Effect of Instrument Assisted Soft Tissue Mobilization on Range of Motion in Children with Diplegic Cerebral Palsy: A Review Article

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Abstract

Cerebral palsy (CP) is a dynamic disorder of posture and mobility, being the motor manifestation of non-progressive brain damage (static encephalopathy) sustained during the period of brain growth in the fetal life, infancy or childhood. The topographic classification of CP is hemiplegia, diplegia, and quadriplegia. Diplegia is the most common type (30-40%). The lower extremities are severely involved and the arms are mildly involved. CP is characterized by increased resistance to passive movement due to spasticity. Spasticity leads to muscle contractures and bone deformities as a result of secondary structure changes of the muscles fibers. These changes in fiber bundles and fewer sarcomeres cause a decreased range of motion. Short muscle-tendon units of the hip and knee flexors and ankle plantar-flexors, particularly the bi-articular muscles, contribute to joint contracture and abnormal joint mechanics. Instrument assisted soft tissue mobilization (IASTM) is a popular treatment for myofascial restriction is applied using specially designed instruments to provide a mobilizing effect to soft tissue (e.g., scar tissue, myofascial adhesion) to decrease pain and improve range of motion and function. Tools used for IASTM produce micro-trauma to soft tissue for healing and restoring normal elasticity and function. The goal of this review was to focus on the effects and causes of movement problems in children with diplegic CP and the role of IASTM in managing these problems.

Key words: Cerebral palsy, Diplegia, Instrument assisted soft tissue mobilization, Range of motion, Spasticity.

1. Introduction

Cerebral palsy (CP) describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorder of CP are often accompanied by disturbances of sensation, perception, cognition, communication, behavior, epilepsy, and by secondary musculoskeletal problems. It begins in early childhood and persists through the lifespan [(1)].

In CP there is increased resistance to passive movement due to spasticity. Spasticity over time will lead to change in soft tissues (muscles, tendons and ligaments) leading to muscle stiffness, atrophy (deterioration or wasting of the muscle) and fibrosis (changes in the properties of the muscle fibres). These changes in fiber bundles and fewer sarcomeres cause a decreased range of motion and muscle shortening that affect the functions [(2)].

The instrument assisted soft tissue mobilization (IASTM) is a non-invasive method that depends on an easy-held, cheap, and light-weighted tool [(3)]. The use of IASTM as a technique to release the tension in shortened muscles is emerging in clinical practice. There is a notion indicating that there is a mechanical advantage behind the use of IASTM which allows the clinician to have better penetration and more focused treatment for the shortened areas of the muscles with less tension on the therapist's hands [(4)]. Besides, IASTM allows the therapist to detect alteration in tissue properties, thus focusing more on the area with more excessive fibrosis [(5)].

IASTM is a promising treatment approach for myofascial restriction that makes use of specifically designed tools to mobilize soft tissue that has developed myofascial adhesion in order to lessen discomfort

and increase range of motion and function. The use of an instrument is supposed to give therapists a mechanical advantage by allowing for more focused treatment and deeper penetration [(6)]. IASTM therapy has demonstrated safety and effectiveness in the soft tissue conditions studied and is reported to be well tolerated by patients [(7)]. The purpose of this review was to search the literature pertaining to the effects and causes of movement problems in children with diplegic CP and the role of IASTM in managing these problems to help the health professionals in their planning of a treatment program.

2. Cerebral palsy

Cerebral palsy is an early-onset lifelong neurodevelopmental condition characterized by limitations in activity due to impaired development of movement and posture, manifesting as spasticity, dystonia, choreoathetosis and/or ataxia. It results from maldevelopment attributed to dysplagia of or injury to the fetal or infant brain that is not degenerative, although the manifestations may change with age. The phenotype of CP is complex and heterogeneous, with each person experiencing a unique presentation. In addition to motor dysfunction, people with CP frequently encounter primary and secondary impairments across various areas of development and functioning, which can significantly impact their participation in daily life [(8)].

It is a well-recognized neurodevelopmental disorder beginning in early childhood and persisting through the lifespan. CP has substantial effects on function and health related quality of life of patients and their cares [(9)]. This static neurologic condition occurs before the completion of cerebral development. Because brain development continues during the first two years of life, CP can result from brain injury occurring during the prenatal, perinatal, or postnatal periods [(10)].

This disorder characterized by abnormal tone, posture and movement and clinically classified based on the predominant motor syndrome; spastic hemiplegia, spastic diplegia, spastic quadriplegia, and extrapyramidal or dyskinetic. The incidence of CP is 2–3 per 1,000 live births. Prematurity and low birth weight are important risk factors for CP; however, multiple other factors have been associated with an increased risk for CP, including maternal infections, and multiple gestation [(11)].

“People living with cerebral palsy have a complex physical disability that makes their muscles unusually stiff and affects their movements. Cerebral palsy is caused by early damage to a part of the brain, which does not get worse in itself but whose consequences become more severe over time. Each person with cerebral palsy is unique and, while all have some degree of physical disability, many face additional learning, communication, visual or other challenges. With the right recourses, therapies, and support from family, people with cerebral palsy can thrive and live fulfilling lives” [(8)].

Patients with CP are characterized by the phenomenon of "early aging" of the musculoskeletal system. Potential areas for the prevention of sarcopenia in children and adults with CP are important. Understanding the described mechanisms of primary and age-related changes in muscle tissue in early center nervous system injuries is necessary for planning the daily activities of patients, choosing the right rehabilitation tactics, minimizing adverse therapeutic effects, and justified correction of concomitant disorders [(12)].

Growth of muscles in CP deviates from typical development, evident as early as 15 months of age. Muscles in CP may be reduced in volume by as much as 40%, may be shorter in length, present longer tendons, and may have fewer sarcomeres in series that are overstretched compared to typical. Macroscale and functional deficits are likely mediated by dysfunction at the cellular level, which manifests as impaired growth. Within muscle fibres, satellite cells are decreased by as much as 40–70% and the regenerative capacity of remaining satellite cells appears compromised. Impaired muscle regeneration in CP is coupled with extracellular matrix expansion and increased pro-inflammatory gene expression; resultant muscles are smaller, stiffer, and weaker than typical muscle. These differences may contribute to individuals with

CP participating in less physical activity, thus decreasing opportunities for mechanical loading, commencing a vicious cycle of muscle disuse and secondary sarcopenia [13].

In CP there are significant changes in the spastic muscles at different structural levels and stages of formation of the muscle tissue. The main changes in spastic muscle include the following: change in the size and differentiation of the muscle fibers; reduction in the elasticity of an individual muscle fiber and reduction in the resistance to stretching of the fiber bundle; proliferation of the extracellular matrix as well as altered structural and mechanical properties; change in the length and number of sarcomeres in the myofibrils of the spastic muscles; change in the gene expression in the tendons and muscle tissue as well as regulation of the expression of genes affecting the composition of the extracellular matrix; change in the length and cross section of the whole muscle. These changes disrupt the mechanical properties of the spastic muscle and its interaction with muscle agonists and antagonists and lead to a change in the biomechanics of motion in CP [14, 15].

Muscle contractures represent a distinct muscle adaptation characterized by increased passive muscle stiffness and limited joint mobility with little or no active force production. As muscle contractures cause issues such as fixated joints in shortened positions, limited use of affected limbs, strength loss, muscle atrophy, and rapid fatigue, the complication can be very debilitating and considerably reduce both the functional abilities and the quality of life of affected individuals [16].

The motor limitations and contracture formation in the spastic forms of CP cannot be explained by a single universal mechanism and represent a combination of structural changes in the muscles and violations of the central control of movement and maintenance of posture. A consideration of all the described changes should be the basis for developing and selecting the optimal methods of rehabilitation and prevention of contractures in CP patients [15].

Clinical management of children with CP is directed towards maximizing function and participation in activities and minimizing the effects of the factors that can make the condition worse. These management strategies include enhancing neurological function during early development; managing medical co-morbidities, weakness and hypertonia; using rehabilitation technologies to enhance motor function; and preventing secondary musculoskeletal problems. Meeting the needs of people with CP in resource-poor settings is particularly challenging [17].

Interventions that show effectiveness outcomes for the treatment of CP include neurological music therapy, aquatic therapy, virtual reality, robotics, electrical stimulation, constraint-induced movement therapy, hippotherapy, and hyperbaric oxygen therapy. When administered alongside physical therapy, neurological music therapy is also considered effective in the treatment of CP. Treadmill gait training combined with robotics to enhance the lower limbs also leads to positive outcomes. In the lower limbs, kinesio taping is beneficial for positioning the ankle, increasing its range of motion as well as for decreasing spasticity. Botulinum toxin injections can lessen spasticity and enhance the range of motion, which makes it easier for individuals to wear splints and receive therapy. Selective dorsal rhizotomy is effective for reducing spasticity and improving gross motor function. Neurorestorative therapies such as cell therapy, Brain-computer interfaces, and transcranial magnetic stimulation can restore neural networks in an effective and positive direction in CP. Rehabilitation alongside neurofeedback and biofeedback is also considered helpful for patients with neurological disorders [18].

3. Diplegic cerebral palsy

Diplegia is a form of CP characterized primarily by motor impairments that affect the legs more than the arms, often manifesting with increased muscle tone and spasticity in the lower limbs. It falls under the broader classification of spastic CP, where muscle stiffness predominantly impacts bilateral body parts [11]. The diagnosis is primarily based on a combination of clinical assessments, detailed medical history,

and neuroimaging results like magnetic resonance imaging to identify brain lesions responsible for the condition [19].

Children with diplegic CP often exhibit delays in motor milestones such as sitting, crawling, and walking. The abnormal increase in muscle tone in diplegic CP, restricts movement and can cause joint deformities over time. This spasticity combined with muscular imbalances significantly alters gait dynamics, necessitating targeted interventions to manage muscle tone and improve function [11].

According to the severity of the case, children with spastic diplegia can achieve independent walking with or without assistive device by age of approximately 4 years, with one of these common gait patterns (true equinus gait / Jumping gait / apparent equinus gait / crouch gait / asymmetric gait). In each of these walking patterns the child adopted to different posture of the spine, in order to remain upright and compensate for these abnormal positions [20].

Spasticity limits the range of passive and active motion in joints, contributes to developing joint contractures and has an adverse effect on the further development of motor functions. It can lead to flexion at the hip (which causes the leg to lift upwards when lying or the body to lean forwards in standing), adduction or 'scissoring' of the thighs (which causes the legs to pull together), flexion at the knees (causing changes in a person's standing posture) and equinovarus foot posture (where the toes point downwards and inwards with the heel off the ground - this results from tightness in the calf muscles) [14, 21].

Muscles that are affected by spasticity have difficulty stretching out to keep up with bone growth - resulting in muscles that are shorter than they should be (shortened muscle-tendon unit in the muscles affected by spastic CP). This prevents a joint achieving its normal full range of movement and is called a contracture. Shortened, contracted muscles can pull on the bony structures of the body leading to bone deformities. Hip, knee, and ankle involvements are present in the vast majority of diplegic CP children. The failure of muscle growth to keep pace with bone growth is most evident in the bi-articular muscles, e.g., the gastrocnemius, hamstrings, and rectus femoris, and contributes to joint contractures. Torsional deformities of the long bones frequently found in bilateral spastic CP, in association with musculotendinous contractures leading to foot deformities which lead to gait abnormalities such as toe-walking and flexed-knee gait [2, 14, 22].

4. Knee joint problems

The knee is the intermediate joint of the lower limb and it allows the movement between the femur, tibia and patella. It consists of the tibiofemoral and the patellofemoral joint. The tibiofemoral is the articulation of the tibia and the femur. It can be represented in the sagittal plane as a hinge joint, with a range of flexion of -5 to approximately 160. The patellofemoral joint, on the other hand, has a special structure. It is a gliding joint in which the patella slides over the trochlear surfaces of the femur during flexion and extension of the knee. This provides additional mechanical leverage in extension because of a greater force arm, as well as reducing wear on the quadriceps and patellar tendons from friction against the intercondylar groove. Under normal conditions there is a normal distribution of the load forces on these articular components in both the static load and during ambulation [23].

Knee movements are controlled by quadriceps and hamstrings. Imbalance between these two groups of muscles results into gait deviation. There are two common knee problems in CP; increased knee flexion during stance phase (Flexed knee gait) and reduced knee flexion during the swing phase of gait (Stiff-knee gait). Hamstring spasticity, quadriceps weakness, soleus weakness, and lever-arm dysfunction are few factors which lead to increased knee flexion during stance phase. Rectus spasticity diminishes knee flexion in the swing. Resulting gait (stiff knee gait) interferes with ground clearance. Both gait patterns result into esthetically poor gait and increased energy consumption. Knee flexion gait may lead to pain in the knee. Natural history of knee flexion gait suggests deterioration over time [24].

Graham *et al.* [25] developed a four-stage classification system of lower limb musculoskeletal pathology: Stage 1: Hypertonia: Abnormal postures are dynamic. Stage 2: Contracture: Fixed shortening of one or more muscle-tendon units. Stage 3: Bone and joint deformity: Torsional deformities and/or joint instability (e.g., hip displacement or pes valgus), usually accompanied by contractures. Stage 4: Decompensation: Severe pathology where restoration of optimal joint and muscle-tendon function is not possible.

Reduced range of motion and spasticity are common secondary symptoms in CP affecting gait, positioning, and everyday functioning. The prevalence of reduced muscle length and higher spasticity level increased with higher gross motor function classification system (GMFCS) level. Range of motion decreased most rapidly before 10 years of age. Passive range of motion continues to decrease to 30 years of age, most pronouncedly for knee extension. The passive dorsiflexion decreased rapidly until the age of 5 years. Conversely, spasticity reaches its peak at a younger age at 5–7 years of age, with a more notable occurrence observed in the gastro-soleus compared with the hamstrings. Less than 50% of individuals had spasticity corresponding to modified Ashworth scale 2–4 at any age. Both hamstring length and knee extension continued to decrease from early childhood to adulthood. The median hamstring length continued to decrease for all GMFCS levels up to adulthood. At the age of 15 years, all GMFCS levels had a median hamstring range of motion < 140°. Knee extension also decreased from childhood to adulthood. Regarding mean range of motion, all GMFCS levels had a median knee extension < 0° from 13 years of age [26].

In diplegia spastic hip flexors and hamstrings combine to flex the knee, causing the ground reaction force to pass behind it and produce a flexion moment. With compromise of the hip extensors and quadriceps muscle, gravity and fatigue force the child into a progressive crouch gait pattern. A flexion deformity of the knee is the inability to fully straighten or extend the knee, also known as flexion contracture. Normal active range of motion of the knee is 0° extension and 140° flexion. An accurate definition of this would be limited knee extension range both actively and passively. It develops as a result of failure of knee flexors i.e. hamstrings muscle to lengthen in tandem with the bone, especially when there is inadequate physical therapy [22, 27].

5. Instrument assisted soft tissue mobilization

Instrument assisted soft tissue mobilization is a skilled myofascial intervention used for soft-tissue treatment that includes the use of specialized tools to manipulate the skin, myofascia, muscles, and tendons by various direct compressive stroke techniques. It is based on the principles of James Cyriax cross-friction massage. A working description such as this may provide a clear understanding of the intervention and may prevent confusion between IASTM and other similar models with specific multimodal treatment protocols such as Graston® and augmented soft tissue mobilization (Astym). Thus, IASTM was described as a tool technique only and then name a specific model if the technique is used in conjunction with other predetermined interventions (stretching, exercise, other modalities, etc.) as guided by the teachings of the instructing body/company [28].

IASTM can be made from varying materials including stainless steel, titanium, plastic, buffalo horn, stone, quartz, and jade. The most common IASTM instruments used are stainless steel with bevelled edges and contours that can conform to different body anatomical locations and allows for deeper penetration. Also it vary in design. The instrument applies a longitudinal pressure along muscle fibers. The instruments allow the clinician to detect altered tissue properties via mechanical vibration within the instrument and to facilitate patient awareness of altered sensations in the treatment area [4, 29].

IASTM is a simple and practical technique. Because the surface of the instrument minimizes the force used by the practitioner, but maximizes the force delivered to the tissues, it is possible to stimulate points of adhesion located in deep areas. The levels of discomfort and fatigue experienced by therapists who treated patients with IASTM were significantly lower than the levels in therapists treating their patients using the metal end of a reflex hammer. Moreover, IASTM has another advantage of being able to produce

positive effects in a much shorter period than friction massage, another mode of soft tissue therapy, which requires 15–20 min [4, 30].

Meanwhile, the side effects that may appear from IASTM include bruising and soreness. In particular, bruising is a response that appears together with bleeding and occurs more readily in soft tissues that have been injured for a longer period of time. Bruising and soreness can be controlled with cryotherapy, following IASTM. In addition, there are relative and absolute contradictions to IASTM. Relative contradictions include cancer, kidney dysfunction, pregnancy, rheumatoid arthritis, varicose veins, osteoporosis, lymphedema, fracture, chronic regional pain syndrome, and use of certain medications (e.g., anticoagulants, steroids, or nonsteroidal anti-inflammatory drugs). Absolute contradictions include the presence of an open wound, unhealed suture sites, thrombophlebitis, uncontrolled hypertension, skin infection, hematoma, myositis ossificans, and unstable fractures [31].

The IASTM treatment is believed to promote connective tissue remodeling by encouraging the removal of unnecessary fibrosis. It also promotes collagen repair and regeneration as a result of fibroblast recruitment. It has been reported that IASTM ultimately allows the clinician to cause micro-trauma in a more precise and localized fashion when compared with manual massage. It is generally believed that this micro trauma initiates Type-1 collagen synthesis and re-alignment via a prostaglandin mediated pathway. It was found to be better at improving tissue fiber alignment and enhancing immediate blood flow. When a stimulus is applied to the injured soft tissue using an instrument, the activity and the number of fibroblasts increase, along with fibronectin, through localized inflammation, which then facilitates the synthesis and realignment of collagen is one of the proteins that makes up the extracellular matrix [28].

The effects of IASTM may provide an ideal environment for resolution of injury and promotion of functionality. It is important to understand the effects of IASTM so it may be used effectively in treating soft tissue injury with sufficient knowledge of how IASTM affects the body, it may become a major tool for maintaining performance and treating common pathologies in active populations [32].

Some studies have reported that IASTM can reduce pain caused due to sports injury and improve soft tissue function and joint range of motion [33, 34, 35]. **Howitt *et al.*** [33] reported that when applied to an athlete who had suffered an acute grade 1 strain in the tibialis posterior muscle, IASTM was able to reduce pain, while **Schaefer and Sandrey** [35] indicated that IASTM improved ankle range of motion in high school athletes with chronic ankle instability. Moreover, **Miners and Bougie** [34] also reported that IASTM helped improve soft tissue function in ordinary people with chronic Achilles tendinopathy resulting from persistent running.

A study by **Ge *et al.*** [36] found the IASTM changes local temperature and has an effect on two-point discrimination and pressure pain threshold. So it has a neurophysiological effect as it stimulates mechanosensitive neurons through skin deformation by the instrument. Mechanosensitive neurons include mechanoreceptors which are responsible for two-point discrimination and mechano-nociceptors which are responsible for pain perception.

Studies has indicated the use of IASTM for improving range of motion in upper and lower extremities [32]. **Laudner *et al.*** [37] conducted a study using Graston technique of IASTM on posterior shoulder muscles and demonstrated an increase in the range of motion on glenohumeral internal rotation and horizontal adduction. **Ikeda *et al.*** [38] found that a 6-week IASTM program improved ankle dorsiflexion range of motion and increased maximal passive torque during dorsiflexion range of motion measurement.

IASTM is a promising treatment approach for CP children. A study by **Miller *et al.*** [39] showed that the use of Astym therapy in addition to a traditional therapeutic treatment protocol resulted in considerable gains in functional gait with active ankle dorsiflexion, lower extremity flexibility, and gross motor development in the spastic diplegic CP patient. The 9-month treatment period also showed positive functional changes, such as elimination of ankle-foot orthoses use and decreased need for aid support for

school activities. These results suggest that Astym therapy can play an important role in a comprehensive physical therapy plan of care seeking to alleviate musculoskeletal performance limitations associated with CP.

A study by **Scheer *et al.*** [7] concluded that the clinicians should consider the use of Astym therapy in treating musculoskeletal soft tissue dysfunction in pediatric patients with CP as it successfully achieve gains in flexibility and strength and allow for improved function of bilateral lower extremities. At the end of treatment, the patient demonstrated improved resting muscle tone in bilateral lower extremities with active 90/90 hamstring flexibility measured at 165° and ankle dorsiflexion active range of motion of 5° without pain at 0° and 90° knee flexion. The patient exhibited an improved gait pattern with even stride length and diminished genu recurvatum, decreased pain with standing and walking, discontinued use of ankle–foot orthoses, and improved activity tolerance and overall function for daily activities.

A study by **Mostafa *et al.*** [3] showed that after the application of four sessions of IASTM in addition to the physical therapy program, the children with diplegic CP reported an improvement in hamstring flexibility. Another study by **Arun Selvi *et al.*** [40] reported a potential efficacy of both soft tissue manipulation and IASTM in addressing calf muscle tightness in children with spastic CP. The reduction in calf muscle spasticity and the improvement of ankle dorsiflexion range of motion were more after the application of IASTM.

Current research suggests IASTM has some positive effects for children with CP. In summary, it was found that IASTM can improve gastrocnemius and hamstrings flexibility and increase active ankle dorsiflexion, to help improve functions. With limitations in range of motion, the body may compensate or adapt to these changes. Sufficient joint range of motion is needed for optimal musculoskeletal function and insufficient flexibility can make one become vulnerable to injuries. Therefore, having sufficient range of motion is important for improving performance, in addition to the rehabilitation a prevention of injury. However, it is still unclear as to which extent structural and functional changes in soft tissues induced by IASTM can induce effect on long run. Therefore, it is necessary to verify these aspects through long-term observations.

6. Conclusion

Cerebral palsy is a chronic motor disorder that various efforts failed to prevent its occurrence. In most cases, the cause is unknown and prematurity remains the commonest risk factor. Spastic diplegia is one of the most common clinical subtypes of CP. Diplegia is characterized by muscle hypertonia of the pyramidal type, with lower limbs are more affected than upper limbs. Spasticity of the hip flexors and hamstrings combine to flex the knee causing flexion deformity of the knee which is the inability to fully straighten or extend the knee, causing adhesions to the soft tissues. IASTM refers to a technique that uses an instrument to remove scar tissue and adhesions that had formed in soft tissues and assists in the healing process by activating fibroblasts. IASTM encompasses a broad range of manual therapy techniques according to previous studies it is used to treat soft tissue deficiencies, reduce pain and inflammation, help improve flexibility, mobility, functional range of motion, and corresponding functional task completion. It is simple and practical and requires only a short period of time for a single treatment. Such positive effects can be helpful in the fields of pediatric physical therapy. Thus, the application of IASTM may provide a more effective solution for improving flexibility and range of motion to the knee joint in diplegic children by increasing blood flow to the muscles around knee and connective tissue remodeling.

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