Benefits of Continuous Passive Motion

FOR MOTOR-IMPAIRED PATIENTS

Continuous Passive Motion

Continuous passive motion (**CPM**) therapy is designed to move patients' joints in a safe and effective way that helps them maintain or reclaim their range of motion and reconnect neural pathways. The Quadriciser is a patented FDA Class I medical device that simultaneously moves all four limbs, imitating natural joint mobility. This gentle, controlled stimulation helps patients stay active when exercise might otherwise prove difficult, increases blood flow to affected areas, enhances muscle tone and dexterity, and improves gait, among many other positive effects.

Though significant research has explored the benefits of CPM in post-operation recovery, this therapy also fulfills a critical need in the regimens of motor-impaired patients.

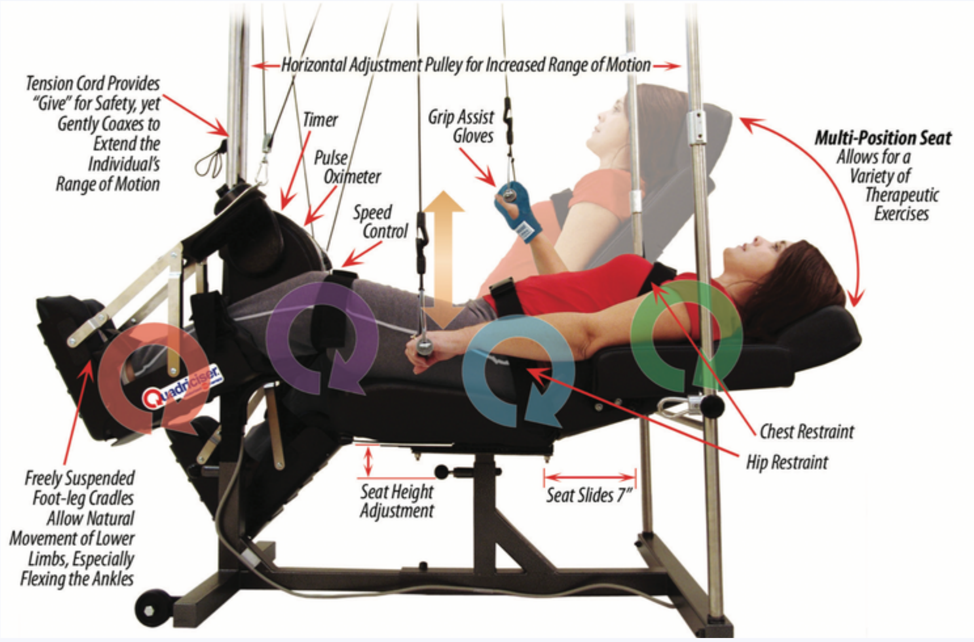
Overview of Benefits

CPM therapy has been implemented for multiple subsets of motor-impaired patients, including those affected by cerebral palsy, traumatic brain injury, and stroke(s), leading to promising improvements in the following areas:

+ *Reduced muscle spasticity, or tightness*
+ *Improved joint integrity/stability and range of motion*
+ *Slowed heterotopic ossification (development of bone within soft tissues)*
+ *Increased blood oxygen level-dependent (BOLD) responses*
+ *Beneficial sustained neuroplastic changes*
+ *Ability to perform daily activities with less difficulty*
+ *Generates a positive mindset*

As illustrated by this broad range of benefits, CPM engages muscles, joints, and the brain to advance overall health. By enabling individuals to take an active role in their rehabilitation, they often make progress with regards to both their physical recovery and mental well-being.

QUADRICISER



The Quadraciser is a versatile system that allows for extensive adjustments to suit the user's level of physicality and specific needs.

Joint Mobility

Following traumatic brain injury (TBI), joint movement tends to be limited by increased muscle spasticity/tone, incoordination, and weakness of agonist muscles such as the hamstring and knee.

Stroke patients who underwent hour-long CPM sessions targeted at their arms demonstrated improved velocity of movement, ability to hold their impaired arm in an extended position with less force, and could initiate movement in formerly difficult directions after training. Individuals with stiff or tight muscles saw a reduction in elevated tone (Reinkensmeyer et al., 2000). Some participants exhibited more consistency or control over their free movements, though this finding appears dependent on one's level of motor ability. Motor improvements likely result from the repetitive stretching of soft tissues surrounding the bones and joints, and activation of pathways previously damaged by TBI.

CPM helps slow, and sometimes reverse, the heterotopic ossification process. Heterotopic ossification (HO) refers to the formation of bone within the muscle and soft tissues, a common signature of irregular tissue repair. CPM was shown to be effective at increasing hip flexion from 50 to 85 degrees, when paired with risedronate, a medication that prevents and treats thinning of the bone (Vasileiadis et al., 2021). CPM also improved range of motion in the knees of a TBI patient presenting with bilateral HO after 4 weeks of rehabilitation (Linan et al., 2001).

In a pilot study of 32 unilateral stroke patients, those treated with CPM displayed a positive trend towards improved shoulder joint stability, in combination with standard daily post-stroke therapy for 3.5 hours per day (Lynch et al., 2005). Joint instability can occur when the tissues or muscles that encircle the joint are stressed, causing an unhealthy range of motion.

Muscle Spasticity

"[CPM]... MOVE(S) INDIVIDUALS WITH SEVERE SPASTICITY TO A LEVEL OF FUNCTION WHERE THEY CAN USE OTHER EFFECTIVE REHABILITATION TECHNIQUES."

- Stephen Noble et al., 2019

Muscle spasticity may develop as a consequence of cerebral palsy, spinal cord injury, multiple sclerosis, or stroke. Noble et al. demonstrate that 6 weeks of 30-minute CPM sessions directed at the ankle joint were able to diminish H-reflex excitability in participants with spasticity (stiff or rigid muscles) induced by a neurological condition. Hyperexcitable reflexes and excessive muscle tone, together, impede contraction of the foot when rising from a seated position, or during walking (Zehr et al., 2012; Thilmann et al., 1991).

As a result, individuals with high H-reflex excitability may find it difficult to walk normally and experience limited mobility and independence.

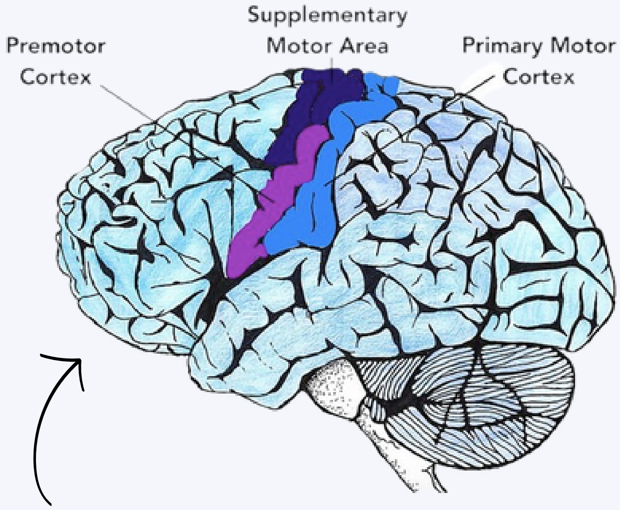
Continued CPM therapy could thus allow patients to regain some walking ability and transition to other types of rehabilitation that require a higher degree of mobility, such as arm and leg cycling, resistance training, and treadmill walking.

Similar results have been replicated by studies with comparable timeframes. 4 weeks of bilateral ankle CPM for 1 hour a day significantly reduced symptoms of excess muscle tone in participants diagnosed with cerebral palsy (Chuang et al., 2022). In conjunction with conventional physical therapy, CPM also benefits stroke patients suffering from hemiparesis, a form of muscle weakness or partial paralysis restricted to one side of the body.

Study participants who used a CPM device at low intensity for 3 weeks exhibited a decrease in muscle spasticity and found it easier to perform daily activities (Stefanova, 2016). Some patients reported that their affected arm felt “lighter” due to a decrease in resistance. Regaining movement of a paralyzed limb is complicated by a lack of sensation and often more difficult in the upper than lower extremities, making these results particularly encouraging.

Brain Function

Passive exercise of the hand using a CPM device has been shown to activate both the supplemental and primary motor cortex (Nasrallah et al., 2019). These areas promote coordination, and play a key role in the execution and control of voluntary movements.



A view of the primary motor cortex and supplementary motor area

CPM is a fundamental intervention for the rehabilitation of paralyzed extremities. Even in the absence of active motor commands, passive movement can induce the re-growth of neural circuitry (Jack et al., 2001). This ability to "rewire," or reorganize structural connections following TBI is referred to as neuroplasticity.

There is considerable evidence showing that passive motion can activate the posterior parietal cortex and secondary somatosensory cortex, in addition to the primary motor cortex and supplementary motor area. Despite its name, the supplementary motor area (SMA) is no less critical to facilitating movement than the primary cortex, and through its connections with parts of the brain, remains intrinsic to motor circuits. Nasrallah et al. reveal that sensory inputs elicited by passive exercise likely modulate the activity of the SMA. These signals, in turn, activate the primary motor cortex.

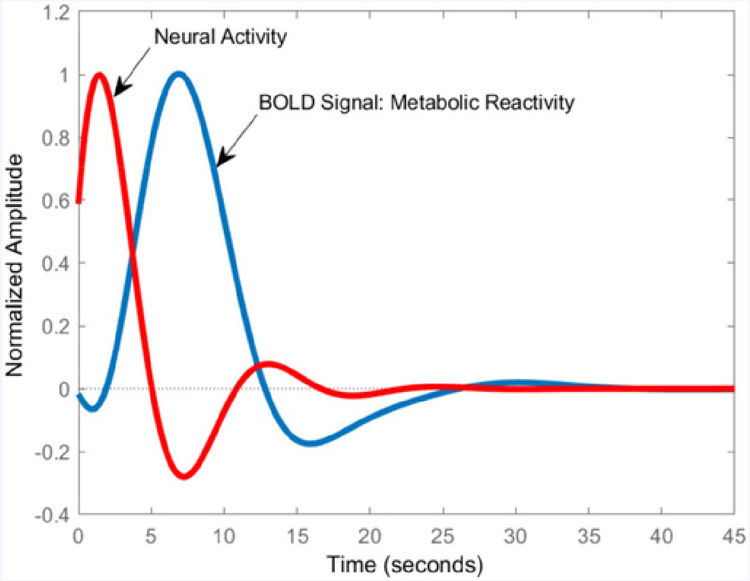
Irrespective of the nature of movement (passive or active), Reddy et al. recorded similar levels of activation in the SMA and ipsi- and contralateral cortexes across multiple sclerosis patient groups. This suggests that CPM may offer the same cognitive benefits as voluntary motion. Ankle CPM therapy also increases ipsi- and contralateral cortical activation (Vér et al., 2016)

BOLD Response

BOLD- Blood Oxygen Level-Dependent

In the same study, Vér et al. observed elevated BOLD responses in several distinct brain regions (the contralateral pre- and postcentral gyrus, superior temporal gyrus, central opercular cortex, ipsilateral postcentral gyrus, frontal operculum cortex, and cerebellum) of stroke patients following short-term ankle CPM. BOLD responses are observed via functional magnetic resonance imaging (fMRI) and reflect localized changes to blood brain flow and oxygenation (Hillman, 2014). Neuronal activity leads to increased BOLD signals.

ANALYTICAL MODEL OF FMRI BOLD SIGNALS



The BOLD signal is a correlated representation of the underlying neuronal response (Schaper, 2019).

Mental Well-Being

CPM regimens tend to generate positive expectancies for improved physical and mental well-being (Sinatra et al.,1990). In stroke patients, for example, CPM therapy creates confidence and a sense of control in the recovery process, which is significantly more beneficial than prolonged immobility (Stefanova, 2016).

Though healthy women who were assigned to a 12-week walking program displayed more pronounced cardiovascular fitness than their counterparts in the CPM group, they were also more likely to terminate their participation prematurely.

"[CPM] IS ASSOCIATED WITH DECREASED ANXIETY AND DEPRESSION."

- Stephen Sinatra et al., 1990

Gentle and Effective Therapy

PASSIVE AND CONTINUOUS

Unlike other CPM machines that target a single joint, the Quadriciser can stimulate the entire body for more comprehensive benefits. These patterns of movement closely mirror walking/crawling in individuals unable to move on their own.

Range of motion	Ensures that joints remain mobile and stable, helping patients regain range of motion more quickly than with conventional physical therapy alone.
Muscle spasticity	Alleviates muscle stiffness and involuntary contractions common in individuals with spasticity; lessens heterotopic ossification processes.
Brain function	Stimulates motor pathways in the brain and related blood oxygen level-dependent responses.
Confidence	Provides positive mental health benefits.

Citations

1. Reinkensmeyer, D. J., Kahn, L. E., Averbuch, M., McKenna-Cole, A., Schmit, B. D., & Rymer, W. Z. (2014). Understanding and treating arm movement impairment after chronic brain injury: progress with the ARM guide. Journal of Rehabilitation Research and Development, 37(6), 653-662.
2. Vasileiadis, G. I., Varvarousis, D. N., Manolis, I., & Ploumis, A. (2021). The Impact of Continuous Passive Motion on Heterotopic Ossification Maturation. American Journal of Physical Medicine & Rehabilitation, 100(12), e194-e197.
3. Linan, E., O'Dell, M. W., & Pierce, J. M. (2001). Continuous passive motion in the management of heterotopic ossification in a brain-injured patient. American Journal of Physical Medicine & Rehabilitation, 80(8), 614–617.
4. Lynch, D., Ferraro, M., Krol, J., Trudell, C. M., Christos, P., & Volpe, B. T. (2005). Continuous passive motion improves shoulder joint integrity following stroke. Clinical Rehabilitation, 19(6), 594–599.
5. Noble, S., Pearcey, G. E. P., Quartly, C., et al. (2019). Robot controlled, continuous passive movement of the ankle reduces spinal cord excitability in participants with spasticity: a pilot study. Experimental Brain Research, 237, 3207–3220.
6. Zehr, E. P., Loadman, P. M., & Hundza, S. R. (2012). Neural control of rhythmic arm cycling after stroke. Journal of neurophysiology, 108(3), 891–905.
7. Thilmann, A. F., Fellows, S. J., & Ross, H. F. (1991). Biomechanical changes at the ankle joint after stroke. Journal of neurology, neurosurgery, and psychiatry, 54(2), 134–139.
8. Chuang, L. L., Chuang, Y. F., Ju, Y. J., Hsu, A. L., Chen, C. L., Wong, A. M. K., & Chang, Y. J. (2022). Effects of ankle continuous passive motion on soleus hypertonia in individuals with cerebral palsy: A case series. Biomedical Journal, 45(4), 708–716.
9. Stefanova, I. (2016). Effects of using continuous passive motion device in the rehabilitation upper limb following stroke. In Proceedings of The 5th Electronic International Interdisciplinary Conference.

(Continued)

10. Nasrallah, F. A., et al. (2019). Functional connectivity of the brain associated with passive range of motion exercise: Proprioceptive input promoting motor activation? NeuroImage, 202, 116023.
11. Jack, D., Boian, R., Merians, A. S, Tremaine, M., Burdea, G. C., Adamovich, S. V., Reece, M., & Poizner, H. (2001). Virtual reality-enhanced stroke rehabilitation. IEEE Transactions on Neural Systems and Rehabilitation Engineering, 9(3), 308–318.
12. Reddy, H., Narayanan, S., Woolrich, M., Mitsumori, T., Lapierre, Y., Arnold, D. L., & Matthews, P. M. (2002). Functional brain reorganization for hand movement in patients with multiple sclerosis: defining distinct effects of injury and disability. Brain, 125(12), 2646–2657.
13. Vér, C., Emri, M., Spisák, T., Berényi, E., Kovács, K., Katona, P., Balkay, L., Menyhárt, L., Kardos, L., & Csiba, L. (2016). The Effect of Passive Movement for Paretic Ankle-Foot and Brain Activity in Post-Stroke Patients. European Neurology, 76(3-4), 132–142.
14. Hillman E. M. (2014). Coupling mechanism and significance of the BOLD signal: a status report. Annual review of neuroscience, 37, 161–181.
15. Schaper, C. D. (2019). Analytic model of fMRI BOLD signals for separable metrics of neural and metabolic activity. bioRxiv.
16. Sinatra, S. T., Allen, G. J., Camaione, D. N., & Abraham, A. (1990). Effects of Continuous Passive Motion, Walking, and a Placebo Intervention on Physical and Psychological Well-Being. Journal of Cardiopulmonary Rehabilitation, 10(8), 279-286.