthopaedic, geriatric, chronic pain, neurologic rehabilitation, and more. Within the rehabilitation setting, most Pilates exercises are performed on several types of apparatus (fig 2). The apparatus work evolved from Pilates' original mat work, which was
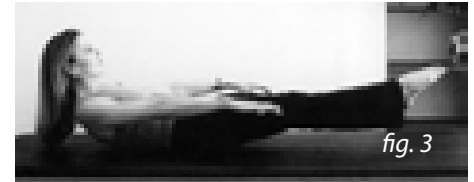

fig. 2

fig. 3

difficult as a result of the relationship of gravity on the body (fig 3). On the apparatus, springs and gravity are used to assist an injured individual to be able to complete movements successfully, aiding in a safe recovery (fig 4). Ultimately, by altering the spring tension or increasing the challenge of gravity, an individual may be progressed toward achieving functional movement.

fig. 4

Today, despite an increased number of health care practitioners using the Pilates-based approach in rehabilitation, there is still a lack of supportive literature examining the phenomena associated with Pilates-based techniques within the field of rehabilitation. This article discusses theoretic foundations of the results experienced by Pilates-based practitioners in the field of rehabilitation. Current scientific theories in motor learning and biomechanics are examined to explain the principles of this old method of movement reeducation.

Motor learning and trunk control associated with the Pilates-based environment

The Pilates-based environment is conductive to designing task-oriented interventions. Within this environment, a faulty movement can be broken down into components using springs and changing the bodies orientation to gravity. By successfully evaluating a patient's needs and accessing the desired movement outcome, be it jumping, sitting, reaching, rotating, or walking, one can easily design a similar movement but with the appropriate level of load to the limb or trunk to support it while it heals. Adapting environmental constraints, such as gravity and base of support, reduces the degrees of freedom that must be controlled by the nervous system (5). The manipulation of the environment can hasten the reeducation process. As the movements are successfully completed, the patient can be progressed by decreasing the assistance or changing the orientation to gravity until the desired outcome is achieved. Commonly, trunk control is a desired outcome for functional movement and requires successful integration of all its components to maintain a normal orientation to gravity.

Research has looked at the importance of trunk control, led by Richardson and Hodges in Australia (14, 16, 21). Their research focused on defining the activity of trunk musculature among healthy subjects and subjects experiencing chronic low back pain during upper extremity movement. The results support the importance of core stiffening of the trunk muscles in preparation for movement of the extremities. For the purpose of this article, the word core is synonymous with trunk. Core stiffening is not thought to restrict movement of the spine but instead to facilitate controlled movement. Such a phenomenon is at the root of Pilates-based work. It was Pilates' belief that core control was the essence of controlling human movement (12). Richardson and Hodges (14, 16) also identified the transversus abdominus muscle as being a primary postural control muscle. It is hypothesized that the transversus abdominus is activated at a subconscious and submaximal contraction, as part of the motor plan, to provide trunk stiffness during dynamic movement. This approach to core control supports the theory of movement advocated by Pilates-evolved practitioners, more so than traditional methods. Pilates-evolved is a term used to differentiate practitioners who are continuing to define and expand on Pilates' work from the traditional Pilates practitioners.

The goal of achieving efficient movement and returning to functional movement and enhanced performance is the foundation of Pilates-evolved work. Pilates-evolved exercises are thought to facilitate such movement behavior by allowing the patient to be in a position that minimizes unwanted muscle activity, often responsible for inefficient movement patterns and early fatigue, which can lead to injury. When a desired movement is challenged by a decrease in proprioception, individuals often overrecruit muscles in an attempt to stabilize. Although it has not been proved, it remains plausible that overstabilization or faulty stabilization inhibits efficiency and often acts as a hindrance to efficient movement. For example, a patient may be able to demonstrate a 90-degree straight leg passively, but when asked to lay on his or her side, with a decreased base of support, the available range of motion on the hip drastically decreases (fig 5). When the base of support and balance are challenged, the degree of efficiency

fig. 5
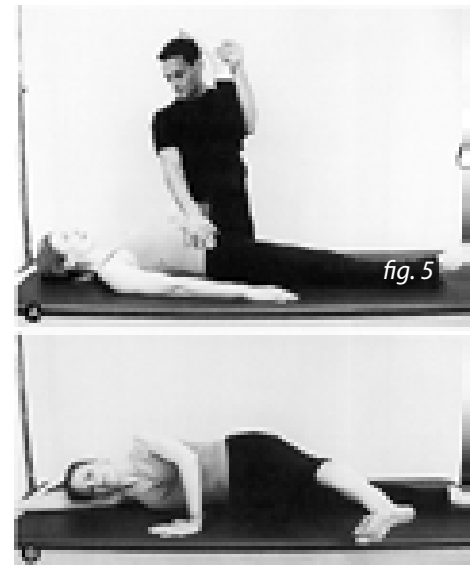
and range of a movement often suffer. The Pilates-evolved environment allows the therapist to decrease the proprioceptive challenge by increasing the base of support and providing adequate assistance and feedback for an optimal motor learning environment. The movement sequence can then be progressed by decreasing the assistance and amount of support, ensuring that the quality of the movement does not suffer. A therapist could then continue the progression toward a more functional task and familiar orientation with gravity. Traditional motor learning theory would teach that a cognitive level of learning take place first with internal and external feedback. Once association takes place and the patient continues to practice, the new movement sequence may become automatic. It is this automatic execution of new movements that reduces the risk of reinjury and increases efficiency.

Another important factor for attaining automatic movement is neurologic feedback from the deep muscles of the trunk, or the multifidi. The multifidi muscles have six times the number of muscle spindles of any other muscle in the trunk (9-11). This great source of kinetic feedback plays a large role in trunk awareness. Richardson et al (14)

showed that patients with chronic low back pain recruited their multifidi with different timing and magnitude of contraction compared with normal subjects. The healthy subjects showed symmetric recruitment bilaterally of the multifidi muscles, whereas the subjects experiencing low back pain showed asymmetry of the multifidi on the affected side. Another study using ultrasonography showed a discrepancy at segmental levels in multifidus girth, correlating to the site of the lumbar lesion (14). Theoretically, if the multifidi and other deep paraspinal muscles are inhibited secondary to pain and pain inhibition, one could hypothesize that the same process would inhibit the proprioceptive feedback mechanism of that muscle (i.e., muscle spindle fiber). The loss of proprioceptive feedback leads to a decrease in trunk awareness and control. Inhibition of core proprioception may be responsible for faulty compensatory patterns that can result in destructive forces that prolong the healing process. Working to overcome faulty compensatory movement patterns is a fundamental goal in the Pilates-evolved method. Treatment and intervention goals are to improve the proprioception of the trunk and to minimize the destructive forces as described by Porterfield and DeRosa (13) in their phase II of rehabilitation biomechanical counseling. Once the patient has shown successful movement without pain, the exercise is progressed by decreasing the assistance and challenging the base of support. This process is consistent with Porterfield and DeRosa's phase III dynamic stabilization (13). The ability to challenge proprioception through a movement phase in the Pilates-evolved environment is endless. The three variables-base of support, length of levers, and degree of assistance-can be manipulated independent of each other, providing greater variety in the precision of the therapist's modification of selected movements.

Polestar Education

Another example of an optimal environment for motor learning is found in Polestar Education, a Pilates-evolved education company focusing on rehabilitation (1). Polestar Education has defined the process of motor reeducation to the spine by breaking it down into three phases.

Phase I: Assistive movement

Assisting movement with the use of springs can allow for a decrease of unwanted muscle activity or guarding often associated with pain or weakness. Phase I, according to Polestar, can be broken down into three stages. These three stages can exist simultaneously.

Disassociation

Disassociation entails isolating movement at the hip or shoulder girdle, independent of pelvis or spine movement. This isolation can begin by creating an environment with a large base of support (i.e. in supine and offering assistance into the de-sired movement of the extremity (fig 6)). Disassociation combined with stabilization provides a favorable environment for protecting further trauma to spine lesions. The large muscles that are often guilty of the unwanted splinting (i.e. quadratus lumborum, gluteus maximus, and superficial erector spinae) can be taught to lengthen eccentrically, allowing the hip to absorb and distribute efficiently potentially harmful flexion forces to the spine.

Stabilization

In the early phase, the interest is in recruitment of deep stabilizers (i.e. transversus abdominus, internal and external abdominal obliques, and multifidi muscles). The stabilizers consist largely of type I fibers and are thought to contract at a submaximal level, which is less than 30% to 40% of a maximal voluntary contraction. This submaximal contraction happens simultaneously while disassociating the extremities or segments above or below the lesion. As the extremity disassociates from the trunk and the pelvis remains in neutral, the deep stabilizers work efficiently to maintain
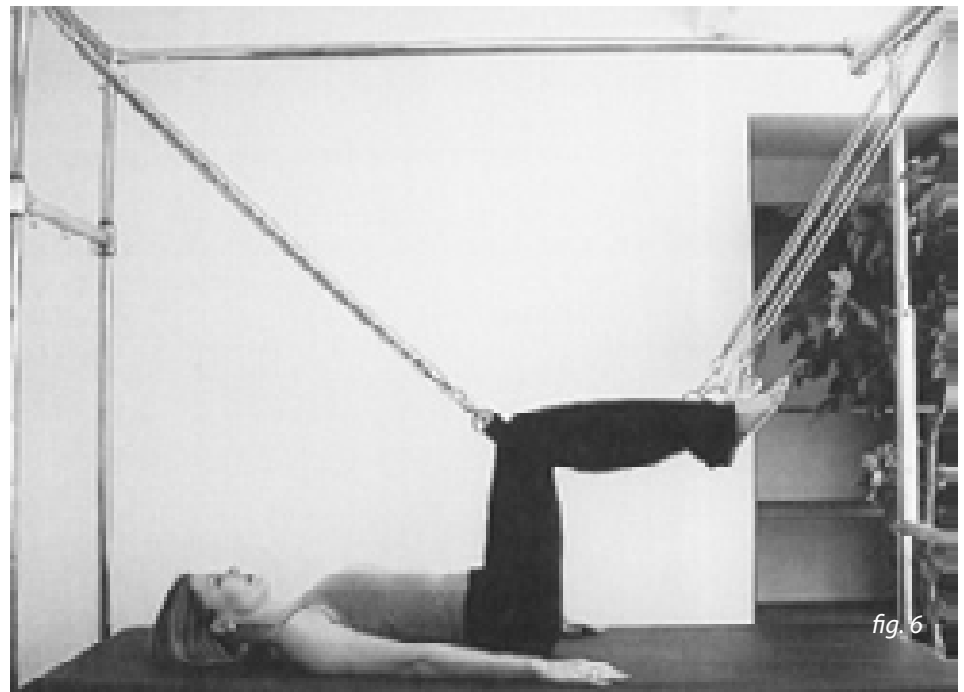

fig. 6

control (fig 7). This efficient use of the deep stabilizers and the decreased guarding is consistent with Porterfield and DeRosa's phase I of rehabilitation, to control pain and to encourage biomechanical counseling.


fig. 7

Mobilization

Mobilization is the restoration of mobility to affected joints and muscles. A therapist can contribute to the pathology if mobilization is too aggressive or premature. Conversely a lesion may be traumatized further if mobility is not restored. This is why the use of assistance is so crucial to restore the desired movement properly. The Pilates-evolved environment allows the therapist to use appropriate feedback and assistance to facilitate successful movement. As the therapist restores mobility to a target joint and surrounding joints, the force can be distributed equally, minimizing destructive forces (fig 8).

fig. 8

Phase II: Dynamic Stabilization

Dynamic stabilization involves challenging the newly acquired mobility or stability in a more functional and gravity dependent environment. This phase is a continuation of disassociation, stabilization, and mobilization is phase I. By decreasing the assistance and base of support or increasing the length of the levers, a movement or exercise difficulty increases. Once the desired movement is restored, the newly acquired movement can be challenged at a level appropriate for goals and expected outcomes. Elite movers often require greater challenges against gravity and resistance than a more sedentary patient (fig 9). Efficiency of movement is the

fig. 9
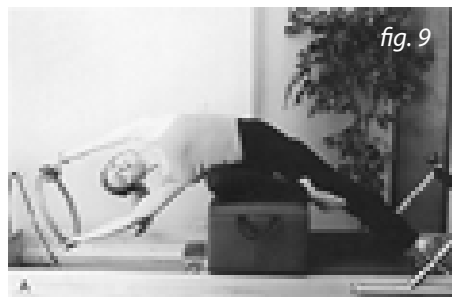
goal. By incorporating breathing and movement principles early in phase I activities, the ability of the patient to recruit secondary stabilizers (i.e., erector spinae, external and internal abdominal obliques, latissimus dorsi, and deep pelvis musculature) improves. The rectus abdominus should be trained for more ballistic movements because it is primarily a type II fiber muscle (fast twitch). The focus in this phase is still control.

Phase III: Functional Reeducation

Specificity training and functional reeducation are popular concepts in the field of rehabilitation. The Polestar approach divides functional reeducation into two stages: (1) foreign environment and (2) familiar environment.

Foreign environment

Task Specificity is a major focus of attention for those researching motor learning. Most research shows that neuromusculature reeducation has carryover only from task-specific movements. To teach a patient how to jump off one leg, practice should consist of jumping off of one leg. It has been experienced clinically, however, that putting a patient back in familiar environments too soon can lead to the patient seeking the path of least resistance, returning to old habits. To continue with the example, if the patient does not tolerate jumping against gravity, the patient can be placed supine and asked to jump with gravity eliminated (fig 10). In a foreign environment, the desired movement can be replicated with less proprioceptive challenges and destructive forces, while providing necessary verbal and tactile clues, facilitating the motor learning process and allowing the patient to perform the movement correctly.

fig. 10

Familiar environment

In the familiar environment stage, the patient is returned to the specific task in their day- to-day environment. The movement task learned within the foreign environment is progressed to a familiar environment with a normal

orientation to gravity. The patient is then challenged and encouraged to build adequate endurance and efficiency of movement in the familiar environment. Tactile and verbal clues used in the foreign environment are repeated to help associate each correct movement with the desired task (fig 11). The final goal is to become autonomous with the movement. In summary of motor learning applications to trunk control, this section has addressed motor learning principles and current research that helps support Pilates-evolved work as a viable mechanism of neuromuscular intervention for rehabilitation.

Biological and Physiologic Principles Associated With the Pilates-Based Approach

Pilates-evolved work identifies various biomechanical and physiologic properties that can help support the Pilates-evolved approach in rehabilitation. Current research associated with connective and neurologic tissue and the muscoskeletal system is considered in this section. Anthropometry is also discussed as a contributing factor toward seeking efficient interventions.

Connective tissue

Connective tissues provide support, transmit forces, and maintain the integrity structurally. All connective tissue is made up of cells and extracellular matrix composed of fibers and ground substance. The elasticity of the connective tissue is based largely on the ratio of collagen fibers to elastic fibers found in the tissue (7, 19). A large portion of connective tissue is avascular or hypovascular. This lack if vasculature would imply that nutrients are received through changes in pressure gradients, osmosis, and chemical and electric concentration (7). The Pilates-based exercises provide a closed-chain environment that facilitates compressive and decompressive forces on the connective tissues. It can be hypothesized, based on animal research, that the degeneration often experienced by immobilization or lack of compressive and decompressive sources can be as destructive to cartilage as overuse to the cartilage (6). Many connective tissue lesions, such as osteoarthritis, osteoporosis, degenerative disk disease, chronic system arthritis, fascial pain syndromes, and cartilage and ligamentous tears and repairs, can benefit from closed-chain movement when the load is modified.

Nervous tissue

Malfunctions of the peripheral and central nervous system continue to be investigated as a source of orthopaedic pathologies (2). The nervous system can be temporarily compromised; become ischemic; and provoke symp-

fig. 11

toms of pain, paresthesia, weakness, and decreased motor control (17). Often these signs and symptoms take on the appearance of a traditional orthopaedic diagnosis but symptoms do not respond to traditional treatments, such as injections, transverse tissue massage, ice, and muscle stretching. Practitioners often experience success in decreasing symptoms through mobilization of the nervous system and its connective tissue. It might be hypothesized, as described by Butler (3), that the cases that fail the more traditional pathways (i.e., joint and soft tissue mobilization, static rest, bracing or stabilization exercises) would do well with movement, or better stated, mobilization of the nervous system and its connective tissues. Pilates-based exercise can serve sd s technique to mobilize the nervous system and its surrounding connective tissues, as described by the practitioner.

Skeletal muscle

Skeletal muscle can be influenced greatly by Pilates-evolved exercises. In contrast to traditional modes of muscle conditioning that seek maximal voluntary contractions, Pilates-evolved muscle conditioning focuses on recruitment of the most effective motor units. This form of recruitment allows for an emphasis to be placed on energy efficiency and quality of performance. Physiologically, most muscle recruitment during day-to-day activities occurs in postural muscles, which contain predominately type I fibers. By facilitating postural muscles in the right sequence, a therapist can assist a patient in improving the efficiency of static and dynamic posture and decreasing significantly the likelihood of self-induced destructive forces. Richardson et al (15) found that the traditional method of eliciting an isolated volitional contraction is

not the most efficacious way to teach a patient movement or to facilitate postural changes. Pilates-evolved practitioners have experienced that movement performance and efficiency are facilitated best by using imagery and feedback mechanisms instead of eliciting maximal voluntary contractions or isolated muscle contractions for gross strength. The movement sequences on various Pilates apparatus allow the practitioner to modify the load to facilitate efficient movement accurately. This approach can be supported with other basic principles of biomechanics and muscle physiology, such as muscle-length-tension curve and velocity training. The variation of strength and mechanics of the joints and levers through an arc of motion can be explained by the muscle-length-tension curve and movement velocity. For example, the greatest assistance can be applied at the beginning and end of the arc, where the strength is least, and the least assistance can be applied through the middle of the arc, where the strength is greatest. In the case of dynamic stabilization, the greatest resistance is applied in the middle of the arc of movement, where available torque is greatest. This is also the range that is least vulnerable to insult. Changing the velocity can also vary the muscle physiologic responses, allowing custom tailoring of the movement sequence to mirror the desired functional task of the patient (8, 9).

Anthropometry

Anthropometry deals with the measure of size, mass, shape, and internal properties of the human body (4). In the Pilates-evolved environment, the equipment adapts to many human body variations. For example, the springs, ropes, and footbar of the clinical reformer can be adjusted such that similar properties of movement

sequencing can be applied to a variety of body types. The adaptability of the clinical reformer allows the practitioner to consider variations of an individuals weight and height. A good example is an exercise referred to as the hamstring arcs on the clinical reformer (fig 4). The objective of the movement sequence is to teach the patient to disassociate movement at the hip, while maintaining the pelvis and lumbar spine quiet or neutral. The foot straps, as an extension of the ropes, are attached to the feet. The springs are set so as to hold the legs effortlessly at approximately 45 degrees flexion. If the legs are long, the ropes can be lengthened to provide the same level of assistance as can be done for a person with much shorter limbs. If the limb is heavy because of muscle mass or fat, the springs can be increased to balance out the weight of the lower limbs can move with control through space without losing control of the pelvis and spine. The flexibility of this environment can take into account multiple anthropometric configurations.

Conclusion

In comprehending current motor learning theories, biomechanical principles, neuromusculoskeletal physiology, and anthropometry, the Pilates-evolved work can be perceived as a viable and effective method of movement reeducation. It is now necessary to subject this method to the rigors of research to investigate its validity as a cost-effective and efficient intervention for rehabilitation, postrehabilitation, and fitness. The use of Pilates-evolved methods in the various fields of rehabilitation, including neurologically involved, chronic pain, orthopaedic, performance based, and pediatric rehabilitation, merits investigation.

References

1 Anderson B, Larkam E: Polestar Education, Approach to rehabilitation in the Pilates Environment. Miami, Polestar's Rehab Course manual for Continuing Education, 1977

2 ButlerDS: Functional anatomy and physiology of the nervous system. In: Mobilization of the Nervous System. New York, Churchill Livingstone, 1991

3 ButlerDS: The clinical consequences of injury to the nervous system. In: Mobilization of the Nervous System. New York, Churchill Livingstone, 1991

4 Chaffin D: Anthropology in occupational biomechanics. In: Occupational Biomechanics. New York, John Wiley, 1990

5 Horak FB: Assumptions underlying motor control for neurologic rehabilitation: Contemporary management of motor control problems. Presented at II Step Conference APTA, Norman, OK, 1991

6 Jurvelin J, Kiviranta I, Tammi M, et al: Softening of canine articular cartilage after immobilization of the knee joint. Clin Orthrop 207:246-252, 1986

7 Nordin M, Frankel VH: Biomechanics of tendons and ligaments. In: Basic Biomechanics of the Muscoskeletal System. Philadelphia, Lea & Febiger, 1989

8 Nordin M, Frankel VH: Biomechanics of skeletal muscle. In: Basic Biomechanics of the Muscoskeletal System. Philadelphia, Lea & Febiger, 1989

9 Norris CM: Spinal stabilisation limiting factors to end-range motion in the lumbar spine. Physiotherapy 81:64-72, 1995

10 Norris CM: Spinal stabilisation active lumbar stabilisation-concepts. Physiotherapy 81:61-64, 1995

11 Norris CM: Spinal stabilisation: Stabilisation mechanism of the lumbar spine. Physiotherapy 81:72-79, 1995

12 Pilates JH, Miller WJ: Result of contrology. In: Return to Life Through Contrology. New York, JJ Augustin, 1945

13 Porterfield JA, DeRosa C: Treatment of lumbopelvic disorders. In: Mechanical Low Back Pain: Perspectives in Functional Anatomy. Philadelphia, WB Saunders, 1991

14 Richardson C, Jull G, Hodges P, et al: Local muscle dysfunction in low back pain. In: Therapeutic Exercise for Spinal Segmental Stabilisation in Low Back Pain. London, Churchill Livingstone, 1999

15 Richardson C, Jull G, Hodges P, et al: Overview of the principles of clinical management of the deep muscle system for segmental stabilization. In: Therapeutic Exercise for Spinal Segmental Stabilisation in Low Back Pain. London, Churchill Livingstone, 1999

16 Richardson C, Jull G, Toppenberg R, et al: Techniques for active lumbar stabilisation fo spinal protection: A pilot study. Australian Physiotherapy 38:2, 1992

17 Sunderland S: The pathology of nerve injury. In: Nerve Injuries and Their Repairs. London, Churchill Livingstone, 1991

18 Van Wingerden BAM: Ligaments and capsule. In: Connective Tissue in Rehabilitation. Lichtenstein, Scipro Verlag-Valduz, 1995

19 Van Wingerden BAM: Muscle. In: Connective Tissue in Rehabilitation. Lichtenstein, Scipro Verlag-Valduz, 1995

20 Van Wingerden BAM: Principles of athletic training. In: Connective Tissue in Rehabilitation. Lichtenstein, Scipro Verlag-Valduz, 1995

21 Wolhfahrt D, Jull G, Richardson C: The relationship between the dynamic and static function of abdominal muscles. Australian Physiotherapy 39:1, 1993

demonstrates a movement that is difficult because of the body's relationship with gravity.

Fig. 4   Hamstring Arcs on the Clinical Reformer demonstrates an assistive environment for hip flexion and disassociation at the hip joint.

Fig. 5   A, Straight leg raise test demonstrating 90 degrees of hip flexion. B, the Sidekick mat exercise demonstrating approximately 60 degrees of available active hip flexion.

Fig. 6   The 90/90 exercise on the Trapeze Table, demonstrating disassociation of the hip joint in an assistive environment with a large base of support.

Fig. 7   The Quadruped exercise on the Clinical Reformer, demonstrating stabilization of the spine and pelvis with disassociation at the shoulder joint.

Fig. 8   The Roll Down exercise on the Trapeze Table (A) and the Spring-Assisted Spine Extension on the Combo Chair (B), demonstrating spine mobilization with spring assistance.

Fig. 9   The Lateral Box Work exercise (A) and the Inverted V Series exercise (B) on the Clinical Reformer, demonstrating advanced abdominal work and dynamic stabilization.

Fig. 10 Jumping on the Clinical Reformer, demonstrating an exercise in a foreign environment.

Fig. 11 Jumping in a familiar environment with a normal orientation to gravity.