

Introduction to Pilates-Based Rehabilitation

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ORIGINS OF PILATES-BASED WORK IN REHABILITATION

As a child, German-born Joseph H. Pilates (Fig. 1) 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 artists 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 difficult as a result of the relationship of gravity on the body (Fig.

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Figure 1 Joseph H. Pilates. (Courtesy of JJ Augustin, Inc., Locust Valley, NY.)

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.

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 conducive to designing *task-oriented* interventions. Within this environment, a faulty movement can be broken down into components by using springs and changing the body's orientation to gravity. Each movement component can then be perfected and integrated, allowing for a return to a nonfaulty movement. Once this movement occurs, the patient can be progressed toward the desired task with a normal orientation to gravity. By successfully evaluating a patient's needs and assessing the desired movement



Figure 2 Pilates-based rehabilitation. (Courtesy of St. Francis Memorial Hospital, San Francisco, CA.)

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 accomplished, 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



Figure 3 The *Hundred* mat exercise demonstrates a movement that is difficult because of the body's relationship to gravity.

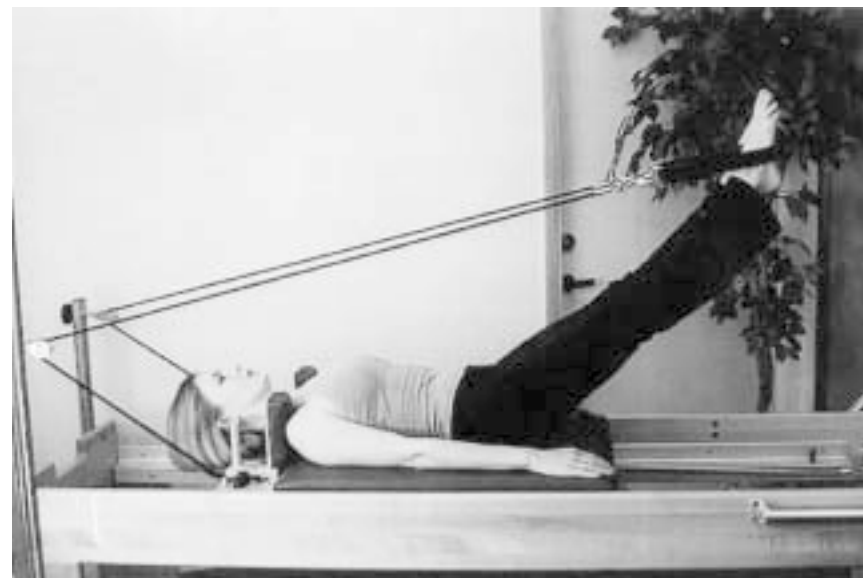


Figure 4 *Hamstring Arcs* on the Clinical Reformer (Balanced Body Inc., Sacramento, CA) demonstrates an assistive environment for hip flexion and disassociation at the hip joint.

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 abdominis muscle as being a primary postural control muscle. It is hypothesized that the transversus abdominis 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, an individual may be able to demonstrate a 90° straight-leg raise passively, but when asked to lay on his or her side, with a decreased base of support, the available range of motion in the hip drastically decreases (Fig. 5). When the base of support and balance are challenged, the degree of efficiency 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 the base 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 must 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 movement 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 kinesthetic feedback plays a large role in trunk awareness. Richardson et al¹⁴ 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

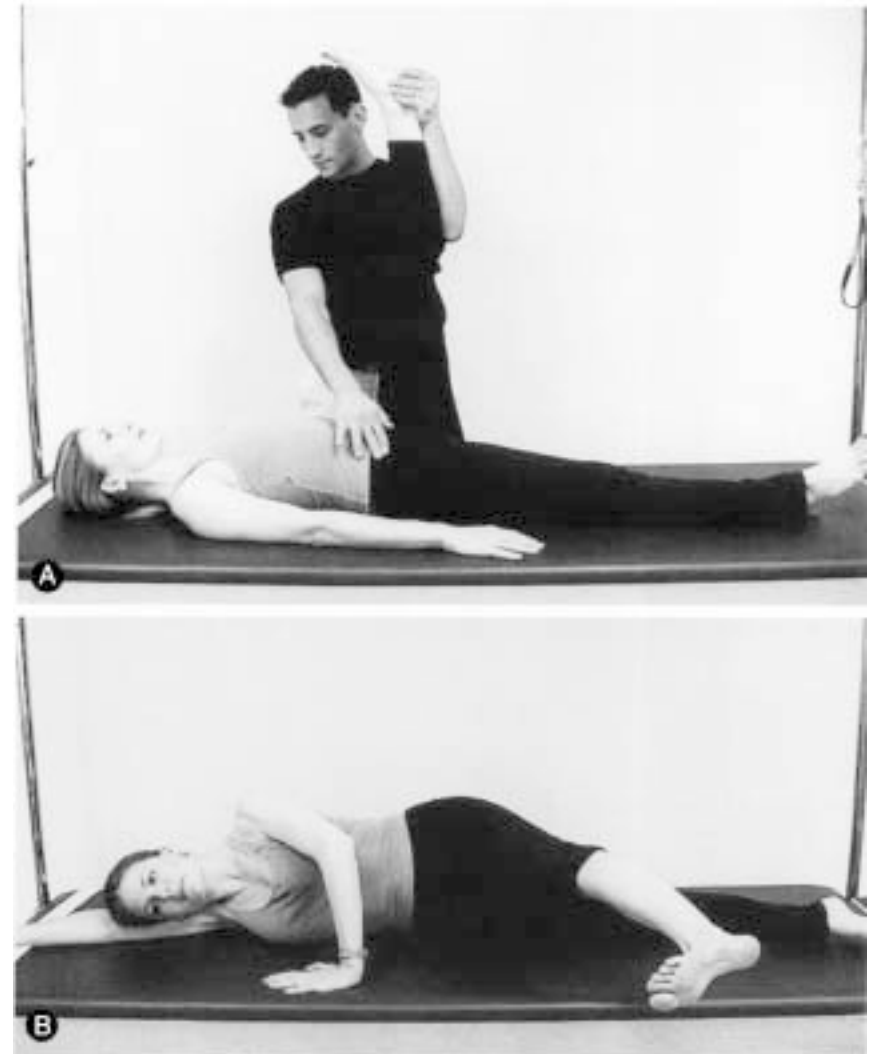


Figure 5 A, Straight leg raise test demonstrating 90° of hip flexion. B, The *Sidekick* mat exercise demonstrating approximately 60° of available active hip flexion.

low back pain showed asymmetry in recruitment 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 DeRosa¹³ 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 desired 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 abdominis, 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

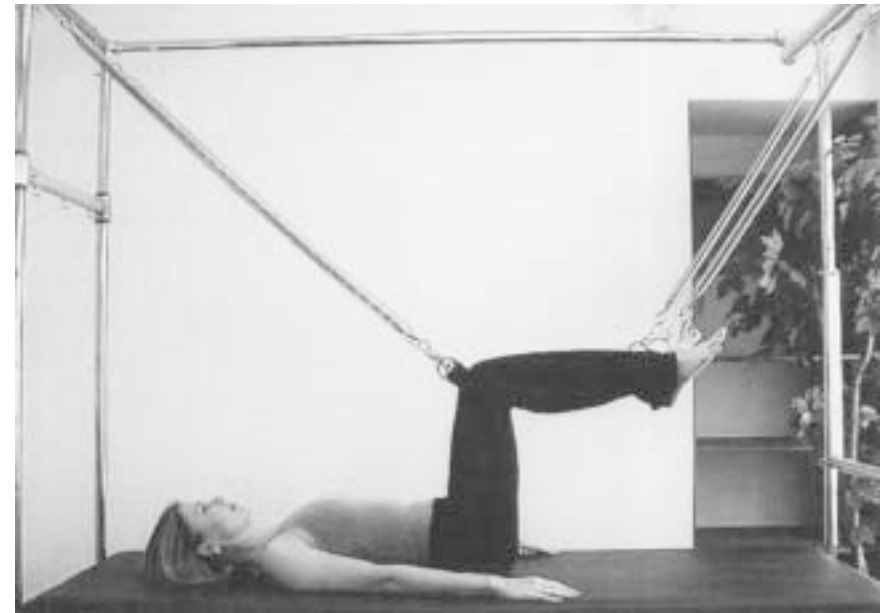


Figure 6 The 90/90 exercise on the Trapeze Table (Balanced Body Inc., Sacramento, CA) demonstrating disassociation at the hip joint in an assistive environment with a large base of support.

contraction.¹⁵ 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 control (Fig. 7). This efficient use of the deep stabilizers and the decreased guarding is consistent with Porterfield and DeRosa's¹³ phase I of rehabilitation, to control pain and to encourage biomechanical counseling.

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).

Phase II: Dynamic Stabilization

Dynamic stabilization involves challenging the newly acquired mobility or stability in a more functional and gravity-dependent environment. This phase



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

is a continuation of *disassociation*, *stabilization*, and *mobilizations* in 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 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.¹⁴ The rectus abdominis 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 neuromuscular reeducation has carryover only from task-specific movements. To teach a patient how to jump off of one leg, practice



Figure 8 The *Roll Down* exercise on the trapeze table (A) and the *Spring-Assisted Spine Extension* exercise on the Combo Chair (Balanced Body Inc., Sacramento, CA) (B), demonstrating spine mobilization with spring assistance.

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

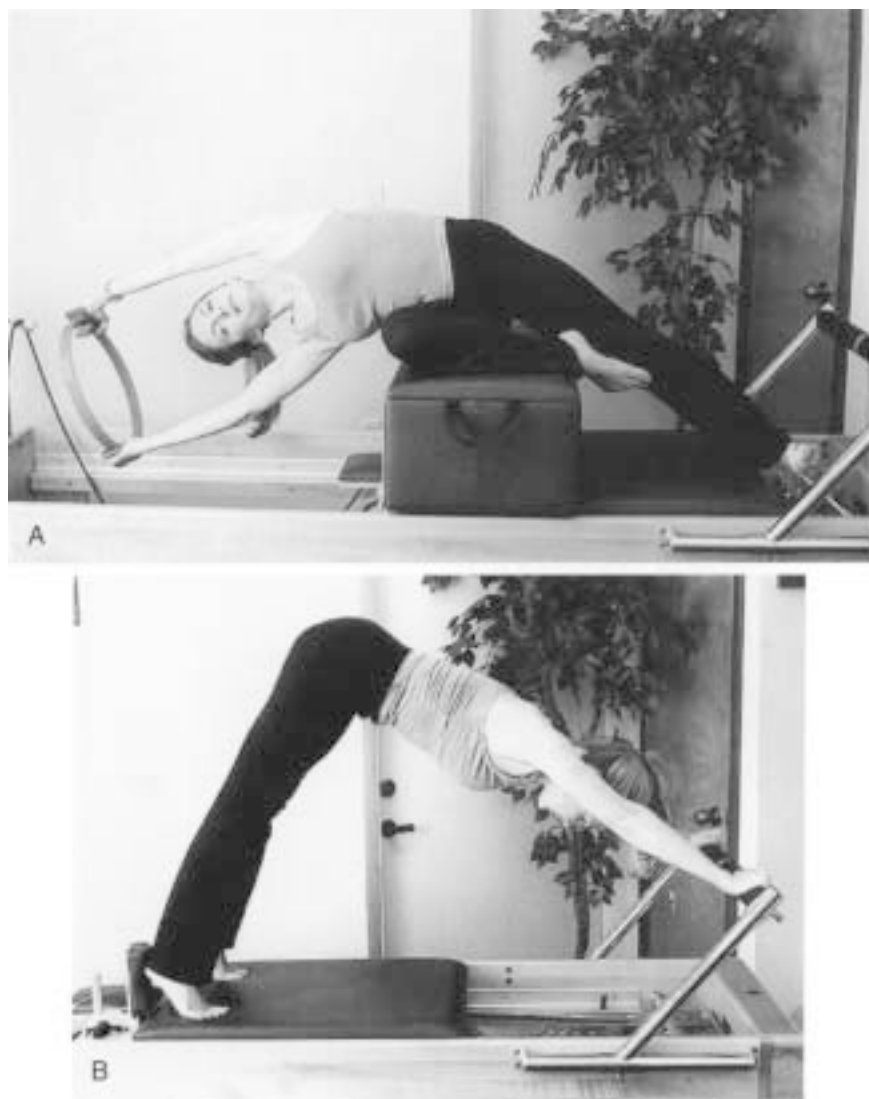


Figure 9 The *Lateral Box Work* exercise (A) and the *Inverted V Series* exercise (B) on the Clinical Reformer, demonstrating advanced abdominal work and dynamic stabilization.

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 cues, facilitating the motor learning process and allowing the patient to perform the movement correctly.



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

Familiar Environment

In the familiar environment stage, the patient is returned to the specific task in his or her 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 cues 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.

BIOMECHANICAL 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 musculoskeletal 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



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

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 of 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. The Pilates environment allows for multiple closed-chain foot and hand placements throughout a full range of motion, theoretically providing articulation and nutrition to a greater surface area of the joint and its 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 systemic ar-

thritis, 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 symptoms of pain, paresthesia, weakness, and decreased motor control.¹⁷ Often these signs and symptoms take on the appearance of a traditional orthopaedic diagnosis but 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 stabilizing exercises) would do well with movement, or better stated, mobilization of the nervous system and its connective tissues. Pilates-based exercise can serve as a technique to mobilize the nervous system and its surrounding connective tissues, as desired 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 predominantly 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 al¹⁵ 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.^{8,19}

Anthropometry

Anthropometry deals with the measure of size, mass, shape, and inertial 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 foot bar 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 individual's weight and height. A good example is an exercise referred to as the hamstring arcs on the clinical reformer (see 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° 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. The desired movement is such that 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.

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