Adaptive Standing in Early Intervention for Children with CP

BY ELENA NOBLE, MPT AND MICHELLE MEIER, PT, DPT

An infant's motor development begins long before birth with in-utero reflexive movements and activity in response to light, sound and touch to help the baby build strength and survive outside the womb. After birth the developmental journey becomes more visible with rapid acquisition of motor skills and cognition within the first few years. These early years are a critical time of development across cognitive, emotional and motor domains. Early active movement and environmental exploration drives development through the building of cortical connections in response to the movement.[1-5]

Infants with developmental challenges who lack early access to independent weight-bearing and mobility, with the associated opportunities to participate and interact with their environment, are unable to take advantage of this critical window of brain plasticity. This results in loss of function with increasing risk for secondary complications later on.[2-5] Through early and "on time" intervention, clinicians and parents take advantage of this critical developmental window to provide appropriate opportunities for young children to move, explore and develop.

Cerebral Palsy: Early Identification and Prognosis

Cerebral palsy (CP) is the most prevalent physical disability in childhood.[6] Although CP is non-progressive in nature, the associated neuro-motor characteristics affect early motor development and the acquisition of sitting, standing and walking skills, so early diagnosis is essential.

Most children with CP or at high risk for CP can be identified before six months of age using neuroimaging and sensitive assessment tools such as the Prechtl's General Movements Assessments (GMA) and the Hammersmith Infant Neurological Assessment (HINE).[2,7] The cut-off scores on the HINE before two years of age also provide a general estimate of the severity of a child's motor function using the five levels of the Gross Motor Function Classification Scale (GMFCS). Children in GMFCS Level I have independent function and ambulation capabilities whereas children in GMFCS Level V are non-ambulant and dependent for most functional activities.[2] However, only after two years of age can a GMFCS level be reliably determined, because in the first two years of life factors such as a late-onset spasticity, continued early development of motor skills, and neuroplastic responses to intervention have a significant impact on a child's motor function.[2]

The prognostic motor curves detailed by Rosenbaum and colleagues indicate that children across all levels of the GMFCS make rapid gains in motor function during the first two years of life, with 90% of skill acquisition occurring by age five.[8] This data provides parents and clinicians a means to understand the developmental path of their infant and plan interventions that are timely, appropriate and effective.

Early Intervention

Clearly intervention cannot start soon enough for infants with CP or those identified at high risk for CP to maximize the critical period of development.[1,9] A comprehensive

set of International Practice Guidelines provides us with a road map for best practice for this population.[1] These evidence-based guidelines describe early interventions for children from birth to two years old with and at high risk for CP across domains including motor, cognition, communication, sleep and musculoskeletal health. For the last of these domains—musculoskeletal health—the guidelines include a strong recommendation for adaptive standing. This is especially relevant for infants and children who are non-weight-bearing and therefore at additional risk for hip dysplasia. The guidelines suggest "regular use of standing equipment for positioning as part of an active intervention program, to potentially decrease hip migration percentage and maintain hip abduction range of motion." In the early intervention population, the benefits of standing certainly extend beyond two years of age with evidence continuing to point to adaptive standing improving hip health and positively impacting bone mineral density in children under five.[1,10-12]

Adaptive standing interventions ideally start at the time when weight-bearing would occur in typically developing age-matched children.[13] Infants often begin pulling to stand around nine months old, or even earlier in some cases and this is a time when differences in muscle growth and development become apparent.[10] According to the CDC's physical developmental milestones, most children will pull to a stand by one year of age.[14] This has implications for young children with CP whose assessment scores place them in the higher GMFCS Levels of IV or V indicating limited or no ability to bear weight, stand or walk. Providing an adaptive stander to these infants is strongly recommended to provide continued developmental experience and to delay or prevent the progressions of hip dysplasia, contractures and bone mineral loss.[13]

Hip Preservation

Children with CP are usually born with normal hip alignment, but abnormal forces on the joint due to motor delay and muscle imbalances can lead to skeletal distortion. Changes in the hips of children with CP indicative of hip instability are noticeable as early as 12 months of age.[15,16] Evidence tells us that in order for the hip to develop normally, the femoral head needs to be seated adequately in the hip socket before the age of five.[17,18] Weight-bearing and walking contribute to healthy development of the hip joint in children with CP.[16] As early hip instability combined with the inability to bear weight predisposes children with CP to painful hip dislocations and further immobility later in life, it is important to recognize and intervene in a timely manner.[13,15,19,20]

As part of a hip surveillance program indicated for all young children with CP, regularly scheduled radiographs are taken to monitor the migration percentage of the developing hip.[21-23] Migration percentage (MP) measures how much of the femoral head is exposed due to lack of coverage by the acetabulum of the pelvis. It is a strong and reliable predictor of hip instability and influences the decision to intervene.[15,16,20,21,24] Children with ambulatory CP are initially assessed for hip stability between 24 and 30 months of age, and those with non-ambulatory CP often as early as 12 months.[16,22,23]

Specifically, a migration percentage under 33% indicates a stable hip; for a child with hip migration greater than 33%, intervention is likely needed.[16] More than a seven % increase in MP over one year needs continued intervention, monitoring and a referral to orthopedics. Bilateral adductor iliopsoas tenotomies (AITs) are usually recommended when the MP exceeds 40% to correct the abnormal forces generated by the tight hip musculature.[12,16]

When indicated by migration percentage, and when provided at the right time and dose, weight-bearing intervention, along with botulinum toxin, early preventative surgery, and motor training, is part of a comprehensive and multidisciplinary program that can prevent hip dislocation.[20,21,24] In fact, if introduced around 12 months of age, adaptive standing in abduction appears effective at maintaining hip stability and maintaining hip range of motion in children with CP up to age five.[19,20] Young

children who stand in abduction after AITs demonstrate even greater improvements in hip stability.[19] This suggests that early weight bearing improves hip alignment, and that the acetabulum can adapt when the femoral head is positioned centrally. In later years, with increasing age, this adaptability may decrease.[24]

A further consideration for implementing adaptive standing for hip health is a child's ambulatory status. This is because the majority of children with CP who do not walk by the age of five go on to develop hip subluxation.[16] This additionally correlates with findings that children in the higher levels of the GMFCS, where independent weight-bearing and walking is limited, experience the highest incidence of hip subluxation and dislocation.[12,25,26]

Conversely, those children with CP who walked at least 10 steps unassisted by 30 months old did not need treatment for their hips by the age of five.[15,16] Assessing a child's ability to independently walk ten steps before the age of 30 months now helps clinicians decide whether or not to intervene with the provision of an adaptive stander.[12,15,16]

Assessment of ambulatory capability additionally includes considering four factors that predict independent ambulation for children with CP.[27] These are the ability to sit by two years of age, the absence of visual impairment, the absence of intellectual disability, and the absence of epilepsy or seizure. As these are strong indicators of independent ambulation, it is therefore possible to predict with reasonable accuracy which children with CP will likely ambulate independently.[27]

The potential for independent ambulation can be assessed as early as 12 months old when a child typically takes their first steps.[12] If at any point a child does not demonstrate good potential to walk ten steps and/or demonstrates negative predictors of ambulation such as the presence of epilepsy, seizure or visual impairment, the provision of an adaptive stander is indicated for the management of hip instability.[12,15,16,27]

When a stander is deemed appropriate for a child with CP, the following overall recommendations for positioning and dosing can be made. The child is placed in standing as close to vertical as possible to maximize weight bearing and with hips in maximum-tolerated abduction.[13,19,20,28] Recommendations for standing time and frequency are approximately one hour per day or at least seven hours per week with the goal being ten hours per week.[19,20]

Bone Mineral Density

Weight-bearing through adaptive standing can reduce osteopenia and improve bone mineral density. Children with CP are at risk for osteopenia, osteoporosis and fractures because of their predisposition to immobility along with poor nutritional intake and the use of anticonvulsants.[11,29-32] These risk factors are present even in early childhood and delay the rate of bone growth and development leading to a reduced bone mineral density as the child grows older.[11,29,32,33]

Overall, weight-bearing status is the risk factor that most likely correlates with bone mineral density.[30-32] In other words, children who cannot stand or walk will demonstrate lower levels of bone mineral density and strength compared to their peers or even other children with CP who are ambulatory.[30-32] Not surprisingly then, non-ambulant children with CP experience the highest rate of bone fractures.[11,29] Providing early opportunities for weight-bearing and ambulation for these children is best practice to increase bone mineral density, reduce osteopenia and fracture risk.[11,13,34-39]

Adaptive standing is an effective tool to implement weight-bearing programs. In fact, a total population study including children with CP under five years old demonstrated a four-fold reduction in fractures in those using standing devices.[11] In other cases, discontinuing standing programs for even a few months resulted in reductions in bone mineral density.[37,38,39]

Targeted research additionally indicates a weight-bearing or standing program for non-ambulant children with CP who have low bone density of the spine or femur.[12,35,36,40] Overall, best practice specifies that any infant with CP who is non-ambulant and presenting risk factors associated with low bone mineral density (low weight, history of prior fracture, on anticonvulsants, feeding difficulties) should begin a standing program in combination with other interventions that may address the risk factors of poor growth and fractures.[11-13,29,31,40]

Best practice also recommends that young children use adaptive standers in a position as close to upright as possible for the most beneficial weight-bearing.[12,41] Children with high tone may demonstrate more weight-bearing in the prone standing position while those with low or normal tone may achieve better weight-bearing results in the supine standing position.[41] Engaging in supported standing five days a week for a total of 60-90 minutes every day can improve bone mineral density in young children with disability.[13] Those children who can tolerate even longer periods in standing may experience additional improvements in bone quality and health.[10]

Range of Motion

Evidence behind adaptive standing for contracture management and maintaining range of motion for young children with CP remains limited. While the exact mechanisms of contracture development are not yet fully understood, we do know that passive manual stretching is inadequate to impact muscle length.[21,42,43]

The findings of an extensive scoping review examining supported standing in children with CP suggest that weight-bearing and activity contribute to maintaining muscle length in the developing child.[10] This is based on the premise that as muscle stiffness appears in children with CP around the time their peers begin walking and standing, then weight-bearing intervention introduced around nine to 18 months may contribute to reducing this muscle stiffness.[10] Studies indicate that infants and children who stand in hip abduction and extension as part of hip health protocols preserve this same range of motion and that older children with non-ambulant CP show improvements in hamstring range of motion as a result of a standing program.[19,20,44,45]

These initial findings offer a promising outlook that implementing an active standing program with an adaptive standing device from an early age, with intentional prolonged gentle stretch to the ankles, knees and hips, may potentially help to prevent developmental contractures.[10] One evidence-informed recommendation indicates that a standing program should be implemented for children at risk for hip flexion, hip adduction and knee flexion contractures who at the same time would benefit from a stander for bone mineral density or hip preservation.[12] Further research is needed to soundly recommend adaptive standing as a primary intervention for range of motion and contracture management in young children.[10,12]

Based on the available research, performing supported standing five days a week for approximately 45 minutes each day (or a minimum of 3.75 hours per week) is appropriate to address range of motion and spasticity management.[12,13] Regular adaptive standing, particularly through periods of rapid bone growth, may help to maintain or improve muscle length, thus preventing the loss of range of motion and the development of joint contracture.

Postural Management

Children with non-ambulant CP in GMFCS Levels IV and V have limited independent mobility and therefore spend much of their day in sedentary or reclined positions. Prolonged passive positioning in combination with the varying muscle tone frequently seen in this population places these children at risk for postural and skeletal asymmetries with associated respiratory issues, problems with skin integrity, impaired sleep, and pain.[46-49] Postural imbalances become apparent only after birth and, without intervention, can lead to hip dislocations before three years of age, scoliosis before the age of five, windswept

deformities at age ten as well as setting the stage for progressing secondary impairments later in life.[50-56]

Addressing postural imbalances at an early stage is vital towards preventing the progression of postural distortions and complications in at-risk children with CP.[46] Known simply as "postural management," this initiative seeks to provide comprehensive positioning opportunities for a child throughout the day and night to decrease secondary complications and improve function and energy. Components of a postural management program include adaptive seating, supported stepping, supported standing and night-time positioning. (Guidelines indicate that sleeping positioning systems should not be introduced before two years old.)[50]

Adaptive standing is an integral part of early postural management as weight-bearing activity maintains and improves hip integrity, bone mineral density and contributes to maintaining range of motion.[46,50,57] Additionally, supported standing offers an important change of position for children with CP during the day.[10,50] Recent evidence-informed clinical perspective on postural management for hip health in non-ambulant children with CP recommends supported standing programs start at nine months of age with infants standing in 10-15 degrees of abduction (20-30 degrees total) for at least one hour every day.[1,50] Other important considerations for a postural management program include positioning in adaptive equipment to encourage function and participation in age-appropriate activities as well as meshing postural management with activities during a child's daily routine (such as supported standing while brushing teeth at the sink).[1,10,50]

24-Hour Activity Guidelines

Postural management programs pair well with the 24-hour activity guidelines for the overall health of developing children. It is widely recognized that forming healthy habits and lifestyles in early childhood, at a time of rapid development and growth, positively affects a child's health later in life. According to the *WHO Guidelines for Physical Activity, Sedentary Behavior and Sleep for Children Under Five Years of Age*, young children should engage in at least three hours of varied types of activity throughout the day, reduce passive sedentary times and experience good quality sleep.[58] Furthermore, these guidelines indicate that there are no major risks to people with disabilities engaging in physical activity when it is appropriate to their health and status.[58-62]

However, physical activity looks different from person to person and this is especially true for young children with non-ambulant CP. For this group, the focus is not so much on meeting the physical activity guidelines as it is on reducing and replacing sedentary behavior with light physical activity or any activity using 1.5-3 METS (metabolic equivalents).[60,61] Activities that fall into this category, for example, include standing, toileting, and casual walking.[60,63] More specifically, a targeted study identified supported standing as contributing towards physical activity levels and reducing sedentary behavior in children with CP especially when incorporated into daily and participatory activities.[2,10,58,61] Utilizing early adaptive standing protocols throughout a child's day then, creates a manageable and feasible path forward to the early establishment of healthy behaviors and attitudes in a population with limited mobility options.

Participation

Best practice in early intervention is the provision of task-based and goal-directed intervention that is timely, appropriate and multimodal while incorporating peer interactions and sociability.[2,5,10,64-66] Beyond using supported standing to address impairments at the level of body functions and structures (hip preservation, bone mineral density, range of motion) and activity levels (improving light physical activity and reducing sedentary behavior), adaptive standing enables participation. Being in a stander affords a child with CP the opportunity to be upright and at eye-level with peers, to interact and participate in meaningful activities.[10] This is perhaps the most important goal of adaptive standing and reflects the umbrella focus of early intervention

as described by the "F-words in Childhood Disability" and initiatives such as "On Time Mobility."[5,64,66]

The F-Words for childhood disability, Fitness, Function, Friends, Family and Fun provide a child-friendly model around which to discuss health and guide intervention within the International Classification of Functioning, Disability, and Health (ICF). The ICF framework takes a wide view to acknowledge that all interventions for children need to be provided in a motivational and participatory environment and include activities that are age-appropriate and engaging (Rosenbaum, Sabet, Jackmann, Novak 2020, 2017, De Campos).[2,5,21,64-66] For children to learn, explore and develop, providing the choice of when and where to stand is an important part of the picture as well.[10]

Similarly, the "On Time Mobility" framework maintains that there is urgency to initiate multi-modal mobility as soon as possible to allow a child to socialize and explore across real-world environments.[5,67] Movement is key in a child's development of social, cognitive, and physical skills, and mobility is a human right that all children deserve.[5,67]

Conclusion

In the end, it's all about the Future, which is the most important F-word. This is especially true when intervening early and during a time of rapid development and growth. Our focus should be on how to best intervene today to optimally affect tomorrow's outcomes. Early adaptive standing is an evidence-based means towards a brighter future for the youngest children with CP. We should advocate for it.

References

1. Morgan C, Fetters L, Adde L, et al. Early intervention for children aged 0 to 2 years with or at high risk of cerebral palsy: International clinical practice guideline based on systematic reviews. *JAMA Pediatr.* 2021;175(8):846-858. doi: 10.1001/jamapediatrics.2021.0878.

2. Novak I, Morgan C, Adde L, et al. Early, accurate diagnosis and early intervention in cerebral palsy: Advances in diagnosis and treatment. *JAMA Pediatr.* 2017;171(9):897-907. doi:10.1001/jamapediatrics.2017.1689.

3. Eyre J. Corticospinal tract development and activity-dependent plasticity. In: Shepherd R, ed. *Cerebral palsy in Infancy*. Oxford, England: Elsevier; 2014:53-66.

4. Shepherd RB, ed. *Cerebral Palsy in Infancy: Targeted Activity to Optimize Early Growth and Development*. Oxford, England: Elsevier Health Sciences; 2014.

5. Sabet A, Feldner H, Tucker J, Logan SW, Galloway JC. ON Time Mobility: Advocating for Mobility Equity. *Pediatr Phys Ther.* 2022;34(4):546-550. doi: 10.1097/PEP.0000000000000939.

6. Centers for Disease Control and Prevention. Cerebral Palsy. Published 2020. Accessed July 3, 2023. http://www.cdc.gov/ncbddd/cp/index/html.

7. Morgan C, Romeo DM, Chorna O, et al. The pooled diagnostic accuracy of neuroimaging, general movements, and neurological examination for diagnosing cerebral palsy early in high-risk infants: A case control study. *J Clin Med.* 2019;8(11):1879. doi: 10.3390/jcm8111879.

8. Rosenbaum PL, Walter SD, Hanna SE, et al. Prognosis for gross motor function in cerebral palsy: creation of motor development curves. *JAMA*. 2002;288(11):1357-63. doi: 10.1001/jama.288.11.1357.

9. Baker A, Niles N, Kysh L, Sargent B. Effect of motor intervention for infants and toddlers with cerebral palsy: A systematic review and meta-analysis. *Pediatr Phys Ther.* 2022;34(3):297-307. doi: 10.1097/PEP.0000000000000914.

10. McLean LJ, Paleg GS, Livingstone RW. Supported-standing interventions for children and young adults with non-ambulant cerebral palsy: A scoping review. *Dev Med Child Neurol.* 2023;65(6):754-772. doi: 10.1111/dmcn.15435.

11. Uddenfeldt Wort U, Nordmark E, Wagner P, Düppe H, Westbom L. Fractures in children with cerebral palsy: a total population study. *Dev Med Child Neurol.* 2013;55(9):821-6. doi: 10.1111/dmcn.12178.

12. Christensen, C. Success with standers: positively influencing lives by following the literature. Nationwide Children's Hospital. Lecture presented at APTA Pediatrics Annual Conference; November 2023; Portland, OR.

13. Paleg GS, Smith BA, Glickman LB. Systematic review and evidence-based clinical recommendations for dosing of pediatric supported standing programs. *Pediatr Phys Ther.* 2013;25(3):232-47. doi: 10.1097/PEP.0b013e318299d5e7.

14. Kretch KS, Willett SL, Hsu LY, Sargent BA, Harbourne RT, Dusing SC. "Learn the signs. Act early.": Updates and implications for physical therapists. *Pediatr Phys Ther.* 2022;34(4):440-448. doi: 10.1097/PEP.0000000000000937.

15. Scrutton D, Baird G, Smeeton N. Hip dysplasia in bilateral cerebral palsy: incidence and natural history in children aged 18 months to 5 years. *Dev Med Child Neurol.* 2001;43(9):586-600. doi:10.1017/s0012162201001086.

16. Gordon GS, Simkiss DE. A systematic review of the evidence for hip surveillance in children with cerebral palsy. *J Bone Joint Surg Br.* 2006;88(11):1492-1496. doi:10.1302/0301-620X.88B11.18114.

17. Harris NH, Lloyd-Roberts GC, Gallien R. Acetabular development in congenital dislocation of the hip. With special reference to the indications for acetabuloplasty and pelvic or femoral realignment osteotomy. J Bone Joint Surg Br. 1975;57(1):46-52.

18. Kalen V, Bleck EE. Prevention of spastic paralytic dislocation of the hip. *Dev Med Child Neurol.* 1985;27(1):17-24. doi: 10.1111/j.1469-8749.1985.tb04520.x.

19. Macias-Merlo L, Bagur-Calafat C, Girabent-Farrés M, Stuberg WA. Standing programs to promote hip flexibility in children with spastic diplegic cerebral palsy. *Pediatr Phys Ther.* 2015;27(3):243-9. doi: 10.1097/PEP.0000000000000150.

20. Martinsson C, Himmelmann K. Effect of weight-bearing in abduction and extension on hip stability in children with cerebral palsy. *Pediatr Phys Ther.* 2011;23(2):150-157. doi:10.1097/PEP.0b013e318218efc3.

21. Novak I, Morgan C, Fahey M, et al. State of the evidence traffic lights 2019: Systematic review of interventions for preventing and treating children with cerebral palsy. *Curr Neurol Neurosci Rep.* 2020;20(2):3. doi:10.1007/s11910-020-1022-z

22. Wynter M, Gibson N, Kentish M, Love S, Thomason P, Kerr Graham H. The consensus statement on hip surveillance for children with cerebral palsy: Australian standards of care. *J Pediatr Rehabil Med.* 2011;4(3):183-95. doi: 10.3233/PRM-2011-0174.

23. Wynter M, Gibson N, Willoughby KL, et al. Australian hip surveillance guidelines for children with cerebral palsy: 5-year review. *Dev Med Child Neurol.* 2015;57(9):808-20. doi: 10.1111/dmcn.12754.

24. Macias-Merlo L, Bagur-Calafat C, Girabent-Farrés M, A Stuberg W. Effects of the standing program with hip abduction on hip acetabular development in children with spastic diplegia cerebral palsy. *Disabil Rehabil.* 2016;38(11):1075-81. doi: 10.3109/09638288.2015.1100221.

25. Connelly A, Flett P, Graham HK, Oates J. Hip surveillance in Tasmanian children with cerebral palsy. *J Paediatr Child Health*. 2009;45(7-8):437-443. doi:10.1111/j.1440-1754.2009.01534.x

26. Soo B, Howard JJ, Boyd RN, et al. Hip displacement in CP. *J Bone Joint Surg Am.* 2006;88(1):121-129. doi:10.2106/JB-JS.E.00071

27. Keeratisiroj O, Thawinchai N, Siritaratiwat W, Buntragulpoontawee M, Pratoomsoot C. Prognostic predictors for ambulation in children with CP: a systematic review and meta-analysis of observational studies. *Disabil Rehabil.* 2018;40(2):135-143. doi:10.108 0/09638288.2016.1250119

28. Herman D, May R, Vogel L, Johnson J, Henderson RC. Quantifying weight-bearing by children with cerebral palsy while in passive standers. *Pediatr Phys Ther.* 2007;19(4):283-7. doi: 10.1097/PEP.0b013e318156cc4d.

29. Mergler S, Evenhuis HM, Boot AM, et al. Epidemiology of low bone mineral density and fractures in children with severe cerebral palsy: a systematic review. *Dev Med Child Neurol.* 2009;51(10):773-8. doi: 10.1111/j.1469-8749.2009.03384.x.

30. Tasdemir HA, Buyukavci M, Akcay F, Polat P, Yildiran A, Karakelleoglu C. Bone mineral density in children with cerebral palsy. *Pediatr Int.* 2001;43(2):157-160. doi: 10.1046/j.1442-200x.2001.01352.x

31. Henderson RC, Lin PP, Greene WB. Bone-mineral density in children and adolescents who have spastic cerebral palsy. *J Bone Joint Surg Am.* 1995;77(11):1671–81. doi: 10.2106/00004623-199511000-00005.

32. Henderson RC, Kairalla J, Abbas A, Stevenson RD. Predicting low bone density in children and young adults with quadriplegic cerebral palsy. *Dev Med Child Neurol.* 2004;46: 416-19. doi:10.1017/S0012162204000672

33. Henderson RC, Kairalla JA, Barrington JW, Abbas A, Stevenson RD. Longitudinal changes in bone density in children and adolescents with moderate to severe cerebral palsy. *J Pediatr.* 2005;146(6):769-75. doi: 10.1016/j.jpeds.2005.02.024

34. Damcott M, Blochlinger S, Foulds R. Effects of passive versus dynamic loading interventions on bone health in children who are nonambulatory. *Pediatr Phys Ther.* 2013;25(3):248-55. doi: 10.1097/PEP.0b013e318299127d.

35. Caulton JM, Ward KA, Alsop CW, Dunn G, Adams JE, Mughal MZ. A randomised controlled trial of standing programme on bone mineral density in non-ambulant children with cerebral palsy. *Arch Dis Child*. 2004;89(2):131-5. doi: 10.1136/adc.2002.009316.

36. Chad KE, Bailey DA, McKay HA, Zello GA, Snyder RE. The effect of a weight-bearing physical activity program on bone mineral content and estimated volumetric density in children with spastic cerebral palsy. *J Pediatr.* 1999;135(1):115-7. doi: 10.1016/s0022-3476(99)70340-9.

37. Pin TW. Effectiveness of static weight-bearing exercises in children with cerebral palsy. *Pediatr Phys Ther.* 2007;19(1):62-73. doi: 10.1097/pep.0b013e3180302111.

38. Stuberg WA. (1991) Bone density changes in non-ambulatory children following discontinuation of passive standing programs. In: Proceedings of the American Academy of Cerebral Palsy and Dev Medicine Conference (AACPDM), Louisville KY. October 10, 1991.

39. Stuberg WA. Considerations related to weight-bearing programs in children with developmental disabilities. *Phys Ther.* 1992 Jan;72(1):35-40. doi: 10.1093/ptj/72.1.35.

40. Hough JP, Boyd RN, Keating JL. Systematic review of interventions for low bone mineral density in children with cerebral palsy:. Pediatrics. 2010;125(3):e670-8. doi: 10.1542/peds.2009-0292.

41. Paleg G, Altizer W, Malone R, Ballard K, Kreger A. Inclination, hip abduction, orientation, and tone affect weight-bearing in standing devices. *J Pediatr Rehabil Med.* 2021;14(3):433-441. doi: 10.3233/PRM-190660.

42. Handsfield GG, Williams S, Khuu S, Lichtwark G, Stott NS. Muscle architecture, growth, and biological remodelling in cerebral palsy: a narrative review. *BMC Musculoskelet Disord.* 2022;23(1):233. doi: 10.1186/s12891-022-05110-5.

43. Harvey LA, Katalinic OM, Herbert RD, Moseley AM, Lannin NA, Schurr K. Stretch for the treatment and prevention of contracture: an abridged republication of a Cochrane Systematic Review. *J Physiother.* 2017;63(2):67-75. doi:10.1016/j.jphys.2017.02.014.

44. Martinsson C, Himmelmann K. Abducted Standing in Children With cerebral palsy:: Effects on Hip Development After 7 Years. *Pediatr Phys Ther.* 2021 Apr 1;33(2):101-107. doi: 10.1097/PEP.0000000000000789.

45. Gibson SK, Sprod JA, Maher CA. The use of standing frames for contracture management for nonmobile children with cerebral palsy:. *Int J Rehabil Res.* 2009;32(4):316-23. doi: 10.1097/MRR.0b013e32831e4501.

46. Sato H. Postural deformity in children with cerebral palsy: Why it occurs and how is it managed. *Phys Ther Res.* 2020;23(1):8-14. doi: 10.1298/ptr.R0008.

47. Jeffries L, Fiss A, McCoy SW, Bartlett DJ. Description of primary and secondary impairments in young children with cerebral palsy: *Pediatr Phys Ther.* 2016;28(1):7-14. doi: 10.1097/PEP.0000000000000221.

48. Bartlett D, Dyszuk E, Galuppi B, Gorter JW. Interrelationships of functional status and health conditions in children with cerebral palsy: A descriptive study. *Pediatr Phys Ther.* 2018;30(1):10-16. doi: 10.1097/PEP.0000000000000469.

49. Boel L, Pernet K, Toussaint M, et al. Respiratory morbidity in children with cerebral palsy: an overview. *Dev Med Child Neurol.* 2019;61(6):646-653. doi: 10.1111/dmcn.14060.

50. Paleg G, Livingstone R. Evidence-informed clinical perspectives on postural management for hip health in children and adults with non-ambulant cerebral palsy. *J Pediatr Rehabil Med.* 2022;15(1):39-48. doi: 10.3233/PRM-220002.

51. Porter D, Michael S, Kirkwood C. Is there a relationship between preferred posture and positioning in early life and the direction of subsequent asymmetrical postural deformity in non ambulant people with cerebral palsy? *Child Care Health Dev.* 2008;34(5):635-41. doi: 10.1111/j.1365-2214.2008.00852.x.

52. Hägglund G, Lauge-Pedersen H, Persson Bunke M, Rodby-Bousquet E. Windswept hip deformity in children with cerebral palsy: a population-based prospective follow-up. *J Child Orthop.* 2016;10(4):275-9. doi: 10.1007/s11832-016-0749-1.

53. Holmes C, Brock K, Morgan P. Postural asymmetry in non-ambulant adults with cerebral palsy: a scoping review. *Disabil Rehabil.* 2019;41(9):1079-1088. doi: 10.1080/09638288.2017.1422037.

54. Hägglund G, Lauge-Pedersen H, Wagner P. Characteristics of children with hip displacement in CP. *BMC Musculoskelet Disord.* 2007;8:101. doi: 10.1186/1471-2474-8-101.

55. Hägglund G, Pettersson K, Czuba T, Persson-Bunke M, Rodby-Bousquet E. Incidence of scoliosis in CP. *Acta Orthop.* 2018;89(4):443-447. doi: 10.1080/17453674.2018.1450091.

56. Yoshida K, Kajiura I, Suzuki T, Kawabata H. Natural history of scoliosis in CP and risk factors for progression of scoliosis. *J Orthop Sci.* 2018;23(4):649-652. doi: 10.1016/j.jos.2018.03.009.

57. Pountney T, Mandy A, Green E, Gard P. Management of hip dislocation with postural management. *Child Care Health Dev.* 2002;28(2):179-85. doi: 10.1046/j.1365-2214.2002.00254.x.

58. World Health Organization. Guidelines on physical activity, sedentary behavior and sleep for children under 5 years of age. April 2, 2019. Accessed July 3 2023. https://www.who.int/publications/i/item/9789241550536

59. Verschuren O, Darrah J, Novak I, Ketelaar M, Wiart L. Health-enhancing physical activity in children with CP: more of the same is not enough. *Phys Ther.* 2014;94(2):297-305. doi: 10.2522/ptj.20130214.

60. Verschuren O, Peterson MD, Leferink S, Darrah J. Muscle activation and energy-requirements for varying postures in children and adolescents with cerebral palsy. *J Pediatr.* 2014;165(5):1011-6. doi: 10.1016/j.jpeds.2014.07.027.

61. Verschuren O, Peterson MD, Balemans AC, Hurvitz EA. Exercise and physical activity recommendations for people with cerebral palsy. *Dev Med Child Neurol.* 2016;58(8):798-808. doi: 10.1111/dmcn.13053.

62. Verschuren O, Hulst RY, Voorman J, et al. 24-hour activity for children with cerebral palsy a clinical practice guide. *Dev Med Child Neurol.* 2021;63(1):54-59. doi: 10.1111/dmcn.14654.

63. Holtermann A, Stamatakis E. Do all daily metabolic equivalent task units (METs) bring the same health benefits? *Br J Sports Med.* 2019;53(16): 991-2. doi: 10.1136/bjsports-2017-098693.

64. Rosenbaum P, Gorter JW. The 'F-words' in childhood disability: I swear this is how we should think! *Child Care Health Dev.* 2012;38(4):457-63. doi: 10.1111/j.1365-2214.2011.01338.x.

65. Jackman M, Sakzewski L, Morgan C, et al. Interventions to improve physical function for children and young people with cerebral palsy: international clinical practice guideline. *Dev Med Child Neurol.* 2022;64(5):536-549. doi: 10.1111/dmcn.15055.

66. De Campos AC, Hidalgo-Robles Á, Longo E, Shrader C, Paleg G. F-words and early intervention ingredients for non-ambulant children with cerebral palsy: A scoping review. *Dev Med Child Neurol.* 2023. doi: 10.1111/dmcn.15682.

67. Feldner H, Tucker J, Logan S, Sabet A. Moving beyond 'early': Introducing ON Time Mobility as a rights-based framework to support movement experiences in young children with disabilities. Oral presentation at APTA Pediatric Conference, November 2022; Portland OR.