Chapter

Orthoses in Conservative Management of Cerebral Palsy and Rehabilitation

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Abstract

Cerebral palsy is the developmental and postural disorder that combines a group of conditions/disease (neuromuscular), occurs in the developing fetal or infant brain, affects movement and intelligence that are ascribed to non-progressive disturbances. Orthotics is the branch of modern health science and rehabilitation that deals with assessment, prescription, fabrication, fitment, and purposeful gait training to the individual who needs orthosis for optimal independence. Orthoses are external devices that applied to increase function, prevent contracture and deformity, maintain the limbs in a functional position, stabilize the segments of the body, support the weak muscle and its functions, increase motor control, reduce spasticity, protect the limbs, and body segments in the postoperative condition.

Keywords: orthosis, orthotics, cerebral palsy, rehabilitation, conservative management

1. Introduction

Cerebral palsy is the developmental and postural disorder that combines a group of conditions/disease (neuromuscular) that occurs in the developing fetal or infant brain, affecting movement and intelligence that are ascribed to non-progressive disturbances [1]. The prevalence of Cerebral Palsy (CP) all over the world reported a range from 1.5 to 4 per 1000 live births and the average birth prevalence is 2 (approx) per 1000 live births. The rate of prevalence observed varies along with the time and region. Now, the rate of CP is relatively stable. However, prematurity and its complication are still the reason for increased prevalence despite improved neonatal and obstetric care [2].

It is important to mention that the one-size-fits-all approach does not work on the population with cerebral palsy. The fitment must be total contact control over the forefoot, hindfoot and ankle to minimize/optimize the deviation in the planes of the foot. Skeletal alignment is the foundation to the operational success of the orthosis. Loosely fitted orthosis may cause discomfort, piston, skin breakdown and ultimately decreased function [3].

In the old world, the "Corpus Hippocraticum" mentions the first medical description of cerebral palsy, which was written by Hippocrates in his work. Nevertheless, it was emerged in the 19th century by William John Little; thus, Little was the first personality to intensely engage cerebral palsy. Two more stalwarts

William Osler and Sigmund Freud added historical hallmarks to cerebral palsy at the end of the 19th century. Since then the significant development has been done in the field of cerebral palsy [4]. William Little argued for the earliest possible diagnosis and intervention in the early stages [5].

The environmental access and daily activities in children with CP are restricted due to the development of secondary complications. However, orthoses play an important role in managing and maintaining posture and balance. The purpose of orthotic treatment is to assist function and gait through correction, prevention and providing the base of support [6]. Orthotics is the branch of modern health science and rehabilitation science that deals with assessment, prescription, fabrication, fitment, and purposeful gait training to the individual who needs orthosis for optimal independence [7]. Orthosis is used to preserve the result of surgical procedures during rehabilitation and prevent reoccurrence with growth. The clinician's poor prescription may lead to rejection of the device, complication to the child and psychological compromise to the family [8]. Ankle Foot Orthosis (AFOs) are used frequently in CP to improve function and prevent contractures and have been found to improve walking speed and energy cost [9]. The hinged AFOs results favor the orthotic implication to the CP child by reducing oxygen demand and ventilator cost [10]. The gait laboratory research suggests that there is an indirect effect of orthosis on the joints of limbs and negative effects can be optimized by the appropriate intervention of the orthosis [11].

2. Risk factors

Children's risk of being born/identified with cerebral palsy may increase due to some medical condition that happens during pregnancy, delivery and post-delivery. These may be categorized as follows:

2.1 Congenital cerebral palsy

This happens before or during birth, damages the brain. In many cases the specific causes are unknown and 80–90% of cases generally found are of congenital cerebral palsy. Some causes increase the chance of a child developing cerebral palsy. Although, it is clear/important that having a risk factor does not confirm that child will have cerebral palsy. Risk factors for Congenital CP areas:

- Low birth weight
- Premature birth
- Multiple births
- Assisted reproductive technology (ART) infertility treatments
- Infections during pregnancy
- Jaundice and kernicterus
- Medical conditions of the mother
- Birth complications

- Blood type incompatibility between mother and child
- Exposure to toxic substances
- Breech presentation
- Small for gestational age

2.2 Acquired cerebral palsy

Nearly 10% of diagnosed cases of cerebral palsy in children are considered to be of acquired cerebral palsy caused by damage that occurred in the brain, post-birth. It is accompanied by infection or head injury. The risk factors for acquired cerebral palsy are:

- Preterm or low birth weight
- Brain infections
- Injury
- Infancy
- Not getting certain vaccinations

3. Classification

Cerebral Palsy causes functional limitations that lead to disorders of motor and postural development ascribed to non-progressive disorders that happen in fetal development or the child's brain [12]. It has been classified mainly into three categories viz. Physiological, Topographical and Functional classification system, includes Gross Motor Function Classification System (GMFCS), the Manual Ability Classification System (MACS), the Communication Function Classification System (CFCS), and the Eating and Drinking Ability Classification System (EDACS) which are complementary to each other.

3.1 Physiological classification of cerebral palsy

I. Spastic—Increased muscle tone in one or more limbs is the primary characteristic. Spastic cerebral palsy is the most common among CP children. It can be unilateral, bilateral, quadrilateral, or hemiplegic [13].

II. Athetotic—It is characterized by the involuntary movement of the affected child and can be recognized in the early days. Hammond described it in 1870 [14].

III. Rigidity

IV. Ataxic

V. Tremor

VI. Atonic

VII. Mixed

VIII. Unclassified [15]

3.2 Anatomical/topographical classification (according to the motor deficit) of cerebral palsy

- Hemiplegia—A condition that causes paralysis of half of the body leads to weakness and lack of muscle control.
- Paraplegia—It is motor or sensory impairment that causes loss of function and control over lower limbs or other two limbs.
- Tetraplegia—It is the partial or complete loss of all 4 limbs. Also, known as quadriplegia.
- Triplegia—It's a condition of lack of control or paralysis of three limbs.
- Monoplegia—There is a lack of control of one limb.

Paraplegia is the commonest one followed by hemiplegia and tetraplegia stands third [16].

3.3 Functional classification system for cerebral palsy

The functional classification system is categorized into four types which are as follow;

3.3.1 Gross motor function classification system (GMFCS)

It is the most recognized and established functional classification for Cerebral Palsy. It narrates the gross motor function of the children with cerebral palsy based on an ordinal five-step classification system. GMFCS considers the developmental milestones according to child's age up to 18 years.

GMFC level I: Individuals able to walk without limitations.

- Less than 2 years can crawl on knees and hands, pull to stand, and are able to attain independent walking between 18 months to 2 years.
- Between 2 to 4 years of a child are able to sit properly and started sitting to standing transition independently.
- Between 4 and 6 years, the individual should able to walk independently indoors and outdoors, start to run and jump, and climbing stairs.
- Between age 6–12 years, they may develop skills and abilities to walk up and down the curbs, walk community distances.
- Between 12 and 18 individuals in GMFCS I show the capability as of aged 6–12 years old.

GMFC level II: Individuals walk with limited endurance and balance with the help of orthoses or assistive devices.

- Before age of 2 children may need body support to sit or stand.
- Between 2 and 4 years, GMFCS II level child may start sitting without support and walk with device support.
- Between 4 and 6 years, they can shift into and out of standing without assistance. Walk indoors without the support and climb up and down the stairs with a railing. However, they cannot jump or run.
- Between 6 and 12 years, children are able to walk on all terrains with certain limitations and need assistive devices or wheeled mobility for long distances.
- Between 12 and 18 years show the same features as of age 6–12 and devices may be required for more safety and support.

GMFC level III: Children categorized under GMFC III can walk indoors with the help of assistive devices. However, community mobility needs wheeled devices.

- Below 2 years, can crawl and roll, if posing in the prone position and sit with device support.
- Between 2 and 4 years, the child can "W" sit on the floor with assistance and may stand and walk with the help of handled mobility devices.
- Between 4 and 6 years, GMFC III level categorized child can sit in a chair with adequate support to achieve some upper limb function. Stairs climbing needs assistance and community activity requires wheeled devices respectively.
- From 6 to 18 years the child's remain need assistance to negotiate the stairs and wheeled mobility is required to perform major ADL (Activity of Daily Living) in the community.

GMFC level IV: In this category self-mobility is limited but can sit with appropriate support. Preferable mobility options are manual or motorized devices.

- Within 2 years, the child can control their head and may need support to sit.
- Between 2 and 4 years, the child can sit with and stand with appropriate adaptive devices and reciprocal gait movement is generally absent.
- Between 4 and 6 years, children need assistive devices to control the trunk, and sit and wheeled mobility is ideal for community movement.
- Between 6 and 12 years, the child may walk with assistance and can do floor mobility with crawling and rolling.
- From 12 to 18 years, GMFC IV shows the same features as of 6–12 year old.

GMFC level V: Power wheeled mobility is possible for self-mobility.

- Below 2 years cannot control head and trunk and assistance is needed for crawling.
- Between 2 and 4 years, a child needs a manual mobility device for mobility.
- After 4 years, the GMFCS V type needs complete assistance in transfer and mobility.

3.3.2 Manual ability classification system (MACS)

It is used in children ages 4 to 18 years, developed by Eliasson et al. in 2006. MACS is used for hand and upper extremities based on a five-point ordinal classification system.

MACS I—Individuals can perform the activities independently with minimal or no limitations in case of heavy/fragile objects.

MACS II—Individuals remain independent in daily activities with slower and decreased performance. They may use different ways to handle the objects and perform the activities.

MACS III—Individuals categorized under MACS III may need support or set-up for the activities. They can perform some activities independently and some activities remain requires assistance to be carried out.

MACS IV—Individuals can not be able to complete the task or activities and depends on adaptive devices and continuous assistance to perform the activities.

MACS V—The individuals categorized in MACS V are unable to handle the objects independently. They depend totally on assistance and can perform simple movement.

3.3.3 Communication function classification system (CFCS)

It is a valid measure to assess everyday communication in Cerebral palsy. It is also a five-scale ordinal classification system.

CFCS I—Individuals are "effective sender and receiver with unfamiliar and familiar partners" and they can communicate easily with familiar and unfamiliar partners.

CFCS II—In comparison to CFCS I, they communicate at a slower pace with familiar and unfamiliar partners. But, effective in sending and receiving communication.

CFCS III—Individuals are effective communicators with familiar partners. But, due to decreased intelligibility, they can not communicate effectively with unfamiliar partners.

CFCS IV—They can not communicate regularly to familiar partners. Some may communicate occasionally.

CFCS V—Individuals categorized under CFCS V rarely communicate effectively with familiar partners. They regularly have ineffective communication [17].

4. Gait patterns in cerebral palsy

The gait patterns ideally vary as per the limb involvement and orthotic treatments take place [18]. The common gait patterns of cerebral palsy that affect the movement and posture can be classified into the following categories based on the sagittal plane kinematics;

A. Unilateral spastic CP

B. Bilateral spastic CP

In 1987 Winters et al. classified the gait pattern in spastic hemiplegia. They classified it into four types based on sagittal plane kinematics, which is widely accepted.

Type I – There is drop foot deformity. In the swing phase ankle goes in plantarflexion (PF) while exhibiting adequate dorsiflexion in the stance phase. Management may be needed is a leaf spring or hinged ankle-foot orthosis (AFO).

Type II – It shows tenacious plantarflexion during the stance and swing phase. It is true equines due to contracture or spasticity of gastro-soleus muscles. Further, it can be classified into equinus with the knee in neutral and hip extension, and equines with the knee in recurvatum and hip extension.

Type III – Quadriceps/or hamstring weakness results in reduced knee extension and leads to stiff knee gait during the swing phase. In addition to that, gastro-soleus spasticity causes impaired dorsiflexion in the swing phase.

Type IV – It is characterized by ankle plantarflexion, knee contracture/or restricted knee and hip internal rotation and adduction with limited flexion and extension [19–21].

In Bilateral Spastic CP four main groups were identified based on the ankle, knee, hip, and pelvis kinematics in the sagittal plane proposed by Rodda and Graham [22, 23]. The contractures in one and more joints, imbalance muscle action and muscle spasticity cause gait difficulty in CP. As per evidence observed, mainly four types of gait deformity of the knee have been identified. These are jump knee, crouch knee, stiff knee, and recurvatum knee. The most frequent gait abnormalities occur in the sagittal plane [23].

4.1 Gait with equinus foot

Caused by Gastrosoleus spasticity and added recurvatum force the entire foot on toes tip. An orthotic device with 90-degree ankle dorsiflexion, knee extension can be used during the day and night hours post-surgery only.

4.2 Jump gait

Children with jump gait show the characteristic of equinus foot, genu flexum, and coxaflecta. Apart from gastrosoleous the spasticity of hamstring and psoas is common in such gait patterns. An orthosis may play an important role in conservative management.

4.3 Gait with apparent equinus

Patients show excessive flexion in the knee and hip which leads equinus gait. However, a normal range of dorsiflexion at the ankle is found.

4.4 Crouch gait

It is diagnosed by excessive dorsiflexion at the ankle and excessive flexion of the knee and hip joints. Conservative management in such cases aims to maintain posture, alignment, and balance [16, 24, 25].

5. Measures to prevent cerebral palsy

Genetics-related cerebral palsy is quite impossible to prevent, and in many cases, the circumstances of congenital cerebral palsy are not fully known and acknowledged. Hence, very little can be done and preventive measures can be taken pre and post-pregnancy to minimize the risk of developmental delays.

Before pregnancy

- Maintaining and improving the health condition of the mother.
- Proper vaccination before getting pregnant.
- Reducing the chance of multiple pregnancies, if opting for assistive reproductive technology (ATR)

During pregnancy

- Parental care training
- Reduce the risk of infection through maintaining hygiene
- Be in touch with the health care provider
- Maintain healthy pregnancy and take nutritious diet

After baby birth

- Keep the baby safe and healthy
- Check for jaundice in and after release from the hospital
- Proper vaccination is needed
- Take preventive measures to prevent injury [26–28].

6. Orthotic management

CP is a "progressive neuromuscular deformity" characterized by static neurological deficit and motor function disorder. An understanding of medical consequences and deformities is essential for appropriate prognosis/diagnosis and conservative treatments. It has been observed that, if left untreated, progressive deterioration and disastrous changes in function and gait pattern arise over time. However, the treatment protocols have been changed drastically during the past 50 years, and the cerebral palsy patient is probable survival in contrast to the general population with appropriate health care and orthotic management [29]. Cerebral Palsy impairments result in difficulty in movement, coordination, and balance. Hence, developing treatment plans in such a complex condition is a challenge to promote the health of the child [30]. To maintain the physical well-being in cerebral palsy, orthoses impart/play an important role. The main aim of orthoses implication is to correct, prevent, provide a base of support, and to improve skills and efficiency in movement and function in the lower limb. However, orthoses manage postural impairment in trunks and upper limbs [31].

6.1 Orthotic management of lower limb

The main aim of orthotic management in the lower limb in an individual with cerebral palsy is to "correct/or prevent the deformity, to provide sufficient base of support, to provide skill training, and to improve gait pattern. The implication ultimately results in improved Range of Motion (ROM) and level of function. It also

helps in maintaining muscle length to bone growth and minimize the secondary effects of the disability [32]. However, orthoses prescribed to correct or prevent the deformities may force some activity limitations by controlling movement [31].

The kinds of orthosis use in the lower limb of cerebral palsy are-as;

1. Foot orthosis (FO)

   Foot orthosis provides a stable base of support. However, it does not interfere with or corrects the deformity.

2. Supra malleolar orthosis (SMO)

   Supra malleolar orthosis may be used to manage foot deformity. Foot management follows the principles of biomechanics, inhibition and facilitation. These biomechanical principles of supra malleolar orthosis must allow the normal pronation and supination to achieve forward movement and normal elongation of the muscles [32]. Supra malleolar orthosis helps in subtalar alignment and gait pattern improvement in children with cerebral palsy and reduces the intensity of symptoms [33]. The supra malleolar orthosis (SMO) also controls midfoot inversion and increases dorsiflexion at the midfoot during the first part of the swing phase [34].

3. Ankle foot orthosis (AFO)

   The most predominantly used orthosis in the lower limb management of CP is AFO. It is used to improve gait patterns, promote stance phase stability, ease swing phase clearance, and limit the contracture of the muscles [35].

4. Floor reaction orthosis (FRO)

   This orthosis is widely used if the child is having crouch gait patterns, which indicate ankle dorsiflexion with increased knee and hip flexion. FROs are also improved postural balance and support the muscles to develop the ability to control the body's Centre of Mass (COM). FROs help in altering the Ground Reaction Forces (GRF) in the sagittal plane and promote external knee extension. Also, it limits the ankle dorsiflexion [36].

5. Knee ankle foot orthosis (KAFO)

   In cerebral palsy Knee Ankle Foot Orthosis (KAFO) is used to maintain posture in standing and during gait training [37]. It is also used to prevent the ankle-foot range of motion in spastic cerebral palsy (SCP) cases [38] and presumed to reduce ankle dorsiflexion ROM at maximum knee extension when applied to six or more than six hours by reducing the muscle-tendon complex stiffness [39].

6.2 Upper limb orthotic management

For an Orthotist, management of spasticity, deformity and contractures in the upper extremity are challenging tasks, as the treatment modalities, intervention and objectives differ according to each child [40]. To maintain the joint's position, the static splint is designed and used to stabilize the joints and restrict further deformity. It has shown positive effect if used for a long time. However, prolonged use may cause muscle atrophy and a decrease in muscle function [41]. In

comparison, the dynamic splints allow a larger range of motion against resistance and prevent contracture and deformity [42]. Clinicians may use casting of the upper extremity to decrease the tone and improve ROM and increase the muscle length [43]. The opponens hand splint, the hand sandwich, and the Australian splint are used frequently to manage the contracture and deformity. Also, elbow and shoulder orthosis have evidence of correcting flexion and rotation of the elbow and arm [44].

6.3 Trunk orthotic management

In general cerebral palsy children do not born with any form of spinal deformity and such things appear with increasing body weight and age. Later on, this may cause respiratory dysfunction and loss of survival [45]. Postural alignment is the major challenge in cerebral palsy children. Prevalence ranges from 15 to 61% with dominance in male children. Spinal deformity increases with age, non-ambulation, spasticity, and muscle weakness [46]. Though the orthotic goal depends on the child's individual needs, the spinal treatment objective is to improve stability/positioning, promote arm and hand function, improve head control, prevent deformity, and improve overall functioning [47]. Some evidence shows that the use of braces may de-accelerate the deformity curve progression in a CP child, proves the technique of conservative management. However, solid evidence is not yet available that spinal braces minimize the rate of surgery [47–49]. The improvement of sitting control and modification in curve progression is the main objective of the conservative management of spinal deformity in cerebral palsy [50]. The improvement in sitting and postural balances was found satisfactory, and a remarkable spinal correction was observed using a 3-point force system with the placement of lateral pads [48]. The nonoperative stable support promotes an upright posture that reduces pain and frees the upper extremity for functional utilization [51]. Braces like Boston, Charleston, Milwaukee, Rosemberger, Wilmington, etc. might be useful to support the cause [52].

7. Discussion

The need for orthotic devices differs among the children with cerebral palsy as the clinical needs vary widely. To optimize the children's motor function and gait a wider range of treatment modalities and interventions are required [53]. The implication of supra malleolar orthosis (SMO) may be suitable for controlling deformities like varus or valgus of the foot. It controls sagittal motion during the swing phase with remarkable mid-foot and forefoot kinematic differences [34]. The AFOs are much helpful in achieving ankle stability that impacts trunk motion and promotes body parts coordination, eliminate flexible spasticity and pathological reflexes [54]. Optimistic results of AFOs intervention are observed on energy expenditure, gait kinetics and spatial–temporal kinematic parameters [54, 55]. However, the user's level of deformity and severity may give varied results in controlling movement, posture and adaptation [56]. The children facing the neuro-biomechanical challenge in controlling knee and hip joints may benefit through the distinct AFOs [57]. A structured interview among the parents of Dynamic Ankle Foot Orthoses (DAFO) users about its efficacy reflects positive effects on postural balance and support in standing and sitting [58]. Also, it allows larger total ankle ROM than solid AFOs [59]. Correction of crouch gait pattern by Floor Reaction Ankle Foot Orthosis (FRAFO) of 17 degrees with a standard deviation of 5 degrees can be achieved. This may align knee and postural balance over a longer period [36, 60]. The higher degree of the knee and hip flexion contracture may be considered as a

contraindication to the prescription of FRAFOs; were found to restrict the effectiveness of orthosis in controlling knee extension in midstance [61]. The spinal orthosis may help the individual where surgery is not possible. It reduces the scoliotic progression by limiting the deforming forces on the spine and reduces the need for surgery in some cases. Improved head control and social interaction can be achieved with the help of appropriate spinal orthosis [11]. If we study the upper limb orthotic intervention to the children with cerebral palsy, there is a lack of outcome evidence of treatment modality. It indicates the need for more research with vigorous methods to measure the effect of upper limb orthoses and its reliability [62]. According to the type of orthosis and severity of the condition, the orthosis applied to the children with cerebral palsy affects the gait pattern and postural support distinclty [63].

8. Conclusions

The orthotic device is part of the health care treatment in cerebral palsy children and it promotes children in maintaining joint, posture and muscle function. The different orthosis has its importance in optimizing functioning and minimizing complications through a stable base of support, improved gait, and reduces spasticity and fall. It helps in creating an accessible environment among children with cerebral palsy, reduces excess energy expenditure. The advancement in diagnosis procedures, development of scientifically proven orthotic devices to limit the primary and secondary impairments through research is the need of the hour. The transparent research on developed orthotic devices for larger number of CP children may create clear consensus on the efficacy.

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Conflict of interest

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References

[1] Cerebral Palsy. PM&R Knowledge now. 2020. Available from: https://now.aapmr.org/cerebral-palsy/

[2] Stavsky M, Mor O, Mastrolia SA, Greenbaum S, Than NG, Erez O. Cerebral palsy-trends in epidemiology and recent development in prenatal mechanisms of disease, treatment, and prevention. Front. Pediatr. 2017;5:1. Available from: www.frontiersin.org

[3] New approaches to orthotic management in children with cerebral palsy. Braceworks Custom Orthotics. 2021. Available from: https://braceworks.ca/2016/08/30/devices/lower-limbs/afo/new-approaches-to-orthotic-management-in-children-with-cerebral-palsy/#Recent-developments-in-healthcare-for-cerebral-palsy

[4] Panteliadis C, Panteliadis P, Vassilyadi F. Hallmarks in the history of cerebral palsy: From antiquity to mid-20th century. Brain Dev. 2013;35:285-292. Available from: http://www.brainanddevelopment.com/article/S0387760412001179/fulltext

[5] Velde, Morgan, Novak, Tantsis, Badawi. Early diagnosis and classification of cerebral Palsy: An historical perspective and barriers to an early diagnosis. J. Clin. Med. 2019;8:1599.

[6] Morris, Christopher SO. Orthotic Management of Children with cerebral Palsy: Journal of Prosthetics and Orthotics. 2002;150-158. Available from: https://journals.lww.com/jpojournal/Fulltext/2002/12000/Orthotic_Management_of_Children_with_Cerebral.5.aspx

[7] Kumar A. Vinita. Current status of prosthetic and orthotic rehabilitation Services in India: Its issues and challenges. Front. Heal. Informatics 2021;10:55. Available from: http://ijmi.ir/index.php/IJMI/article/view/258

[8] Indications for orthoses to improve gait in children with Ce. Journal of the American Academy of Orthopaedic Surgeons. 2021. Available from: https://journals.lww.com/jaaos/Fulltext/2007/03000/Indications_for_Orthoses_to_Improve_Gait_in.8.aspx

[9] Wingstrand M, Hägglund G, Rodby-Bousquet E. Ankle-foot orthoses in children with cerebral palsy: A cross sectional population based study of 2200 children. BMC Musculoskelet. Disord. 2014;15:327. Available from: http://bmcmusculoskeletdisord.biomedcentral.com/articles/10.1186/1471-2474-15-327

[10] Maltais D, Bar-Or O, Galea V, Pierrynowski M. Use of orthoses lowers the O2 cost of walking in children with spastic cerebral palsy. Med. Sci. Sports Exerc. 2001;320-325.

[11] College W, Morris C, Condie D, Fisk J. Recent Developments in Healthcare for Cerebral Palsy: Implications and Opportunities for Orthotics Report of a Meeting. 2008.

[12] Iara Pfeifer L, Baleroni Rodrigues Silva D, Araújo Rodrigues Funayama C, Lício Santos J. Classification of Cerebral Palsy Association between Gender, Age, Motor Type, Topography and Gross Motor Function. 2009.

[13] O'Shea TM. Diagnosis, treatment, and prevention of cerebral Palsy. Clin. Obstet. Gynecol. 2008;51:816-828. Available from: https://journals.lww.com/00003081-200812000-00019

[14] Foley J. Occasional review the athetoid syndrome. A review of a personal series. Neurosurgery, and Psychiatry 1983;46:289-298. Available from: http://jnnp.bmj.com/

[15] Minear WL. A Classification of Cerebral Palsy. 2021. Available from: https://pediatrics.aappublications.org/content/pediatrics/18/5/841.full.pdf

[16] Dana TUGUI R, Antonescu D, Raluca Tugui D. Maedica. Journal of Clinical Medicine Cerebral Palsy Gait, Clinical Importance. 2013.

[17] Andrea Paulson JVA. Overview of four functional classification systems commonly used in cerebral Palsy. Children 2017;4:30. Available from: https://chrome-extension://dagcmkpagjlhakfdhnbomgmjdpkdklff/enhanced-reader.html?pdf=https%3A%2F%2Fbrxt.mendeley.com%2Fdocument%2Fcontent%2Fa66ca803-847e-3450-a8f3-c47428463516

[18] Armand S, Decoulon G, Bonnefoy-Mazure A. Gait analysis in children with cerebral palsy. EFORT Open Rev. 2016;1:448-460. Available from: http://online.boneandjoint.org.uk/doi/10.1302/2058-5241.1.000052

[19] Winters TF, Gage JR, Hicks R. Gait patterns in spastic hemiplegia in children and young adults. J. Bone Jt. Surg. - Ser. A 1987;69:437-441.

[20] Tsitlakidis S, Horsch A, Schaefer F, Westhauser F, Goetze M, Hagmann S, et al. Gait classification in unilateral cerebral Palsy. J. Clin. Med. 2019;8:1652. Available from: https://pmc/articles/PMC6832635/

[21] Classification of Gait Patterns in Cerebral Palsy. Physiopedia. 2021. Available from: https://www.physiopedia.com/Classification_of_Gait_Patterns_in_Cerebral_Palsy#cite_ref-Winters_5-0

[22] Rodda J, Graham HK. Classification of gait patterns in spastic hemiplegia and spastic diplegia: A basis for a management algorithm. Eur. J. Neurol. 2001;8:98-108. Available from: http://doi.wiley.com/10.1046/j.1468-1331.2001.00042.x

[23] Sutherland DH, Davids JR. Common gait abnormalities of the knee in cerebral palsy. Clin. Orthop. Relat. Res. 1993;139-147. Available from: http://www.ncbi.nlm.nih.gov/pubmed/8458127

[24] Armand S, Decoulon G, Bonnefoy-Mazure A. Gait analysis in children with cerebral palsy. EFORT Open Rev. 2016;1:448-460. Available from: http://online.boneandjoint.org.uk/doi/10.1302/2058-5241.1.000052

[25] Classification of Gait Patterns in Cerebral Palsy. Physiopedia. 2021. Available from: https://www.physiopedia.com/Classification_of_Gait_Patterns_in_Cerebral_Palsy

[26] Causes and Risk Factors of Cerebral Palsy. CDC. 2020. Available from: https://www.cdc.gov/ncbddd/cp/causes.html

[27] Nelson KB. Causative Factors in Cerebral Palsy. 2008.

[28] Cerebral Palsy. Hope Through Research. National Institute of Neurological Disorders and Stroke. 2020. Available from: https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Hope-Through-Research/Cerebral-Palsy-Hope-Through-Research#3104_7

[29] KN V. Natural history of cerebral Palsy. In: Cerebral Palsy and Early Stimulation. Jaypee Brothers Medical Publishers (P) Ltd.; 2014. page 164-164. Available from: https://www.jaypeedigital.com/book/9789350903018/chapter/ch12

[30] Surveillance of cerebral palsy in Europe: A collaboration of cerebral palsy surveys and registers. Dev. Med. Child Neurol. 2001;42:816. Available from: http://doi.wiley.com/10.1017/S0012162200001511

[31] Morris C. Orthotic Management of Children with cerebral Palsy. J. Prosthetics Orthot. 2002;14:150-158. Available from: http://journals.lww.com/00008526-200212000-00005

[32] Nference C, Management B. International Society for Prosthetics and Orthotics.

[33] Vadivelan K, Manikandan T, Sivakumar VPR. Effect of orthotic subtalar alignment with Co-activation exercise for alteration in gait endurance in a child with cerebral Palsysingle case study. Int. J. Physiother. 2016;3. Available from: https://www.ijphy.org/index.php/journal/article/view/317

[34] Liu X-C, Embrey D, Tassone C, Klingbeil F, Marquez-Barrientos C, Brandsma B, et al. Foot and ankle joint movements inside orthoses for children with spastic CP. J. Orthop. Res. 2014;32:531-536. Available from: http://doi.wiley.com/10.1002/jor.22567

[35] Stott NS. Cerebral pals. In: Management of Chronic Conditions in the Foot and Lower Leg. Elsevier; 2015. page 214-250. Available from: https://linkinghub.elsevier.com/retrieve/pii/B978070204769500008X

[36] Bahramizadeh M, Mousavi ME, Rassafiani M, Aminian G, Ebrahimi I, Karimlou M, et al. The effect of floor reaction ankle foot orthosis on postural control in children with spastic cerebral palsy. Prosthetics Orthot. Int. 2012;36:71-76. Available from: https://journals.lww.com/00006479-201236010-00009

[37] Kwon SH, Lee BS, Lee HJ, Kim EJ, Lee JA, Yang SP, et al. Energy efficiency and patient satisfaction of gait with knee-ankle-foot orthosis and robot (ReWalk)-assisted gait in patients with spinal cord injury. Ann. Rehabil. Med. 2020;44:131-141. doi: 10.5535/arm.2020.44.2.131

[38] Maas JC, Dallmeijer AJ, Oudshoorn BY, Bolster EAM, Huijing PA, Jaspers RT, et al. Measuring wearing time of knee-ankle-foot orthoses in children with cerebral palsy: Comparison of parent-report and objective measurement. Disabil. Rehabil. 2018;40:398-403. Available from: https://www.tandfonline.com/doi/full/10.1080/09638288.2016.1258434

[39] Maas JC, Dallmeijer AJ, Huijing PA, Brunstrom-Hernandez JE, van Kampen PJ, Jaspers RT, et al. Splint: The efficacy of orthotic management in rest to prevent equinus in children with cerebral palsy, a randomised controlled trial. BMC Pediatr. 2012;12:38. Available from: https://bmcpediatr.biomedcentral.com/articles/10.1186/1471-2431-12-38

[40] Chin TYP, Duncan JA, Johnstone BR, Kerr Graham H. Management of the upper limb in cerebral palsy. J. Pediatr. Orthop. B 2005;14:389-404. Available from: http://journals.lww.com/01202412-200511000-00001

[41] Upper Limb Orthotics/Orthotic Intervention for Children with Cerebral Palsy, Wikiversity. 2021. Available from: https://en.wikiversity.org/wiki/Upper_Limb_Orthotics/Orthotic_Intervention_for_Children_with_Cerebral_Palsy

[42] Burtner PA, Poole JL, Torres T, Medora AM, Abeyta R, Keene J, et al. Effect of wrist hand splints on grip, pinch, manual dexterity, and muscle activation in children with spastic hemiplegia: A preliminary study. J. Hand Ther. 2008;21:36-43. Available from: https://linkinghub.elsevier.com/retrieve/pii/S089411300700155X

[43] Lannin NA, Novak I, Cusick A. A systematic review of upper extremity casting for children and adults with central nervous system motor disorders. Clin. Rehabil. 2007;21:963-976.

Available from: http://journals.sagepub.com/doi/10.1177/0269215507079141

[44] Stamp WG. Bracing in Cerebral Palsy.

[45] SATO H. Postural deformity in children with cerebral palsy: Why it occurs and how is it managed. Phys. Ther. Res. 2020;23:8-14. Available from: https://www.jstage.jst.go.jp/article/ptr/23/1/23_R0008/_article

[46] Morrell DS, Pearson JM, Sauser DD. Progressive bone and joint abnormalities of the spine and lower extremities in cerebral Palsy. Radio Graphics 2002;22:257-268. Available from: http://pubs.rsna.org/doi/10.1148/radiographics.22.2.g02mr19257

[47] Pettersson K, Rodby-Bousquet E. Prevalence and goal attainment with spinal orthoses for children with cerebral palsy. J. Pediatr. Rehabil. Med. 2019;12:197-203. Available from: https://www.medra.org/servlet/aliasResolver?alias=iospress&doi=10.3233/PRM-180596

[48] Terjesen T, Lange JE, Steen H. Treatment of scoliosis with spinal bracing in quadriplegic cerebral palsy. Dev. Med. Child Neurol. 2000;42:S0012162200000840. Available from: http://doi.wiley.com/10.1017/S0012162200000840

[49] James WV. Spinal bracing for children with atonic cerebral palsy

[50] Cloake T, Gardner A. The management of scoliosis in children with cerebral palsy: A review. J. Spine Surg. 2016;2:299-309. Available from: http://jss.osspress.com/article/view/3684/4361

[51] Howard JJ, Sees JP, Shrader; M Wade. Current Concept Review Management of Spinal Deformity in Cerebral Palsy. 2019. Available from: www.jposna.org

[52] Zaina F, De Mauroy JC, Grivas T, Hresko MT, Kotwizki T, Maruyama T, et al. Bracing for scoliosis in 2014: State of the art. Eur. J. Phys. Rehabil. Med. 2014;50:93-110. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24622051

[53] Degelaen M. Effect of ankle–foot orthoses on motor performance in cerebral palsy. Dev. Med. Child Neurol. 2018;dmcn.14069. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/dmcn.14069

[54] Degelaen M, Leurs F, De Borre L, Kerckhofs E, De Meirleir L, Cheron G, et al. Effect of ankle-foot orthoses on gait in typically developing children: Developmental trend in segmental coordination. J. Pediatr. Rehabil. Med. 2010;3:163-170. Available from: https://www.medra.org/servlet/aliasResolver?alias=iospress&doi=10.3233/PRM-2010-0125

[55] Sukal-Moulton T, de Campos AC, Alter KE, Huppert TJ, Damiano DL. Relationship between sensorimotor cortical activation as assessed by functional near infrared spectroscopy and lower extremity motor coordination in bilateral cerebral palsy. Neuro Image Clin. 2018;20:275-285. Available from: https://linkinghub.elsevier.com/retrieve/pii/S2213158218302353

[56] Aboutorabi A, Arazpour M, Ahmadi Bani M, Saeedi H, Head JS. Efficacy of ankle foot orthoses types on walking in children with cerebral palsy: A systematic review. Ann. Phys. Rehabil. Med. 2017;60:393-402. Available from: https://linkinghub.elsevier.com/retrieve/pii/S1877065717300799

[57] Morris C, Bowers R, Ross K, Stevens P, Phillips D. Orthotic management of cerebral palsy: Recommendations from a consensus conference. Neuro Rehabilitation 2011;28:37-46. Available from: www.ispoint.org.

[58] Bjornson K, Zhou C, Fatone S, Orendurff M, Stevenson R, Rashid S. The effect of ankle-foot orthoses on community-based walking in cerebral Palsy. Pediatr. Phys. Ther. 2016;28:179-186. Available from: https://journals.lww.com/00001577-201628020-00009

[59] Lam WK, Leong JCY, Li YH, Hu Y, Lu WW. Biomechanical and electromyographic evaluation of ankle foot orthosis and dynamic ankle foot orthosis in spastic cerebral palsy. Gait Posture 2005;22:189-197. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0966636204001663

[60] Böhm H, Matthias H, Braatz F, Döderlein L. Effect of floor reaction ankle–foot orthosis on crouch gait in patients with cerebral palsy. Prosthetics Orthot. Int. 2018;42:245-253. Available from: https://journals.lww.com/00006479-201842030-00001

[61] Rogozinski BM, Davids JR, Davis RB, Jameson GG, Blackhurst DW. The efficacy of the floor-reaction ankle-foot orthosis in children with cerebral Palsy. J. Bone Jt. Surgery-America, 2009;91:2440-2447. Available from: http://journals.lww.com/00004623-200910000-00017

[62] Garbellini S, Robert Y, Randall M, Elliott C, Imms C. Rationale for prescription, and effectiveness of, upper limb orthotic intervention for children with cerebral palsy: A systematic review. Disabil. Rehabil. 2018;40:1361-1371. Available from: https://www.tandfonline.com/doi/full/10.1080/09638288.2017.1297498

[63] Kumar A. A prospective evaluation of orthotic device implication on the lower limb in children with cerebral palsy original scientific paper. Hum. Res. Rehabil. 2021;11:12-16.